ALICE prospects: the short and long-time future

5th Workshop on High pt Physics at LHC
ICN UNAM Sept 2010

- **A minimum of history**
- **The Heavy Ion Run**
- **2011**
- **The long term**

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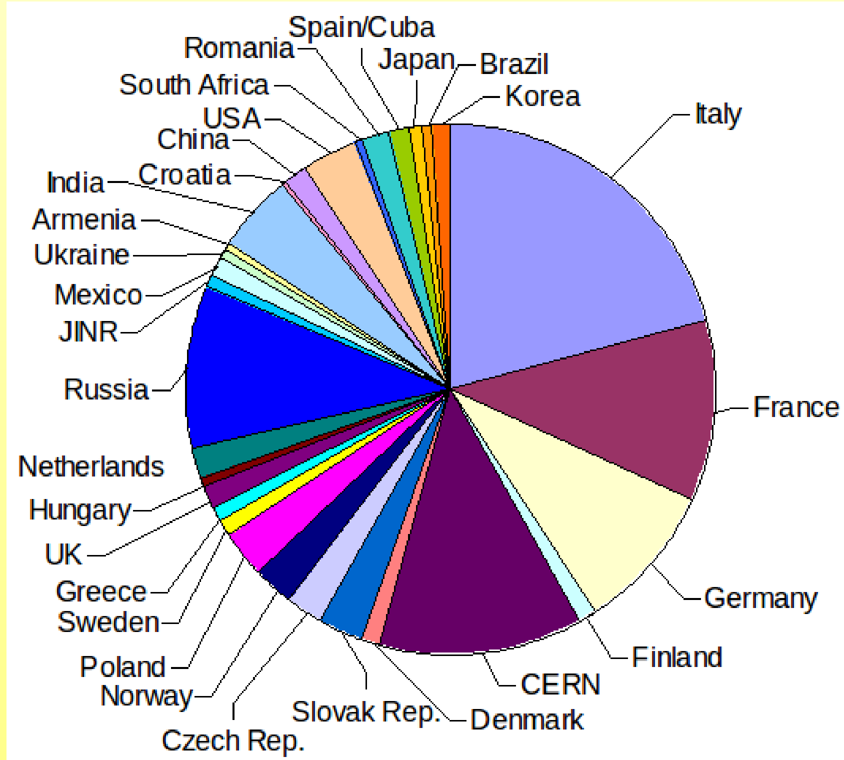
ALICE

~ 1000 **Members and growing… from both NP and HEP communities**

~30 **Countries**

~100 **Institutes**

~ 150 **MCHF capital cost**
(+ 'free' magnet)



History: two decades …

1990-1996: Design

1992-2002: R&D

2000-2010: Construction

2002-2007: Installation

2008 -> : Commissioning

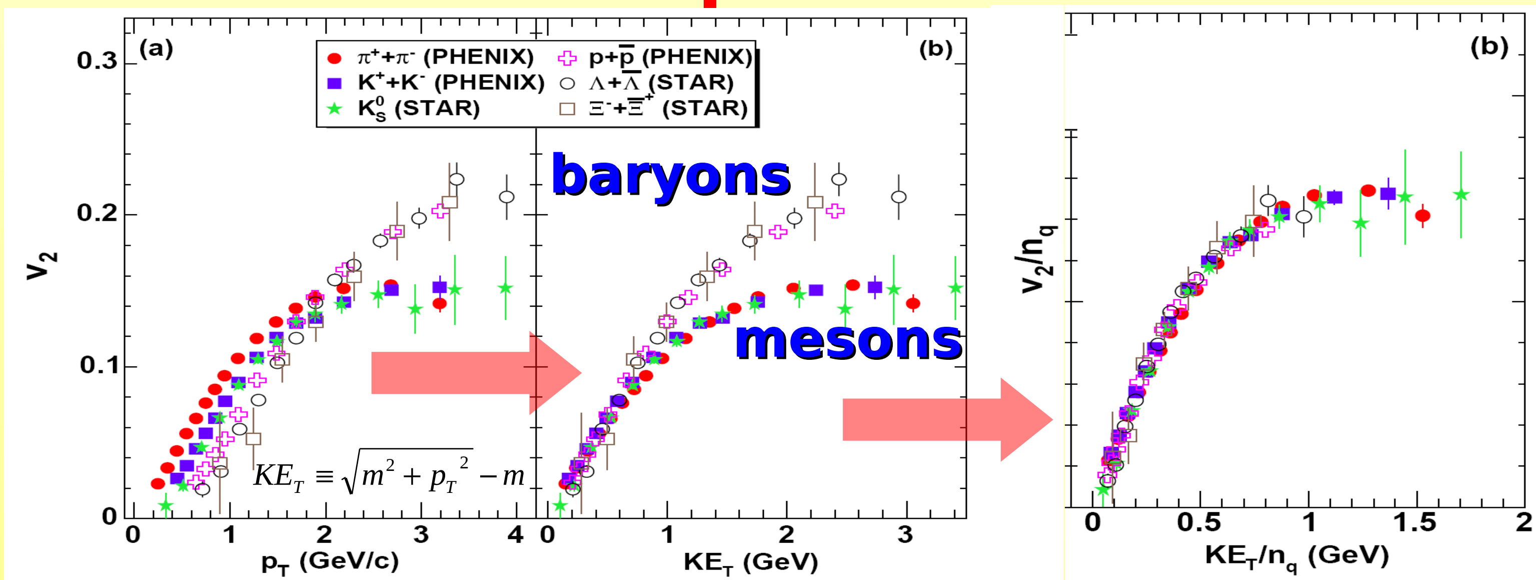
4 TP addenda along the way: 1996 : muon spectrometer 1999 : TRD 2006 : EMCAL 2010 : DCAL

ALICE is different…

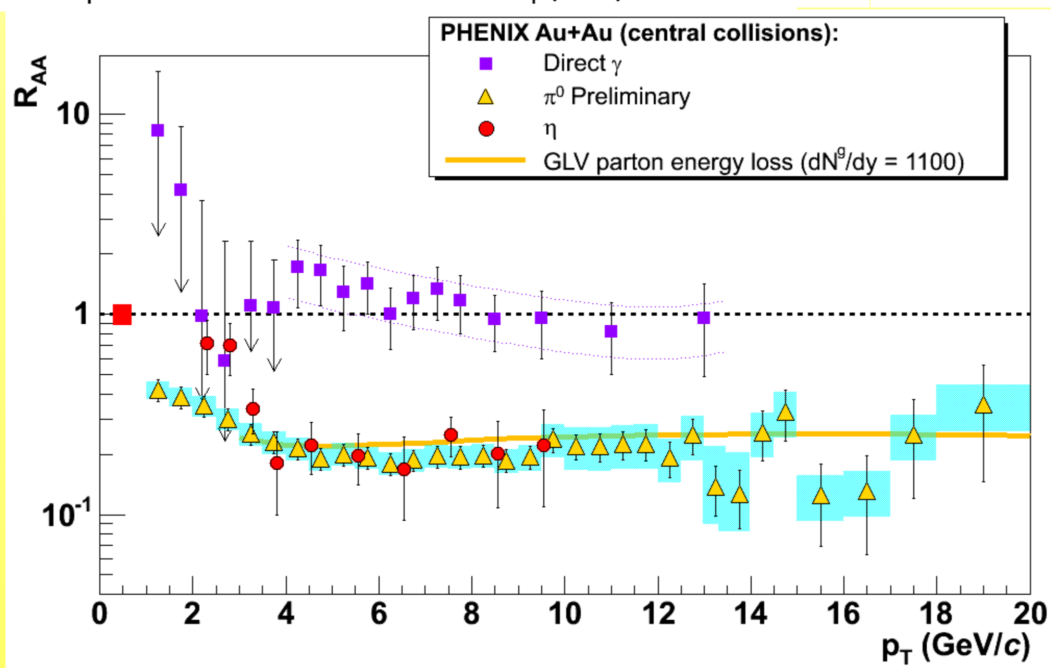
- What makes ALICE different from ATLAS, CMS and LHCb ?
  - Experiment designed for Heavy Ion collision
    - only dedicated experiment at LHC, must be comprehensive and be able to cover all relevant observables
    - VERY robust tracking
      - high-granularity detectors with many space points per track, very low material budget and moderate magnetic field
    - PID over a very large p_T range
    - Hadrons, leptons and photons
    - Very low p_T cutoff
    - Excellent vertexing
  - Price to be paid:
    - Slow detectors
    - Limited η and p_T coverage
- Complementary to the other experiments

EXAMPLES FROM RHIC:
relevance of PID and photon detection…

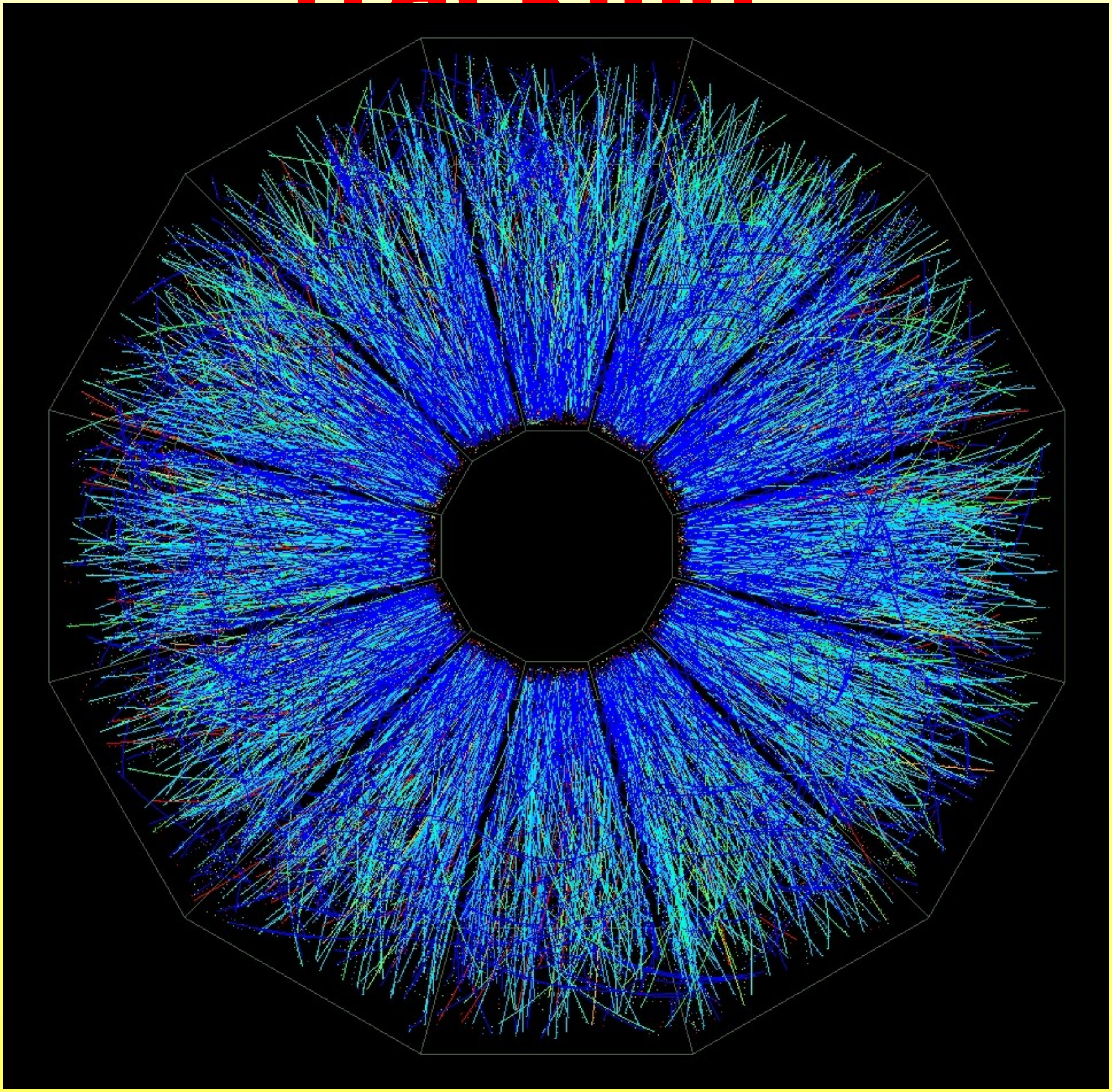
Flow



R_{AA}



and of robust tracking



STAR

central Au-Au event

@ ~130 GeV/nucleon

CM energy

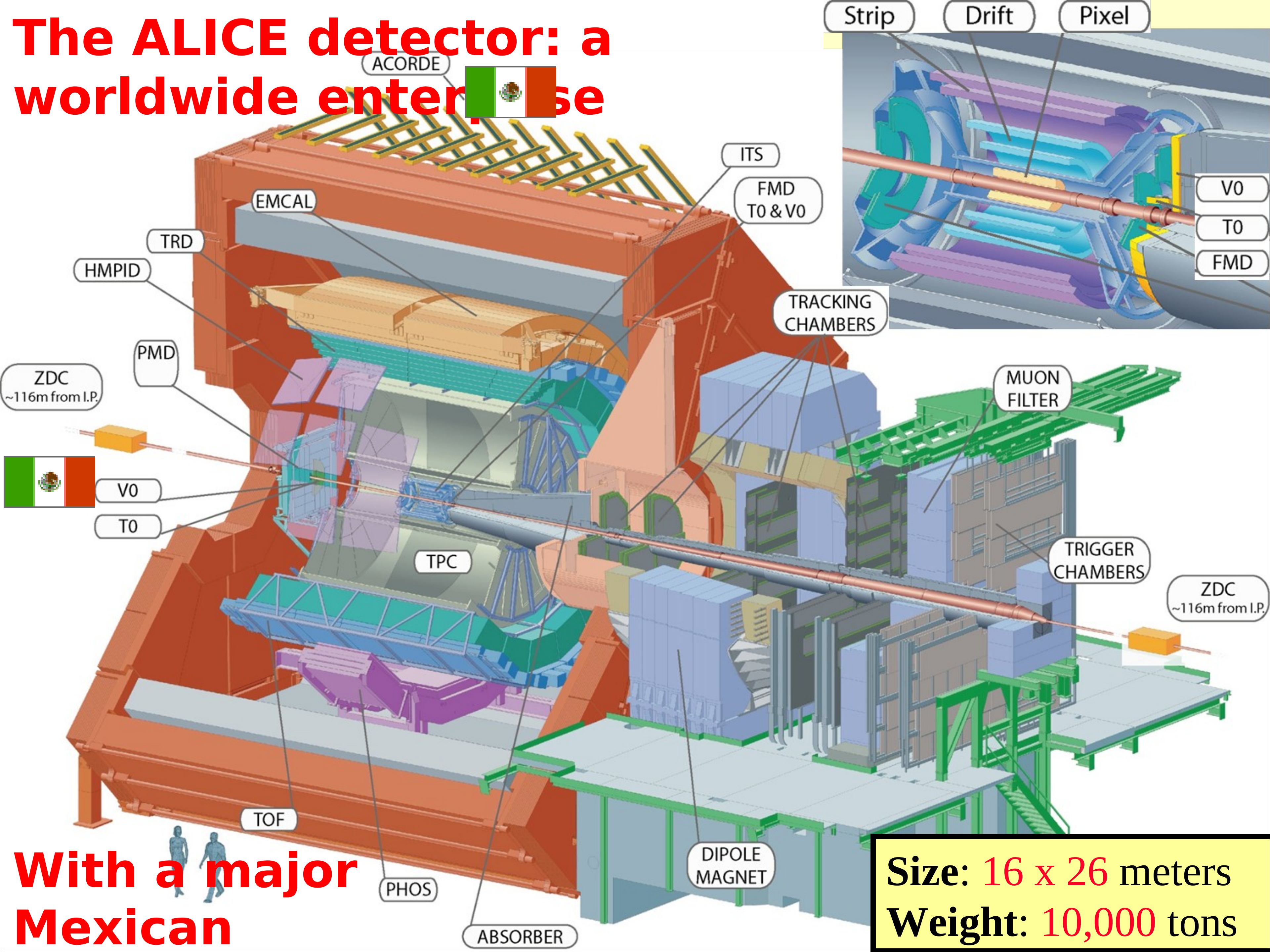
Experimental Constraints
(from the Heavy Ion running)

- extreme particle density ($dN_{ch}/d\eta \sim 2000 – 8000$)
  - **x 500** compared to pp @ LHC
- large dynamic range in p_T:
  - from very soft (**0.1 GeV/*c***) to fairly hard (**100 GeV/*c***)
- lepton ID, hadron ID, photon detection
- secondary vertices
- modest Luminosity and interaction rates
  - **10 kHZ** (Pb-Pb) to **300 kHZ** (pp) (< 1/1000 of pp@10^{34})

Experimental Solutions

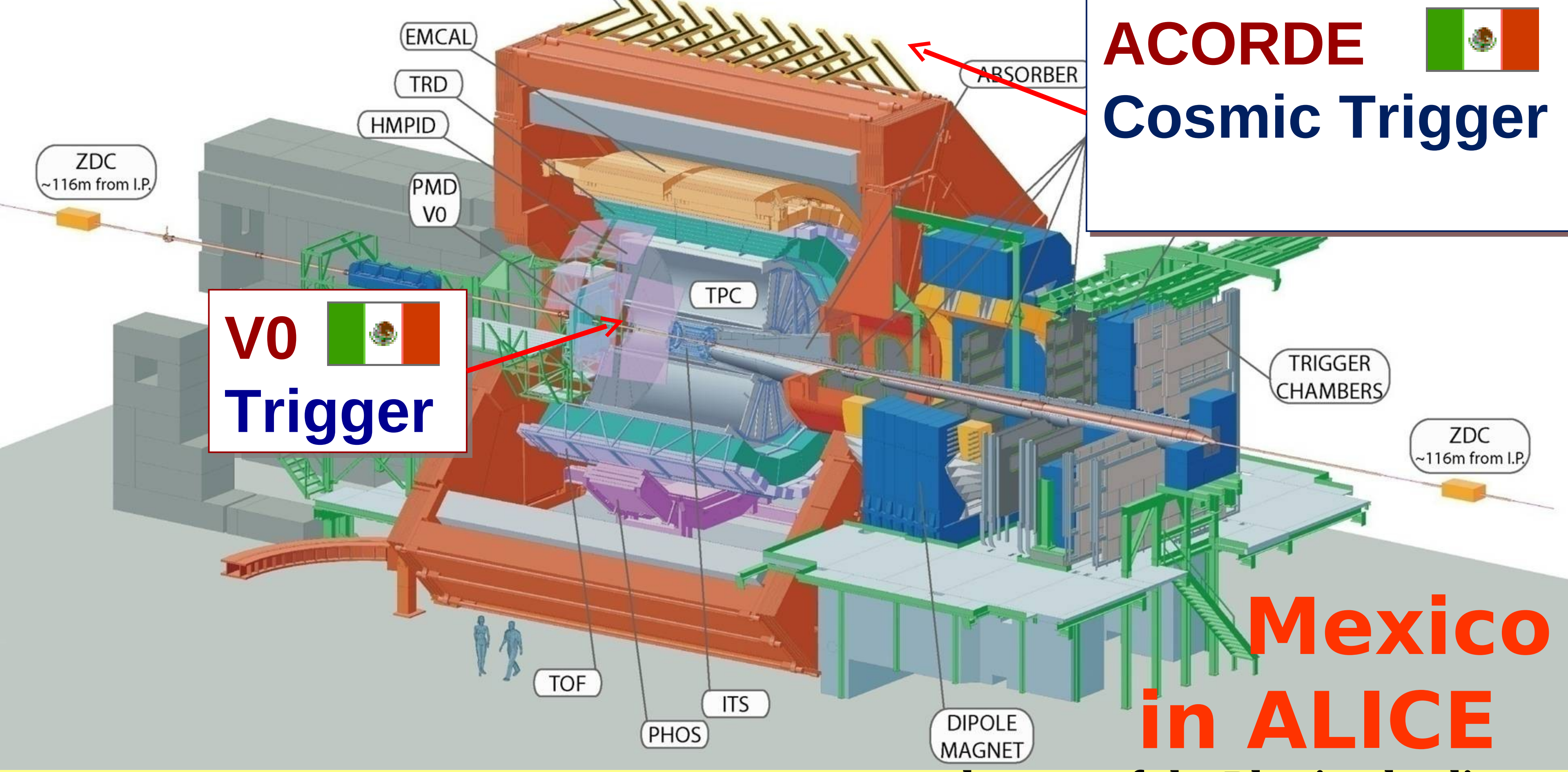
- **$dN_{ch}/d\eta$:** high **granularity**, **3D** detectors (**560 million** pixels in the TPC alone, giving 180 space points/track, largest ever: $88 m^3$), large **distance** to vertex (use a VERY large magnet)
  - emcal: high-density crystals of $PbWO_4$ at **4.5 m** (typical is 1-2 m !)
- **p_t coverage**: **thin** det, moderate field (low p_t), large lever arm + resolution (large p_t)
  - ALICE: **< 10%X_0** in r < 2.5 m (typical is 50-100%X_0), B= **0.5T**, **BL^2** ~ like CMS !
- **PID**: use of essentially all known technologies
  - dE/dx, Cherenkov & transition rad., TOF, calorimeters, muon filter, topological,
- **rate:** allows slow detectors (TPC, SDD), moderate radiation hardness

The ALICE detector: a worldwide enter se



With a major Mexican

Size: 16 x 26 meters
Weight: 10,000 tons



• at the core of the detector, two 100% Mexican projects:

⇨ **V0L :**

⇨ trigger, vital element of the first analysis!

⇨ **ACORDE:**

⇨ Cosmic ray trigger for calibrations and Cosmic Ray Physics

⇨ **+ UPGRADES: VHMIPD, AD**

• at the core of the Physics, leading role in three key fields:

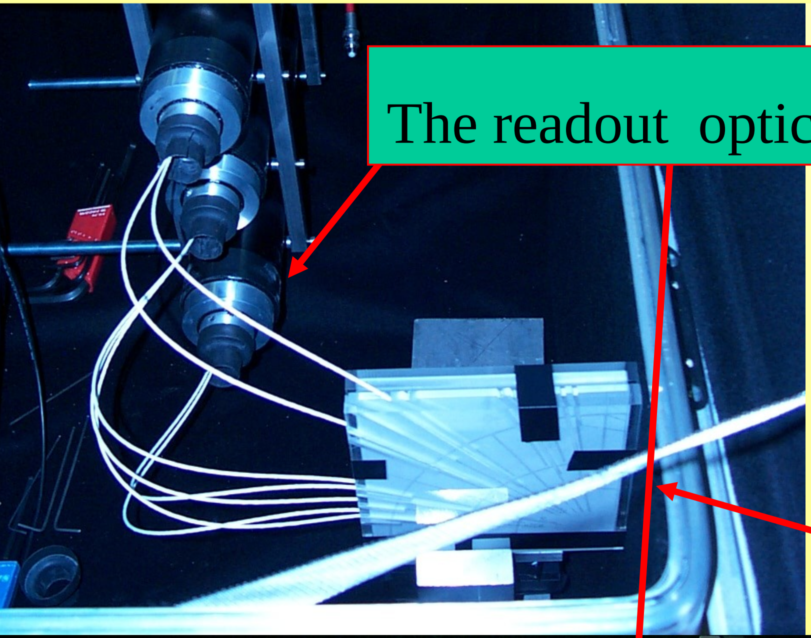
⇨ **Jets/ Event Structure**

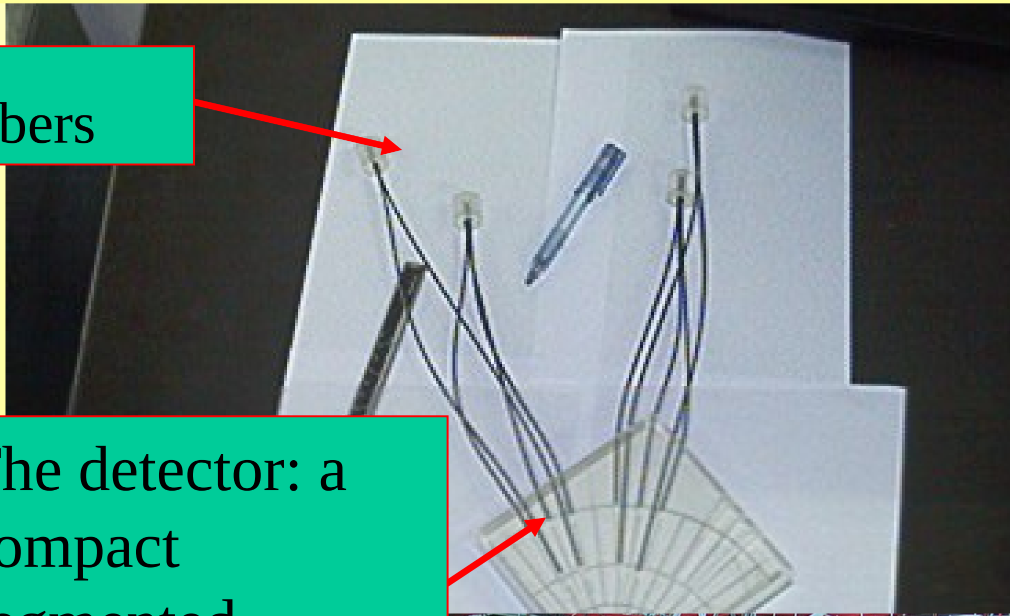
⇨ **Cosmic Ray Physics**

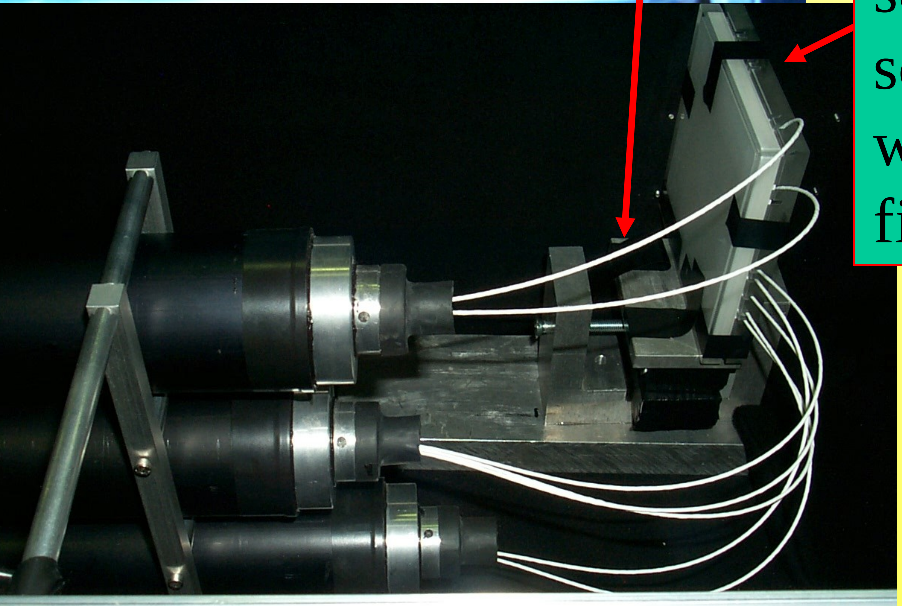
⇨ **Diffractive Physics**

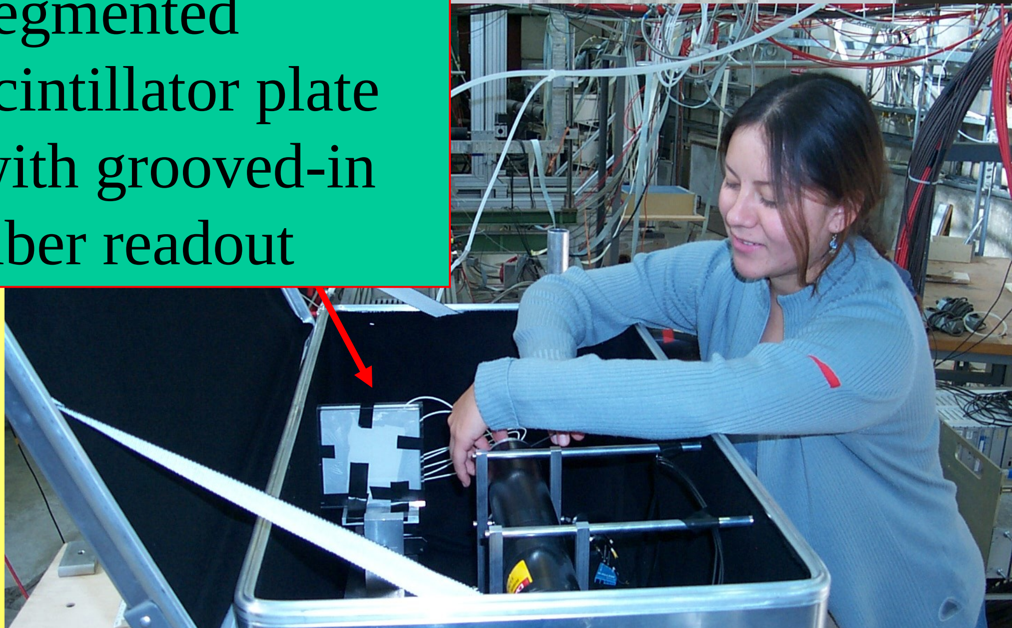
+ Computing ….

The $V0_L$ prototypes under test on beam



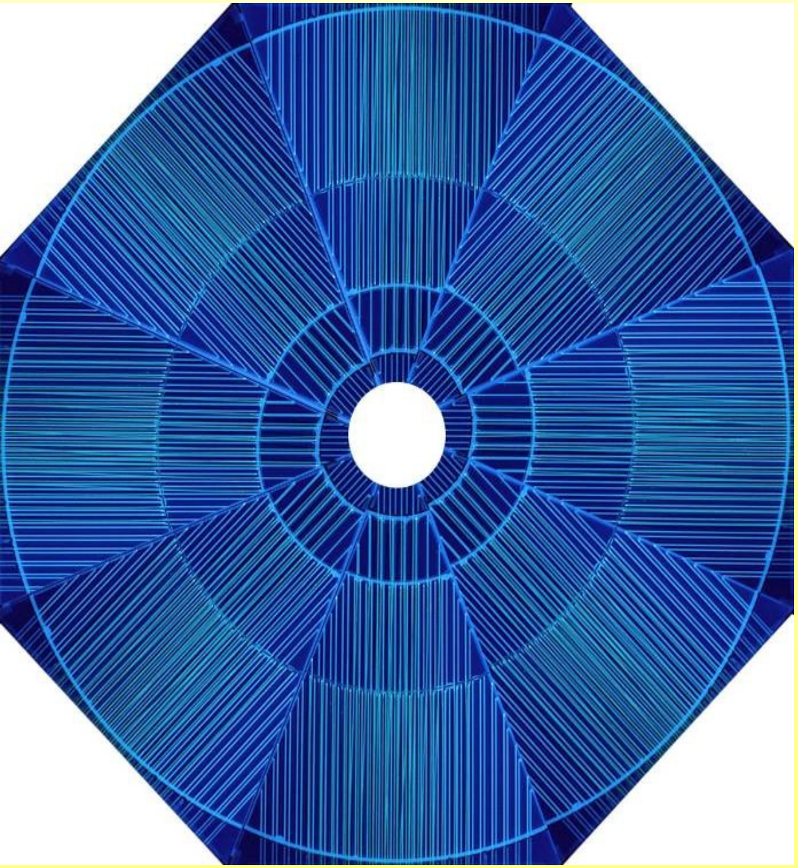






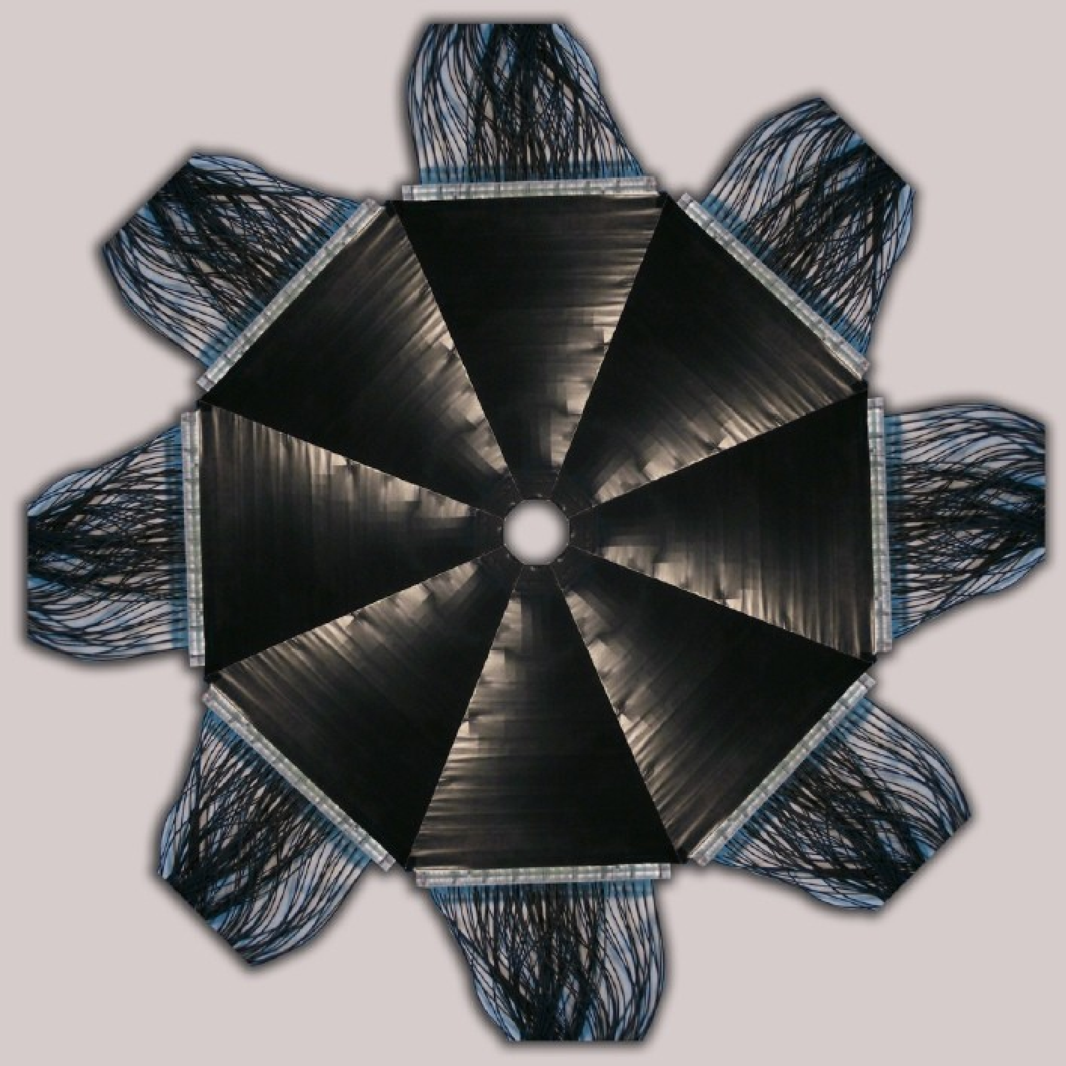
The readout optical fibers

The detector: a compact segmented scintillator plate with grooved-in fiber readout



Vo with

its optical fibers



VO complete

ACORDE...

ACORDE leaving MEXICO in dec 2005

Acorde installation

9 de octubre de 2006

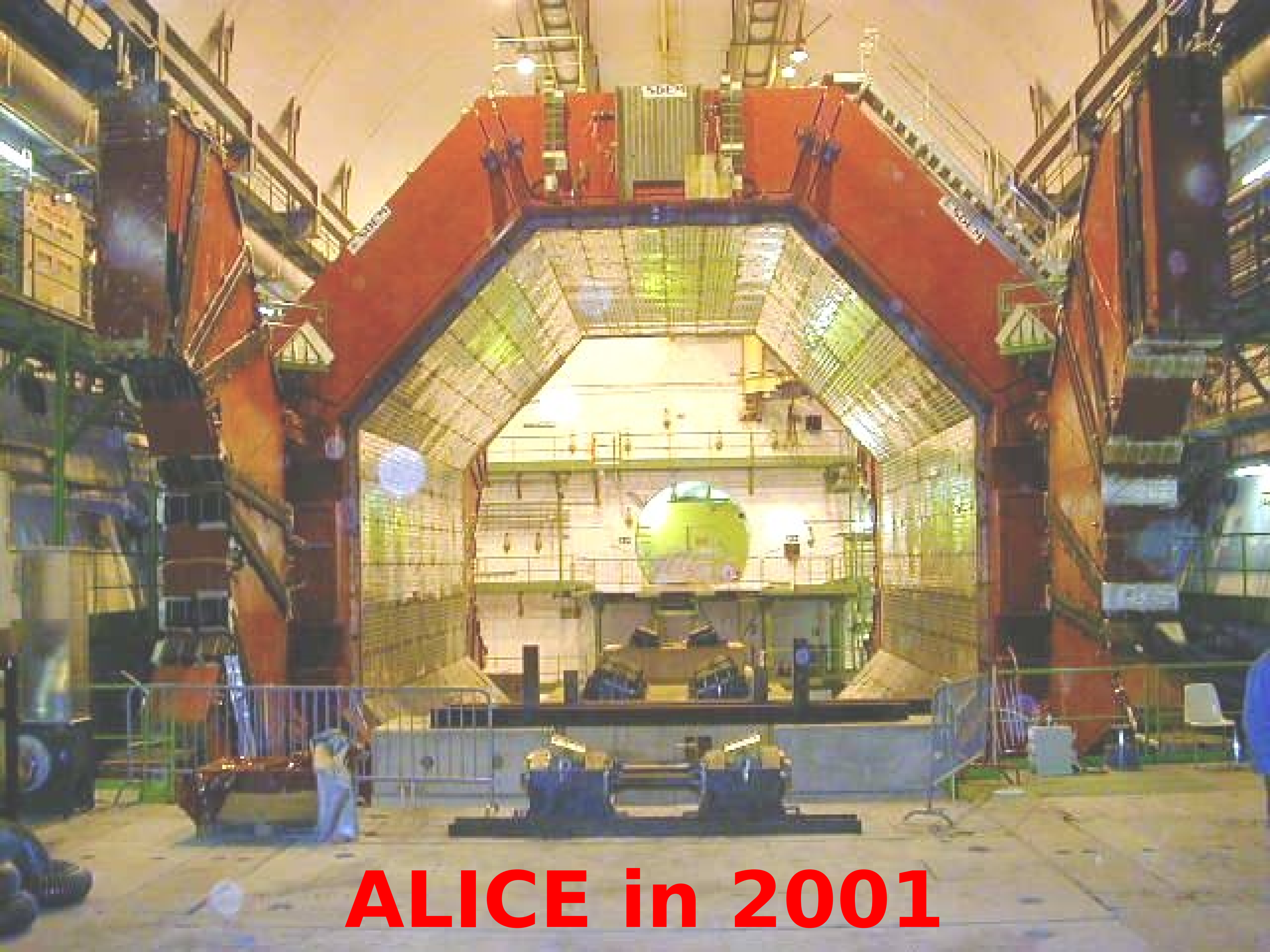
ALICE Computing

- 30,000 cores
- 70 computer centres (1T0, 5T1, 64T2)
- America, Europe, Africa and Asia

- Stable and smooth operation 24 x 7
- Operated according to the Computing Model

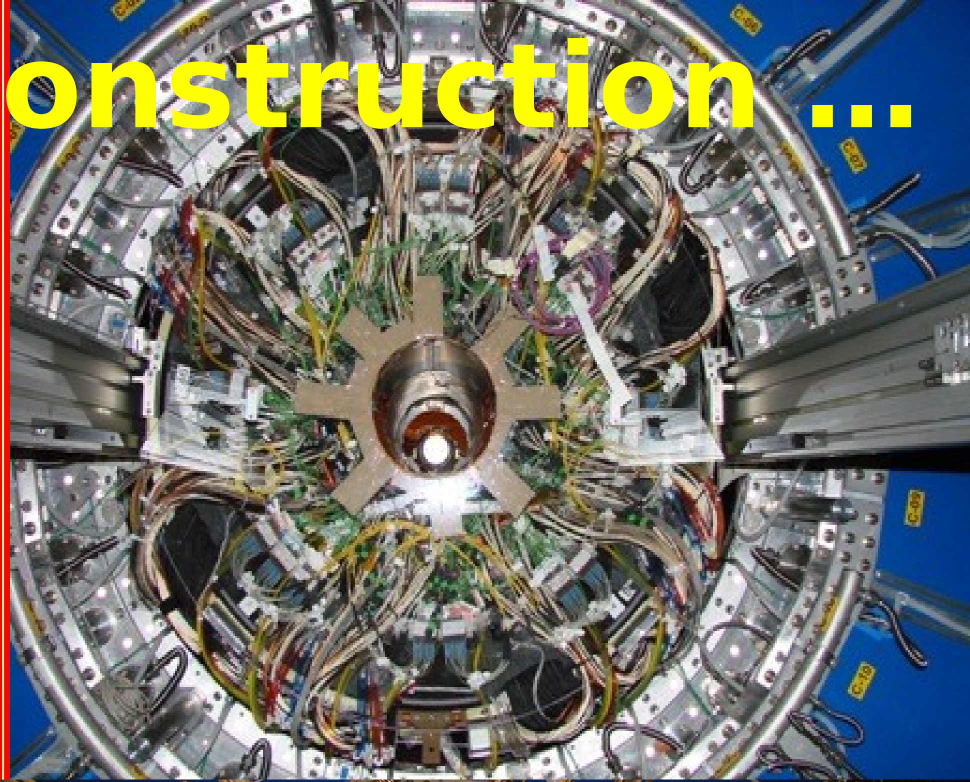
COMSATS/Pakistan and LBL/USA entered operation in the last three months

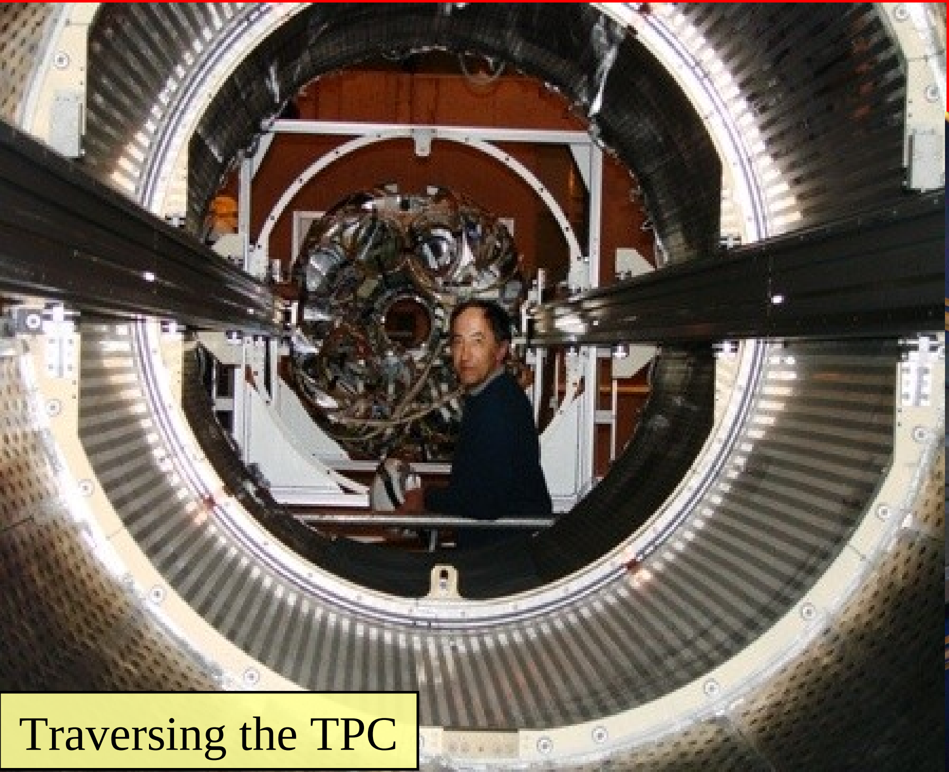
- KISTI experimenting T1 service
- LLNL & Yerevan expected in operation soon

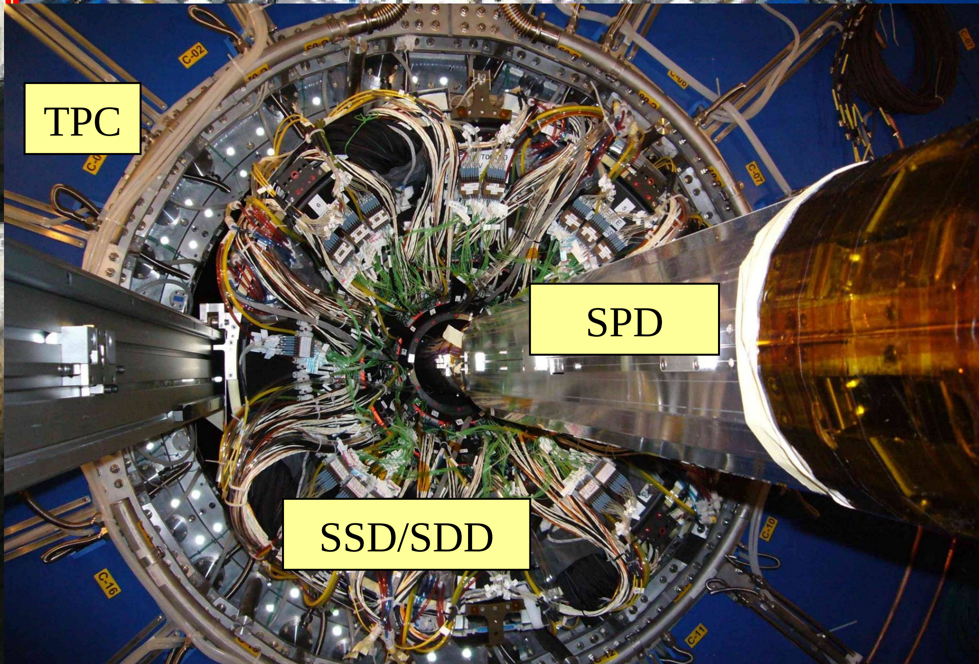


ALICE in 2001

... in construction ...

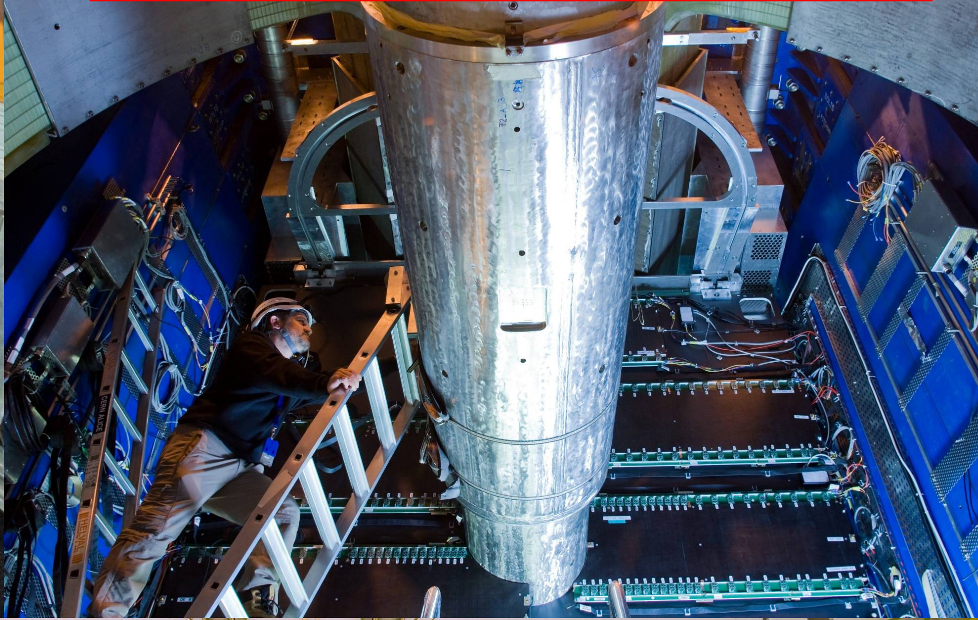






Insertion of final TOF super module

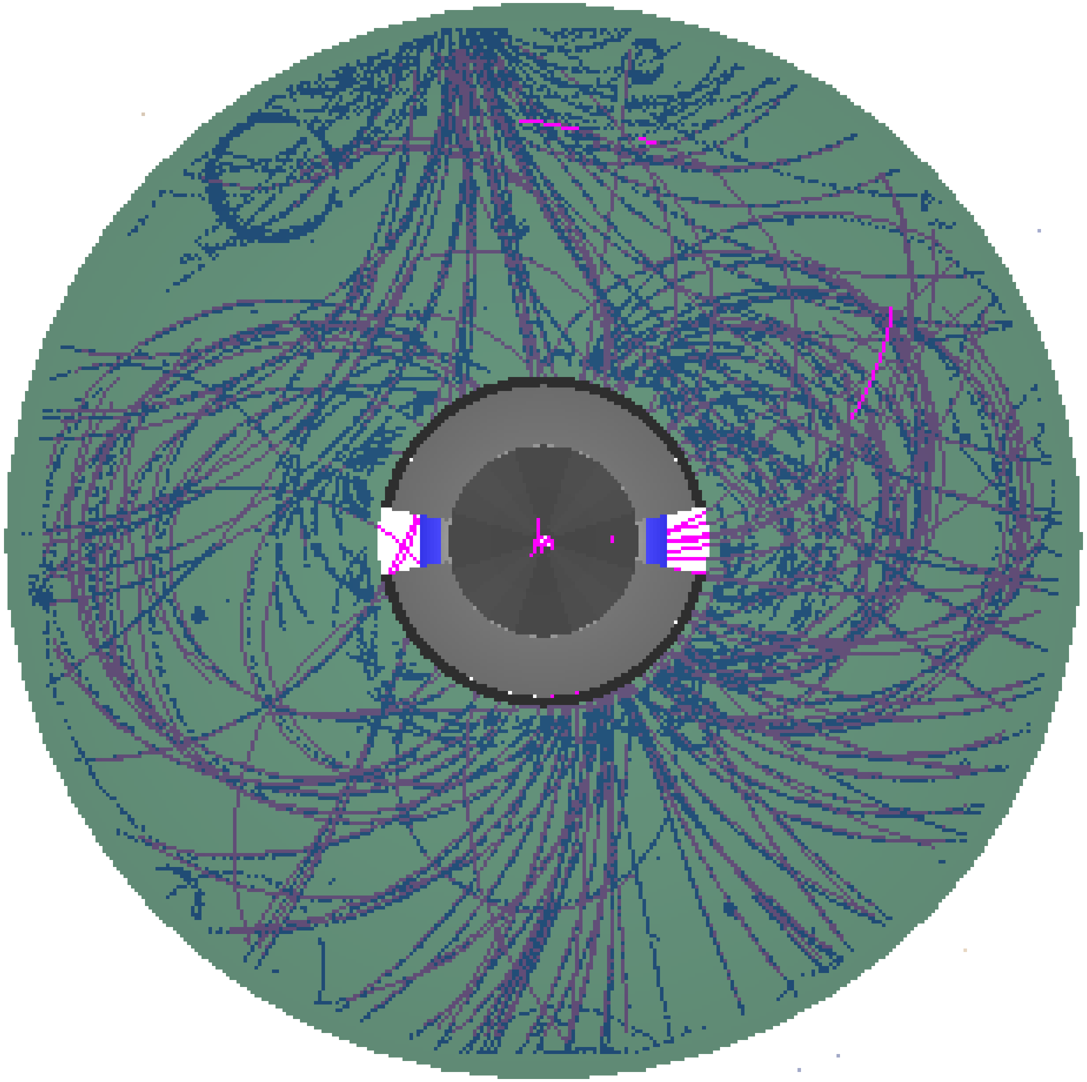
Installation of final muon chamber



ALICE in 2008

Formal end of ALICE installation July 2008

2008: Cosmics!



- Pretty pictures, but also lots of calibrations, alignment, timing and tuning….

TPC performance

Results from cosmics

(7 million events)

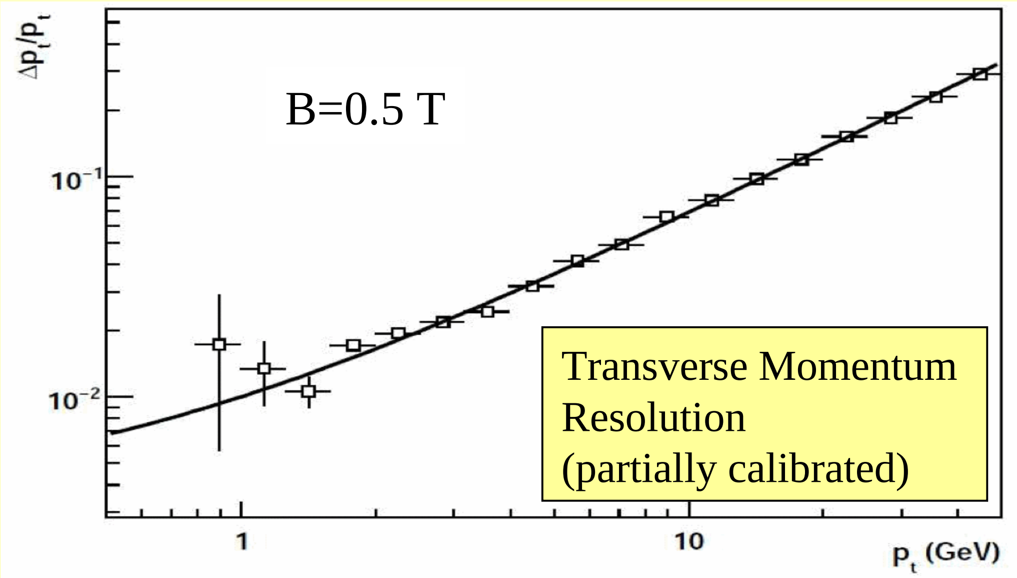
dE/dx resolution (PPR goal: ~ 5.5%)

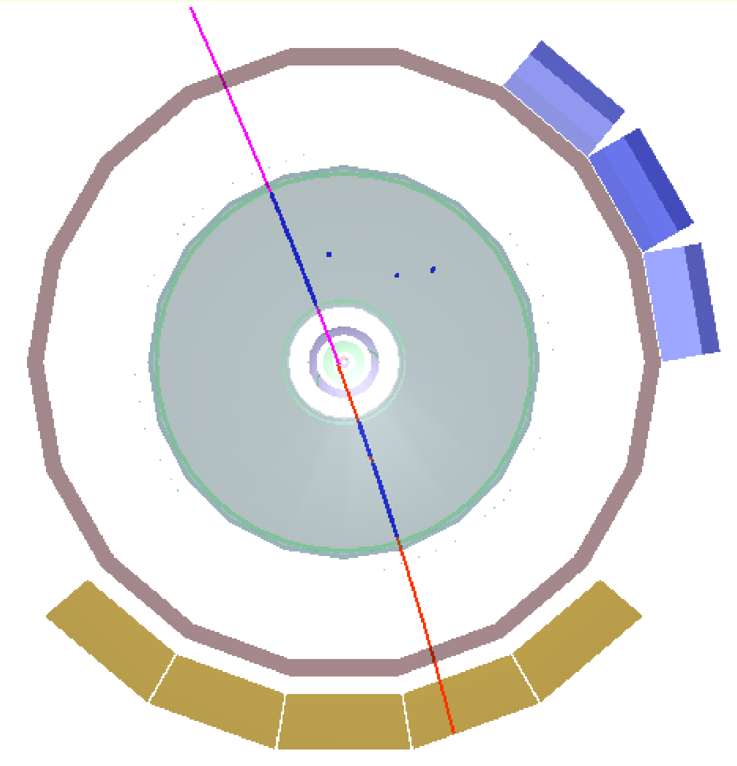
Measured **5.7 %**

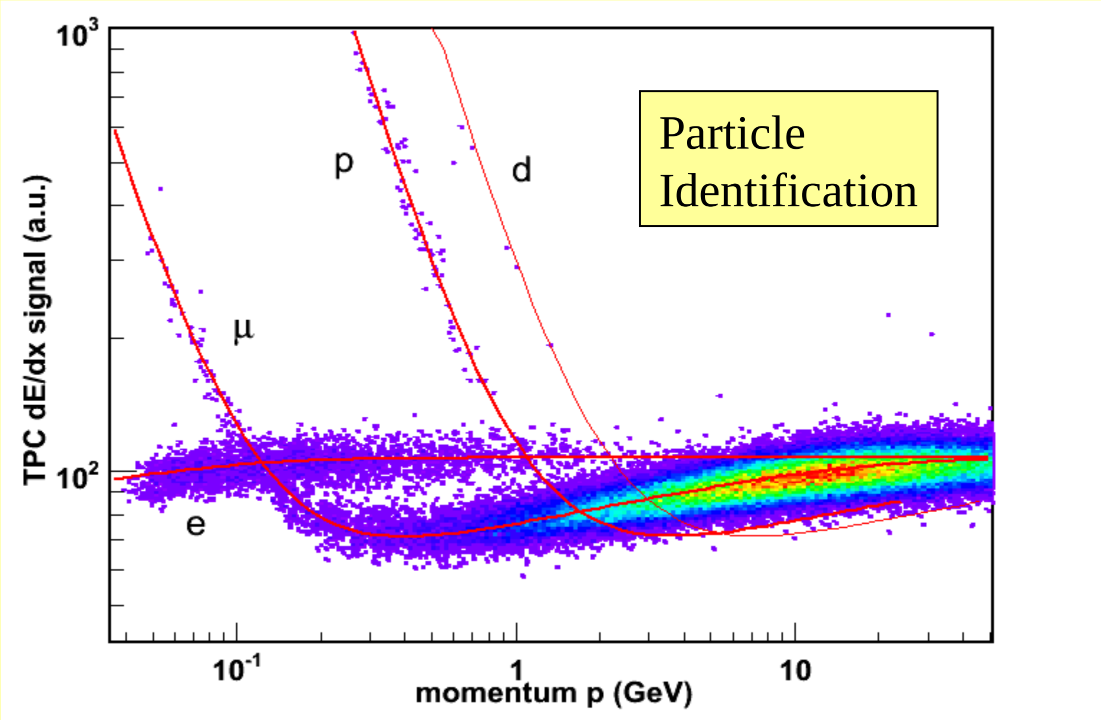
p_t resolution (PPR goal: ~ 5% @ 10 GeV)

measured **~ 6.5% @ 10 GeV** with partial calibration

(was 10% in October 2008)

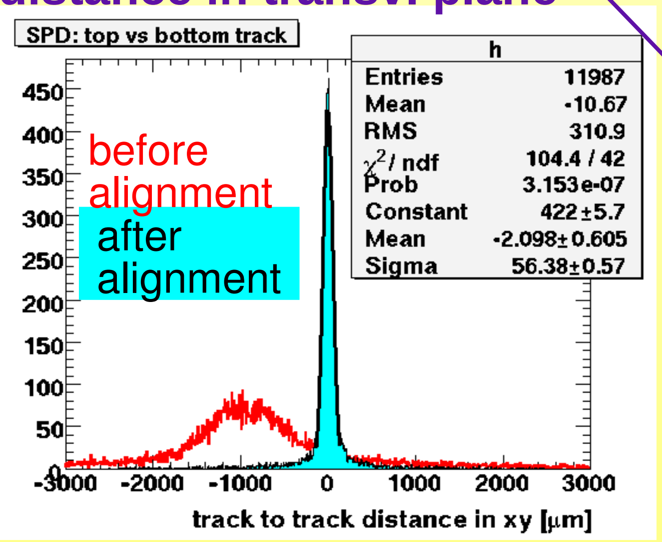




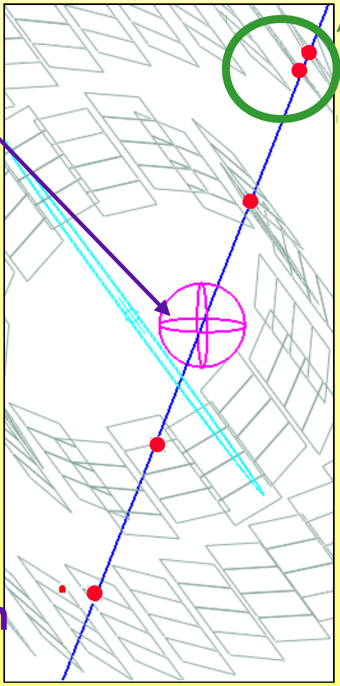


ITS Alignment

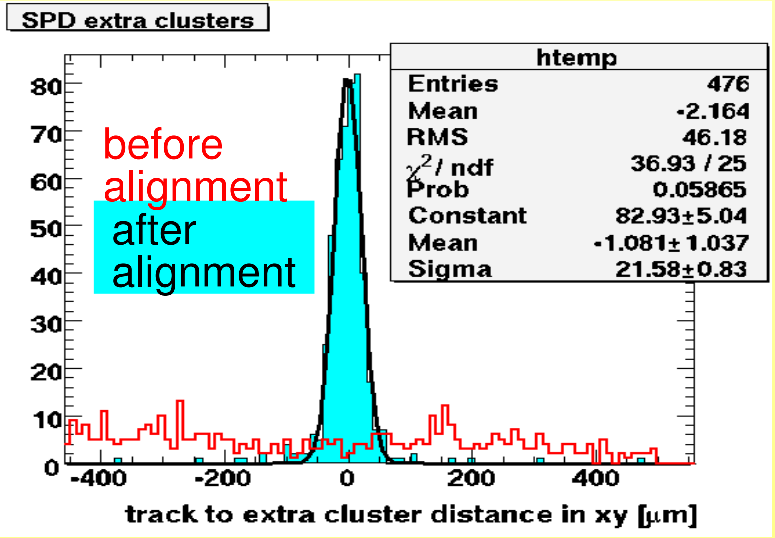
Track-to-track (top vs bottom) distance in transv. plane



σ = 55 μm (vs 40 μm in simulation without misalignment)



Track-to-"extra clusters" distance in transv. plane (sensor overlap)

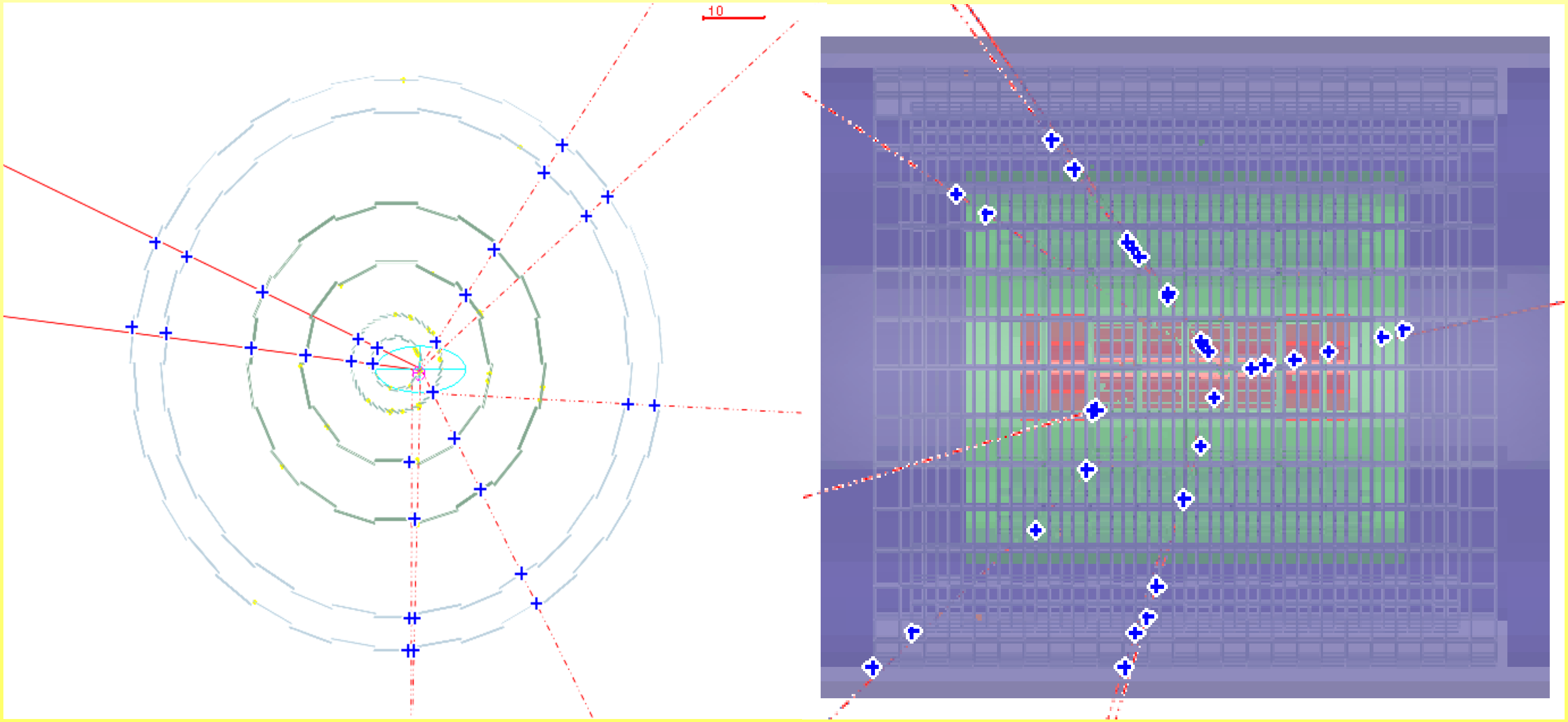


σ = 21 μm (vs 15 μm in simul. without misalignment)

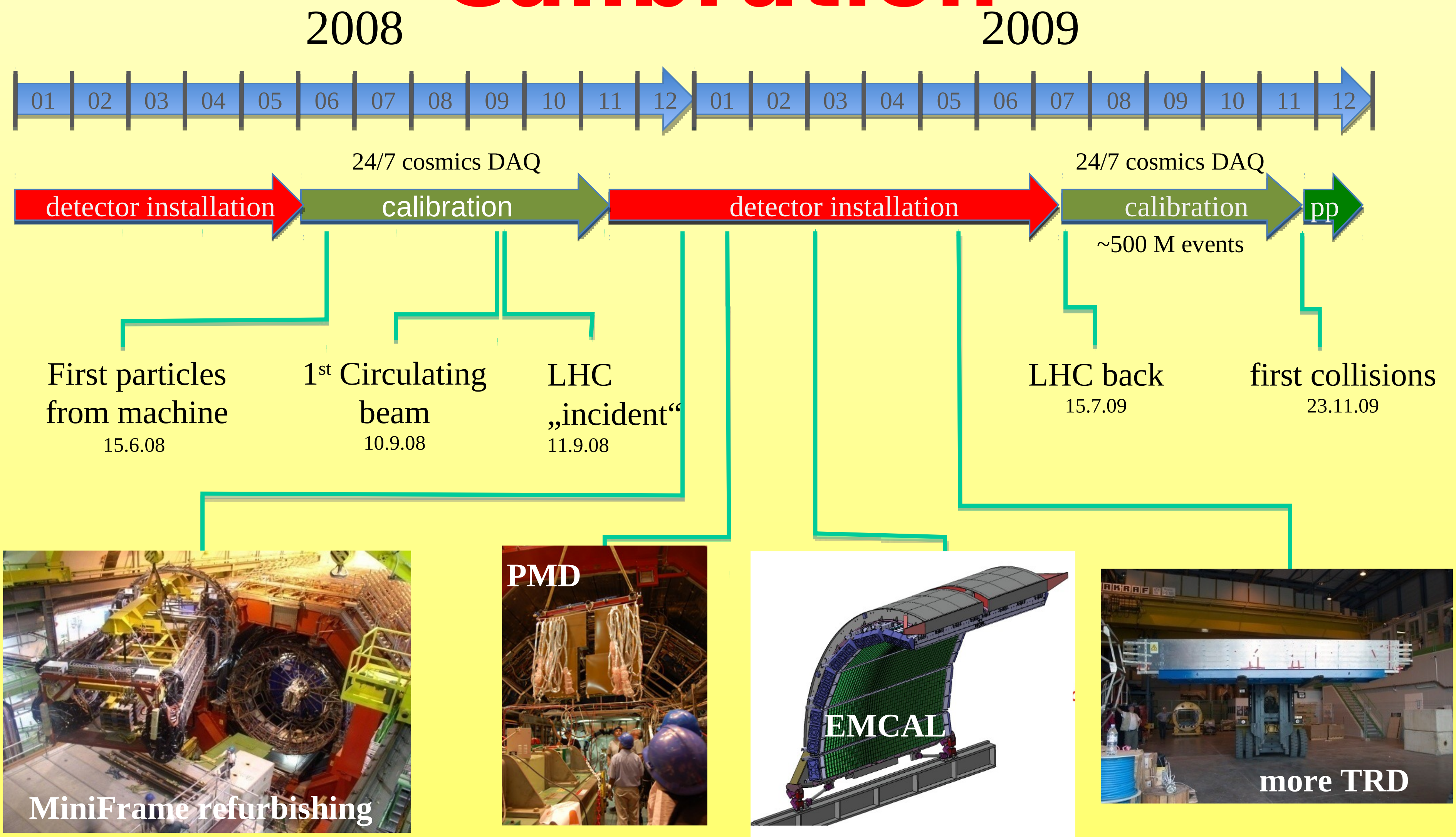
- After realignment with cosmics using SPD triggered data and Millepede:
  - Residual misalignment < 10 μm
  - Detector position resolution rφ 12 μm

First Interaction in ALICE just before the LHC incident

- LHC beam circulation tests on 11.09.2008.
- Collision of beam-halo particle with SPD: 7 reconstructed tracks from common vertex.

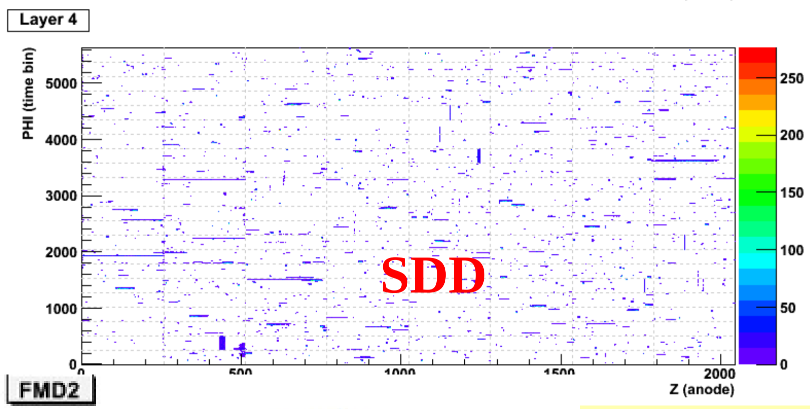


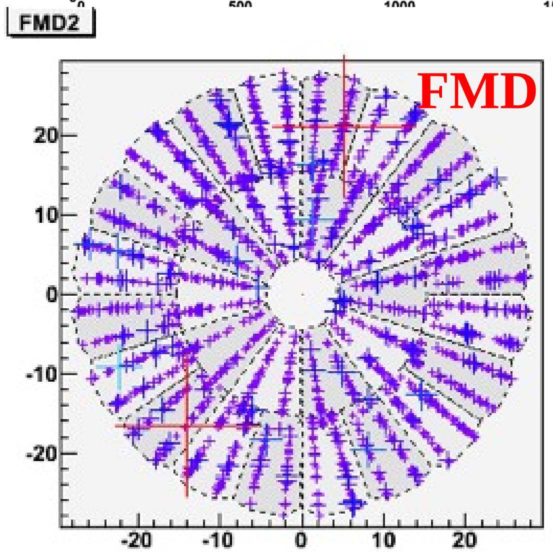
Commisioning and Calibration

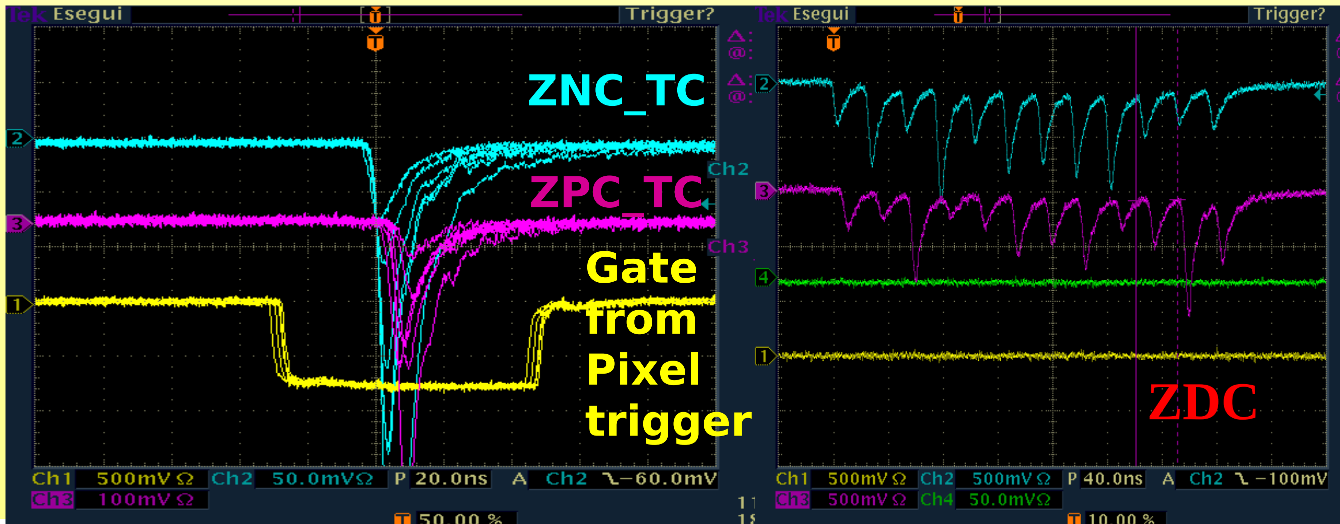


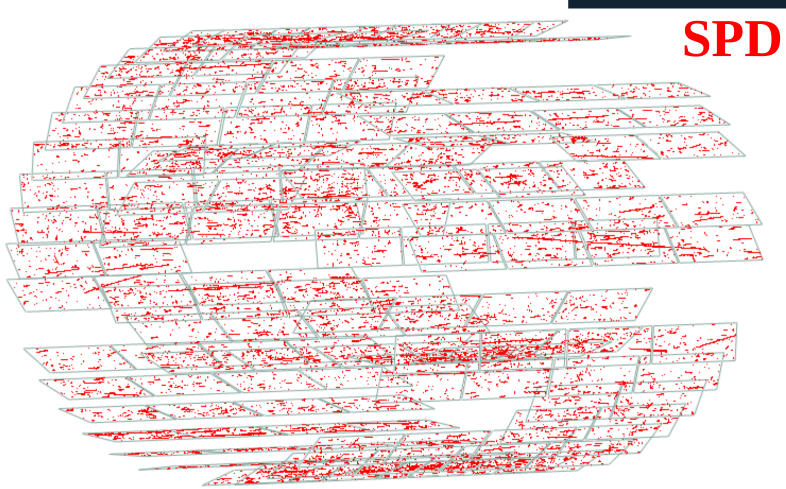
11-12 July 09 LHC extraction test: Back in Business!

Single –bunch 0.4x 10^{10} p each and 12-bunch trains (25 ns apart) with 25 x 10^9 particles per bunch Very busy day: trigger timing (MTR, SPD, V0, T0), FMD calibr, gate adjustments, SDD delay tuning

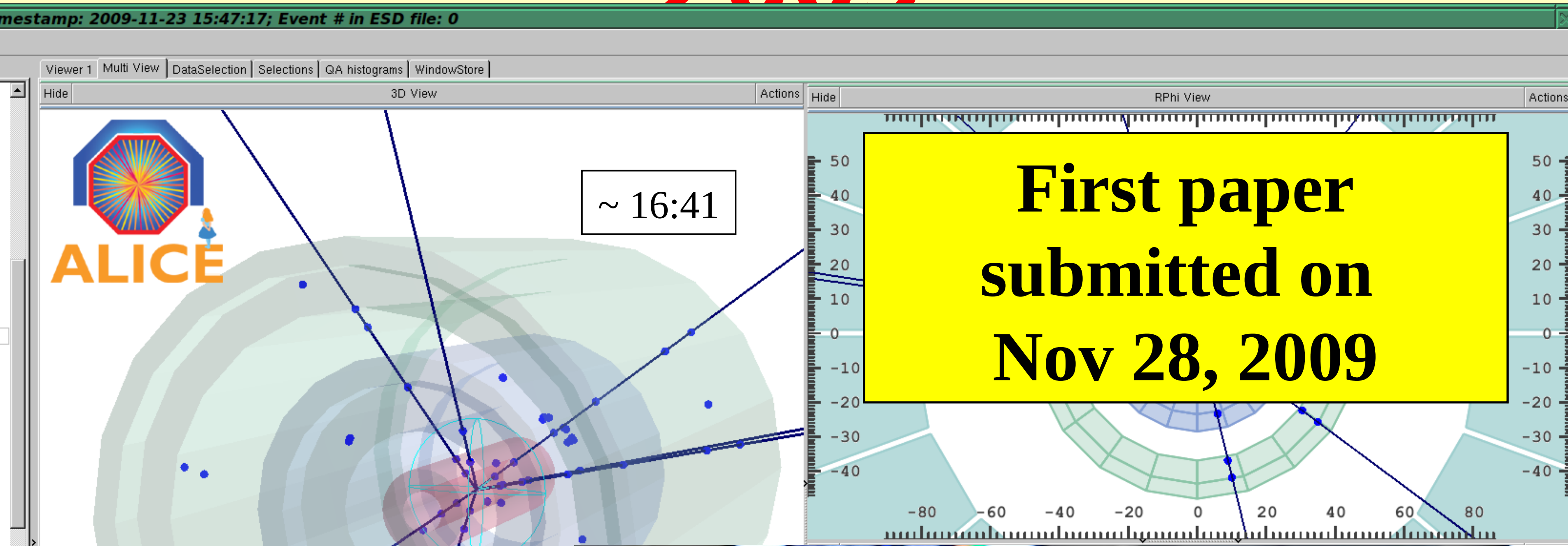








Collisions at last: 23 Nov. 2009



~ 16:41

First paper submitted on Nov 28, 2009

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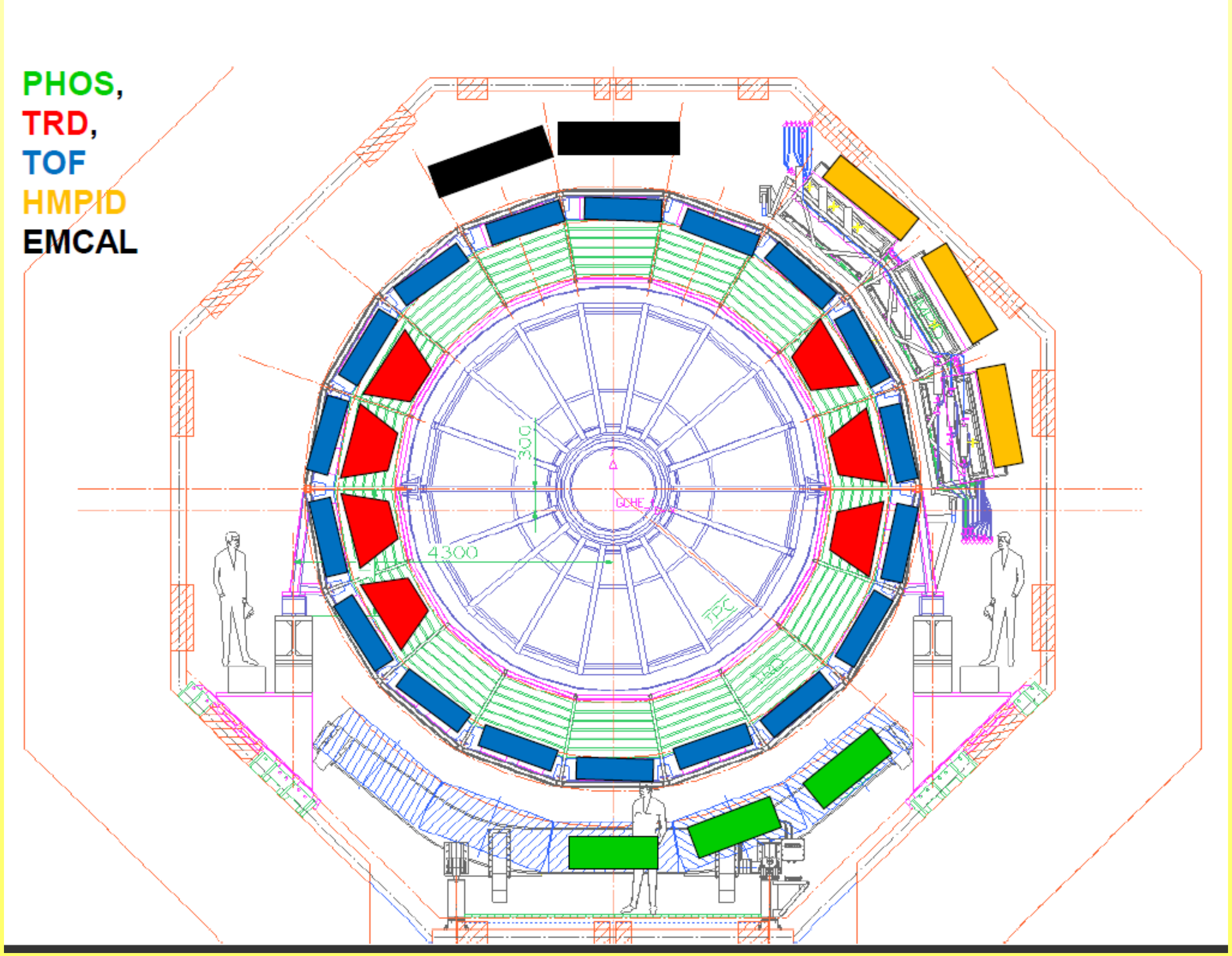
ALICE 2010

- **ITS, TPC, TOF, HMPID, MUON, V0, T0, FMD, PMD, ZDC (100%)**
- **TRD* (7/18)**
- **EMCAL* (4/12)**
- **PHOS (3/5)**



*upgrade to the original setup

ALICE Trigger configuration (so far)

- minimum bias interaction trigger
  - Si pixels (two inner layers of ITS) OR V0 (scintillators)
  - → ~ at least one charged particle in 8 pseudorapidity units
- + rare triggers:
  - single-muon in muon arm
  - high multiplicity (> 65 charged detected in three central units of η)
- activated in coincidence with the bunch crossings (BX):
  - BX with bunches from both sides
  - for control BX with bunch from side A or C only
  - for control BX with no bunches
- + a fraction of 'bunch-crossing' trigger (no condition on trigger detectors)
  - for control
  - for diffraction studies
- no further event rejection in High Level Trigger

pp collisions at LHC

- pp collisions at LHC energies:
  - collisions of incoming quarks and gluons
  - QCD
- quantitative description only established at large momentum transfers
  - pQCD
- but still phenomenological input needed
  - parton distributions
  - fragmentation functions
- and large fraction of the particles is soft, even at LHC
  - phenomenological approaches to combine hard and soft part of the particle spectrum
  - PHOJET, PYTHIA → large number of parameters to be tuned to data
- understanding of global („min bias“) characteristics in pp important for
  - „new physics“ in pp → underlying event
  - „new physics“ in Pb-Pb → pp reference

ALICE role in pp Physics at the LHC: plans…

- ALICE detector performs very well in pp
  - very low-momentum cutoff (<100 MeV/c) x_T-regime down to 4×10^{-6}
  - p_t-reach up to 100 GeV/c
  - excellent particle identification
  - efficient minimum-bias trigger
  - Excellent vertexing capabilities

- first physics in ALICE
  - provides important reference data for heavy-ion programme
  - Minimum bias running
- unique pp physics in ALICE e.g.
  - Physics at high multiplicities, reachable thanks to the multiplicity trigger from the pixel detectors (7-10 times the mean multiplicity of minimum bias collisions)
    - Same set of measurements and themes of Heavy-Ion collisions (strangeness production, jet-quenching, flow, …)
  - baryon transport
  - measurement of charm and beauty cross sections down to very low transverse momentum (major input to pp QCD physics) both open charm mesons and quarkonia

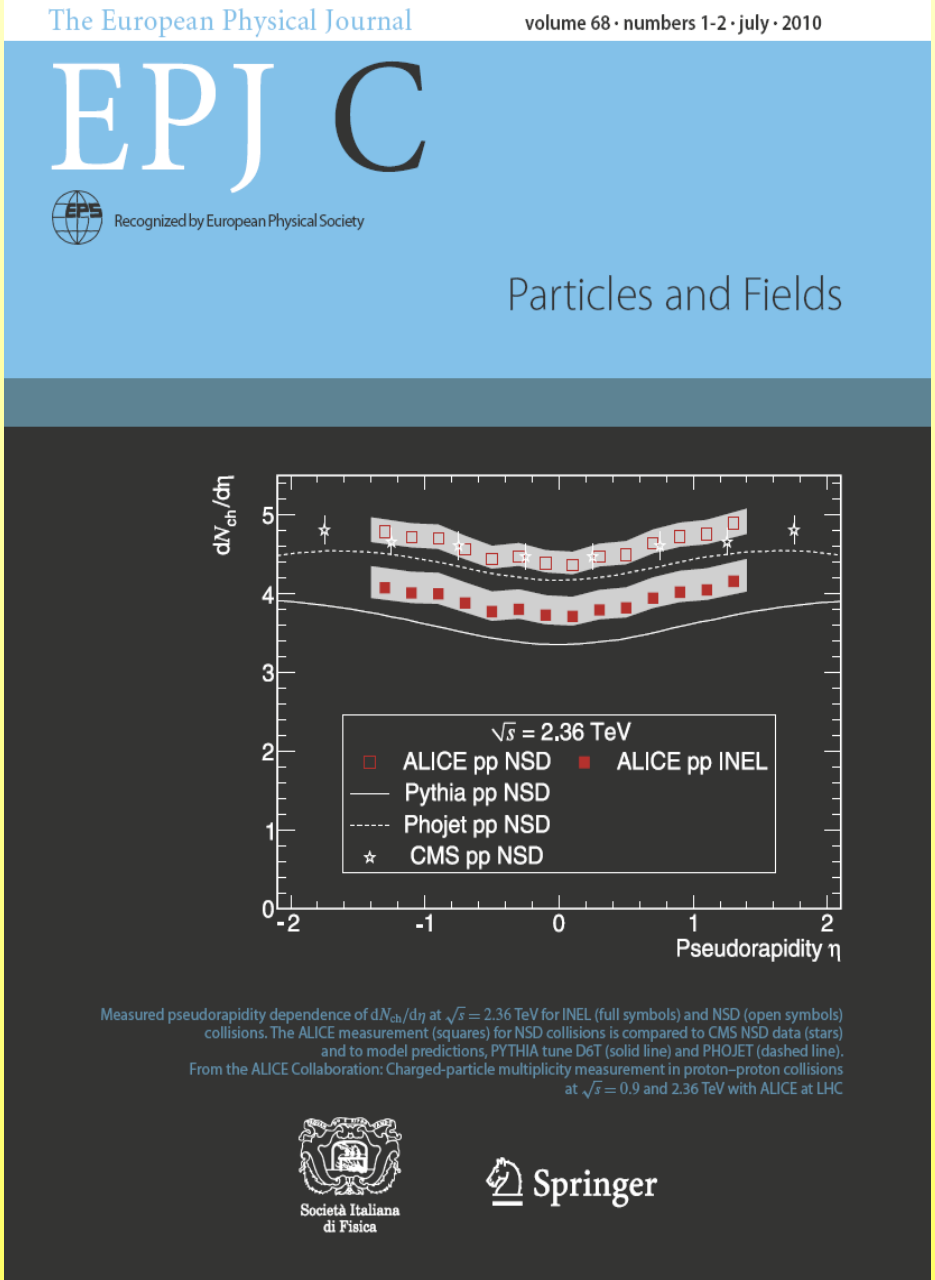
And results! Six papers so far

- First proton-proton collisions at the LHC as observed with the ALICE detector: measurement of the charged particle pseudorapidity density at sqrt(s) = 900 GeV
  - → K Aamodt et al: EPJ C 65 (2010) 11, arXiv:0911.5430
- Charged-particle multiplicity measurement in proton-proton collisions at sqrt(s) = 0.9 and 2.36 TeV with ALICE at LHC
  - → K Aamodt et al: EPJ C 68 (2010) 89, arXiv:1004.3034
- Charged-particle multiplicity measurement in proton-proton collisions at sqrt(s) = 7 TeV with ALICE at LHC
  - → K Aamodt et al: EPJC: Vol. 68 (2010) 345, arXiv:1004.3514,
- Midrapidity antiproton-to-proton ratio in pp collisions at sqrt(s) = 0.9 and 7 TeV measured by the ALICE experiment
  - → K Aamodt et al: PRL 105 (2010) 072002, arXiv:1006.5432
- Two-pion Bose-Einstein correlations in pp collisions at sqrt(s) = 900 GeV
  - → K Aamodt et al: PRD: Vol. 82 (2010) 052001 , arXiv:1007.0516
- Transverse momentum spectra of charged particles in proton-proton collisions at sqrt(s) = 900 GeV with ALICE at the LHC
  - → K Aamodt et al: PL B: Vol. 693 (2010) 53 ,arXiv:1007.0719

- **And many more analysis in preparation**
  => Talk by JPR

... a fast start!


The European Physical Journal
volume 65 · numbers 1–2 · january · 2010
EPJ C
Recognized by European Physical Society
Particles and Fields
ALICE
The first pp collision candidate shown by the event display in the ALICE counting room (3D view, $r-\phi$ and $r-z$ projections), the dimensions are shown in cm. The dots correspond to hits in the silicon vertex detectors (SPD, SDD and SSD), the lines correspond to tracks reconstructed using loose quality cuts.
From the ALICE Collaboration: First proton–proton collisions at the LHC as observed with the ALICE detector: measurement of the charged particle pseudorapidity density at $\sqrt{s} = 900$ GeV
Società Italiana di Fisica
Springer


The European Physical Journal
volume 68 · numbers 1-2 · july · 2010
EPJ C
Recognized by European Physical Society
Particles and Fields
$dN_{ch}/d\eta$
Pseudorapidity η
$\sqrt{s}$ = 2.36 TeV
ALICE pp NSD
ALICE pp INEL
Pythia pp NSD
Phojet pp NSD
CMS pp NSD
Measured pseudorapidity dependence of $dN_{ch}/d\eta$ at $\sqrt{s} = 2.36$ TeV for INEL (full symbols) and NSD (open symbols) collisions. The ALICE measurement (squares) for NSD collisions is compared to CMS NSD data (stars) and to model predictions, PYTHIA tune D6T (solid line) and PHOJET (dashed line).
From the ALICE Collaboration: Charged-particle multiplicity measurement in proton–proton collisions at $\sqrt{s} = 0.9$ and 2.36 TeV with ALICE at LHC
Società Italiana di Fisica
Springer

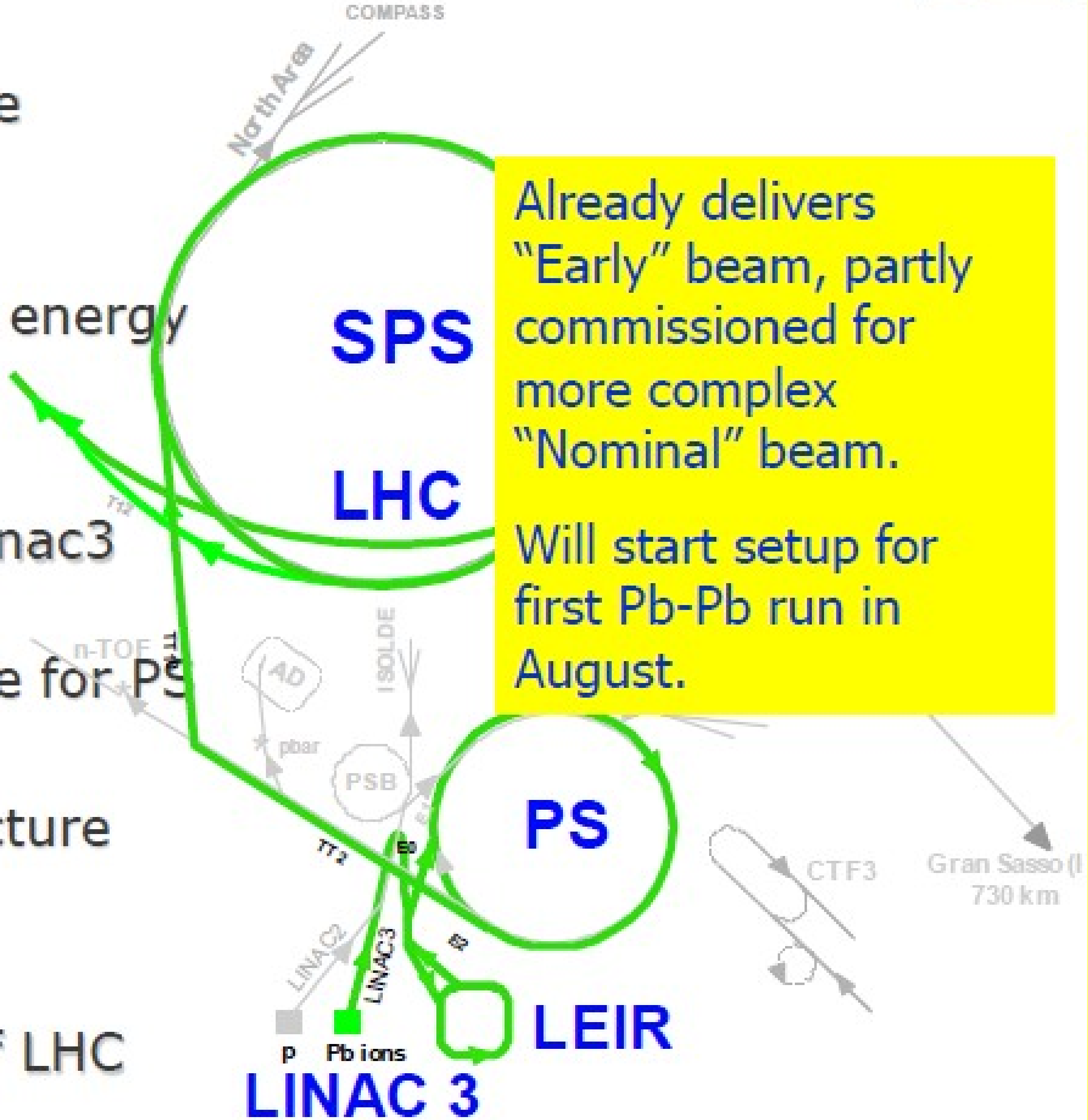
What next: Pb in the LHC

- 1 month/year for heavy-ion programme, initially $^{208}Pb^{82+}$- $^{208}Pb^{82+}$
  - Later p-Pb, lighter A-A, ...
- Even at initial half-nominal energy, pushes the energy frontier for laboratory nuclear collisions a factor 13.7 (later up to 28) beyond RHIC,
  - We are about to make the biggest energy step that will ever be made by any collider in history, past or future, over its predecessor
- The first Pb-Pb run will start on 6 November

J.M. Jowett, The first heavy ion collisions at the LHC – HIC10, CERN, 3/9/2010

LHC Ion Injector Chain

- ECR ion source (2005)
  - Provide highest possible intensity of Pb^{29+}
- RFQ + Linac 3
  - Adapt to LEIR injection energy
  - strip to Pb^{54+}
- LEIR (2005)
  - Accumulate and cool Linac3 beam
  - Prepare bunch structure for PS
- PS (2006)
  - Define LHC bunch structure
  - Strip to Pb^{82+}
- SPS (2007)
  - Define filling scheme of LHC



Already delivers "Early" beam, partly commissioned for more complex "Nominal" beam.

Will start setup for first Pb-Pb run in August.

Target luminosity in 2010 vs. "Nominal"

		Early (2010/11)	Nominal
$\sqrt{s_{NN}}$ (per colliding nucleon pair)	TeV	2.76	5.5
Number of bunches		62	592
Bunch spacing	ns	1350	99.8
β^*	m	$2 \rightarrow 3.5$	0.5
Pb ions/bunch		7×10^7	7×10^7
Transverse norm. emittance	μm	1.5	1.5
Initial Luminosity (L_0)	$cm^{-2}s^{-1}$	$(1.25 \rightarrow 0.7)\ \ 10^{25}$	10^{27}
Stored energy (W)	MJ	0.2	3.8
Luminosity half life (1,2,3 expts.)	h	τ_{IBS}=7-30	8, 4.5, 3

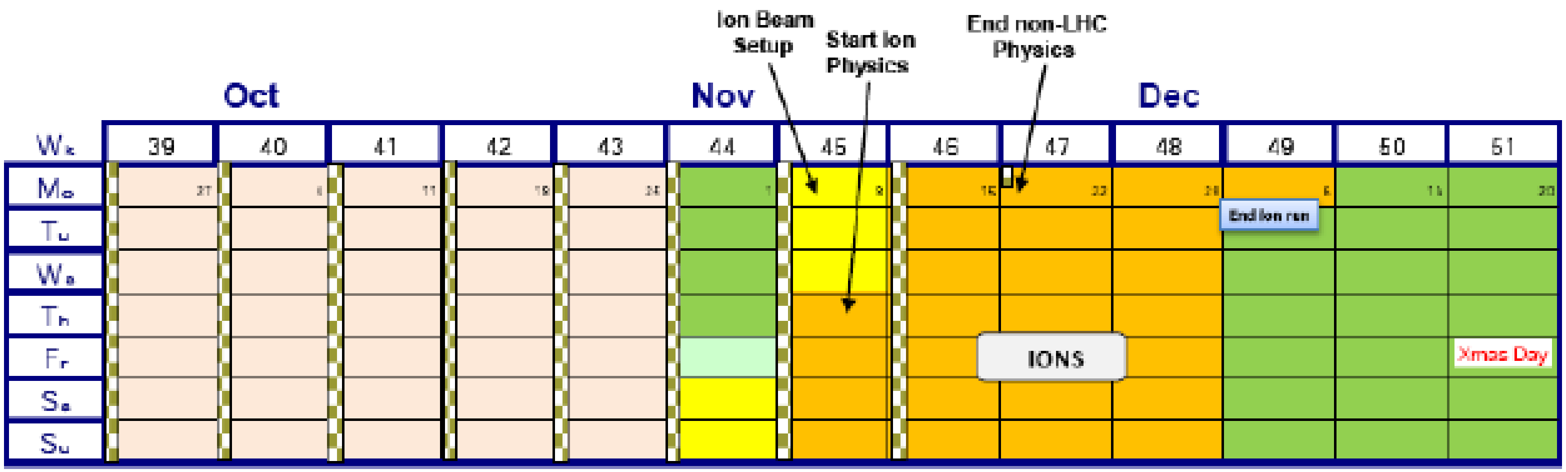
Caveat: assumes design emittance

Initial interaction rate: 50-100 Hz (5-10 Hz central collisions b = 0–5 fm)

~10^8 interaction/10^6s (~1 month)

In 2010: integrated luminosity 1-3 μb^{-1}

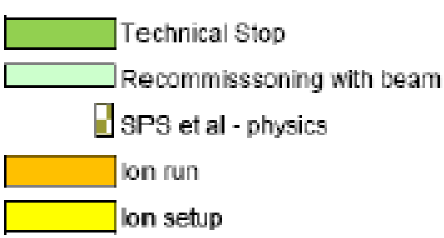
Schedule (as of 15/8/2010)



Lead-up to lead in LHC involves a lot of work in the ion injectors.

Possibility of a short pilot run in mid-October is under discussion.

At present, we can only anticipate that the "Early Beam" can be delivered to LHC with the design parameters.



Outlook for 2010 Pb-Pb run

- expected luminosity ~ 2 orders of magnitude below nominal
  - 10^{27} cm^{-2} s^{-1} → 10^{25} cm^{-2} s^{-1}
  - ~ /10 from number of bunches
  - ~ /10 from increased beam size (lower energy, less focussing)

  → 50 – 100 Hz min bias

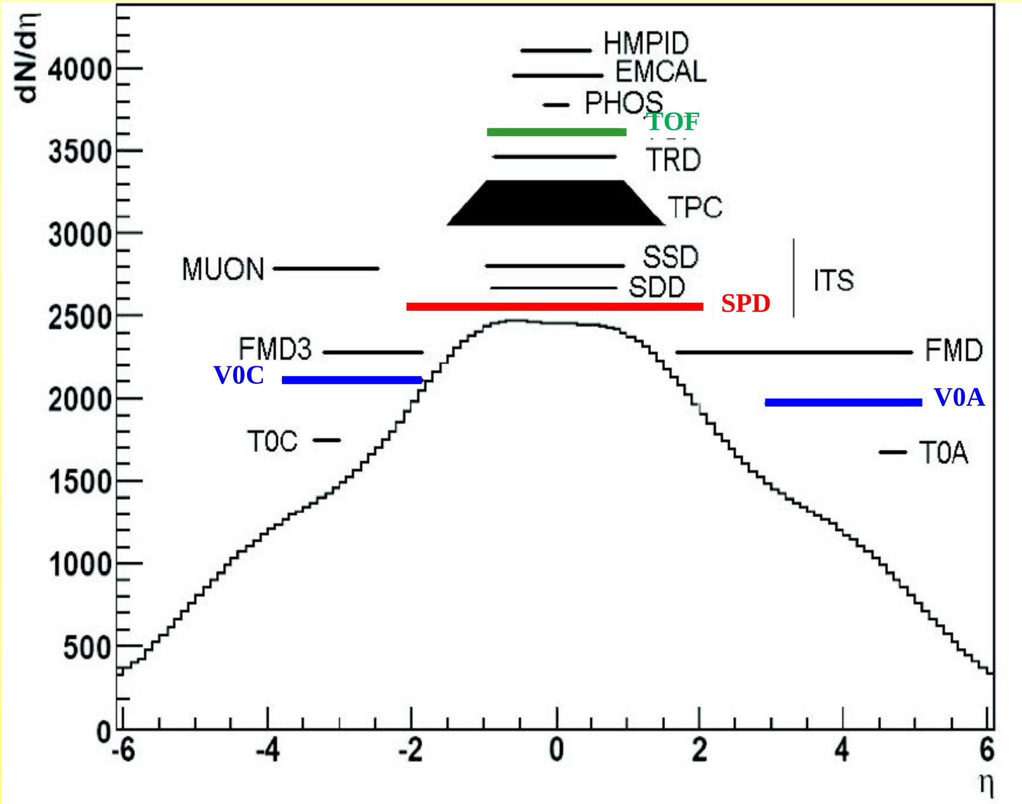
  → strategy: low bias trigger
- expected data sample?
  - estimate from J Jowett : ~ 1 – 3 μb^{-1} (@ TH workshop, 3/IX/2010)
    - e.g.: 2 μb^{-1} = 1.6 10^{7} min bias events
  - for comparison: ALICE targets:
    - 0.5 nb^{-1} for rare triggers
    - a few 10^{7} central events for central physics
  - caveat: any of the parameters could swing up or down…

Triggering

- low bias
  - basically as low as backgrounds allow

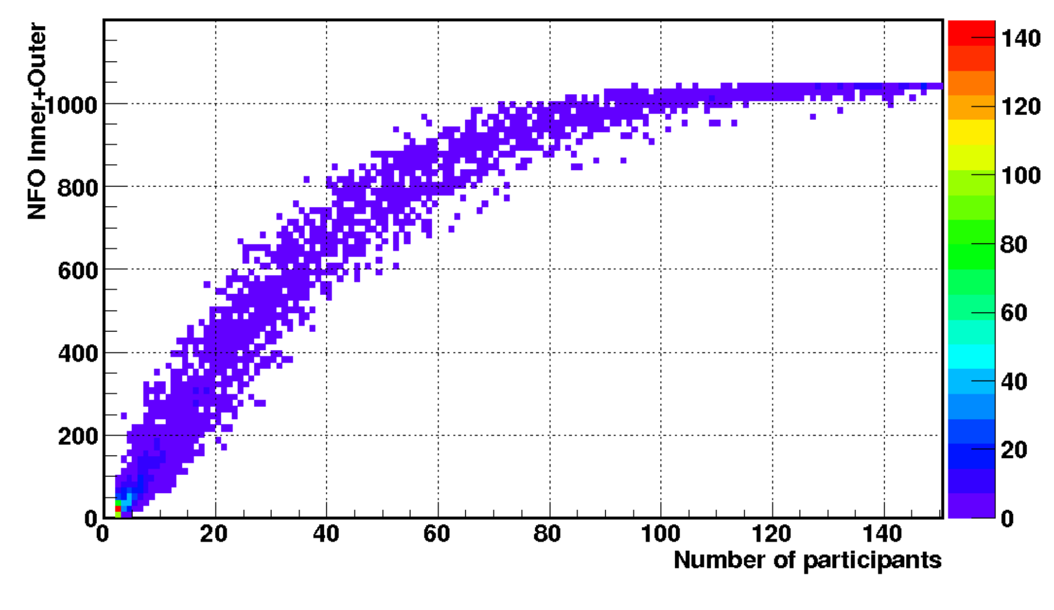
- <u>little information on expected backgrounds</u>
  → important to measure early-on with circulating beams

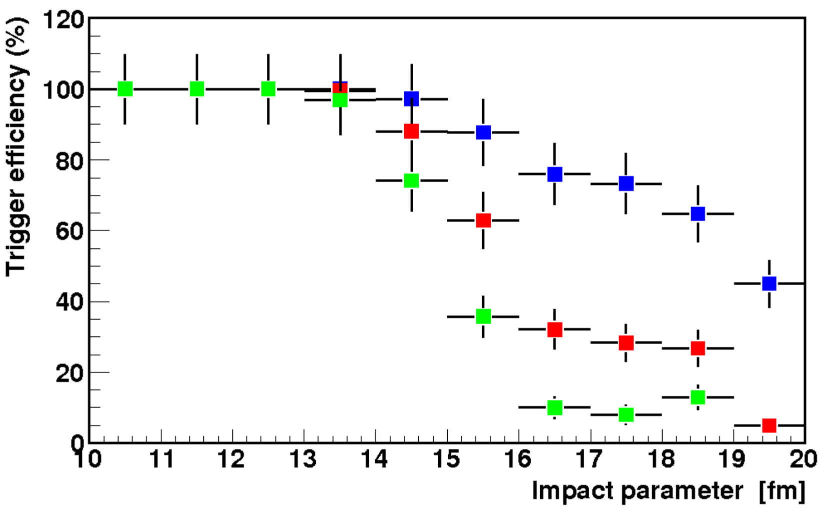
- three triggers running in parallel: from SPD, TOF, V0



SPD trigger

- Using chip-by-chip FASTOR
  - 1200 chips in complete SPD barrel





<u>Inefficiency vs threshold:</u>

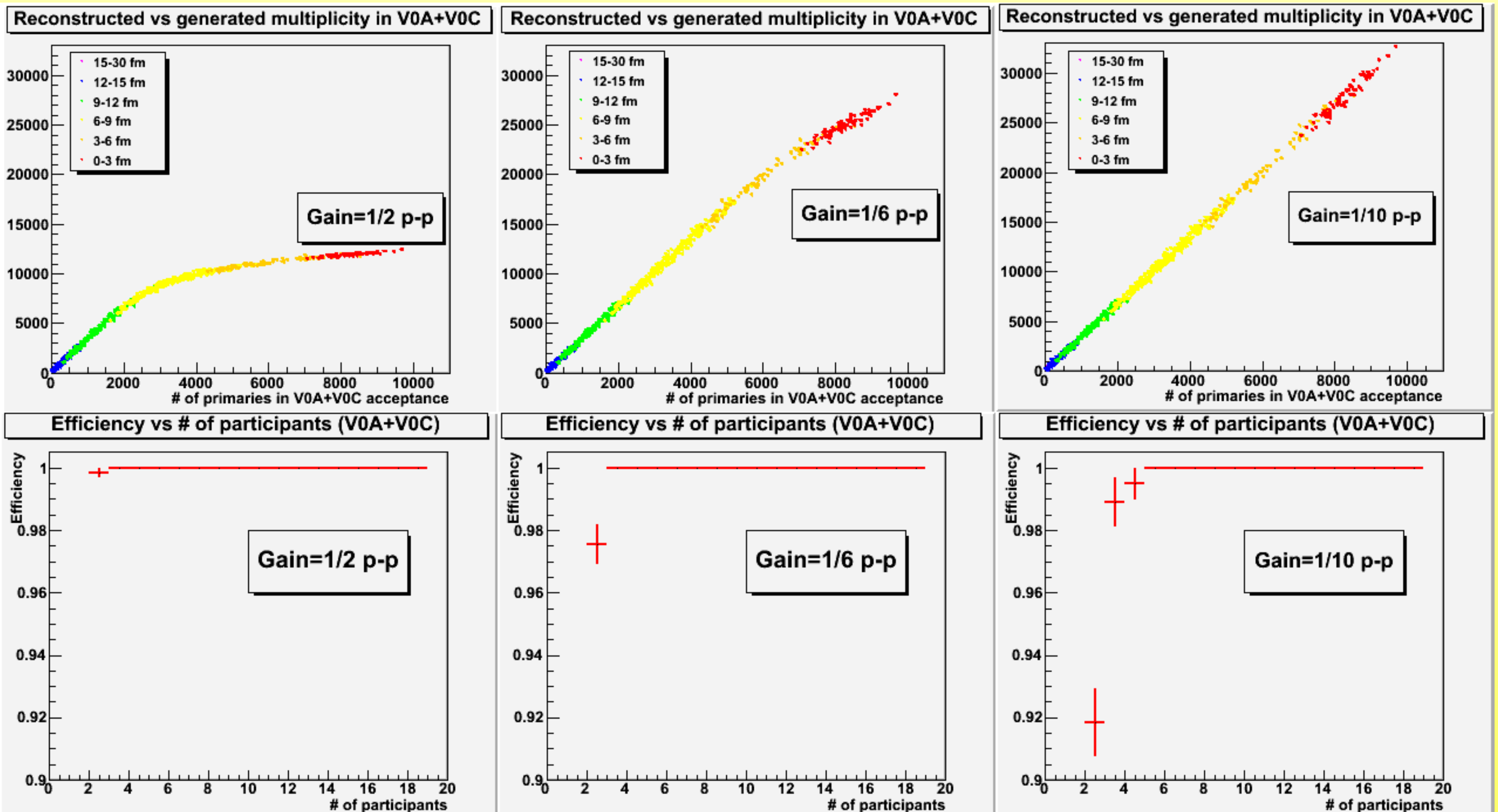
3.5% (nFO > 20)

10.4% (nFO > 50)

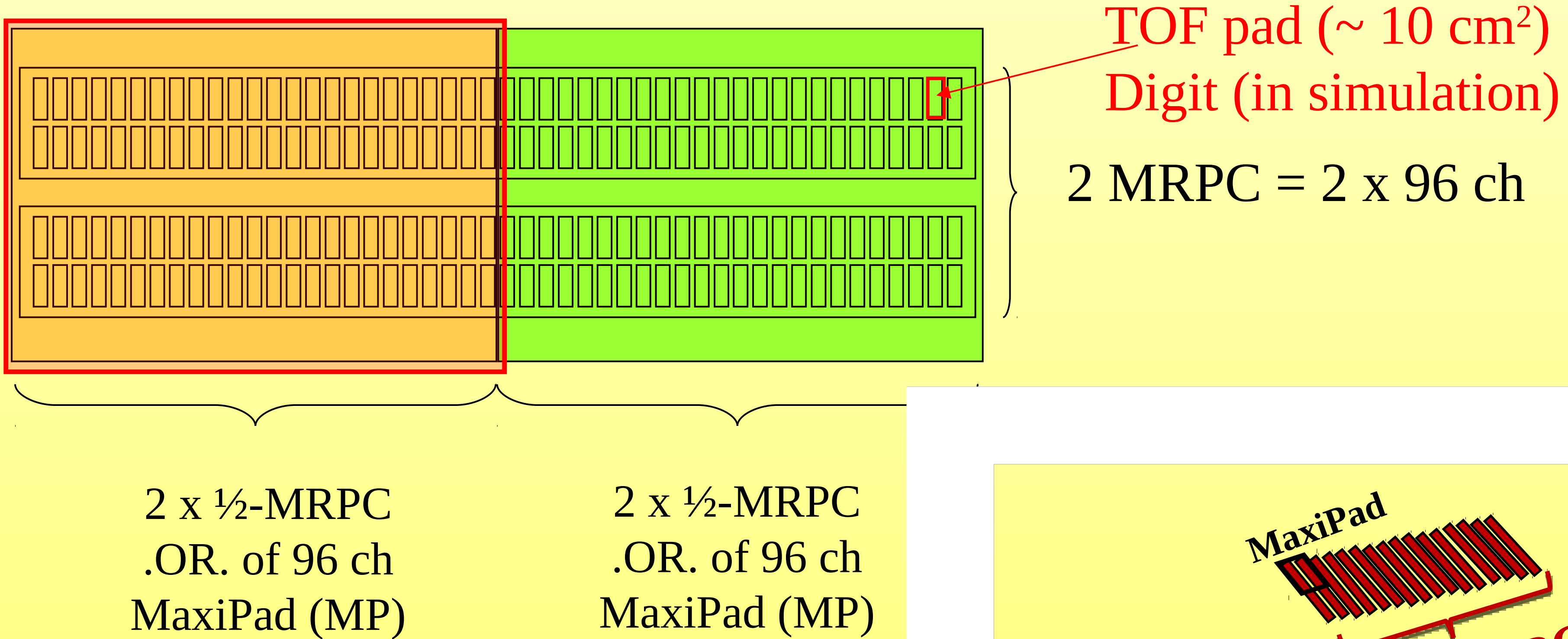
16.5% (nFO > 100)

V0 trigger

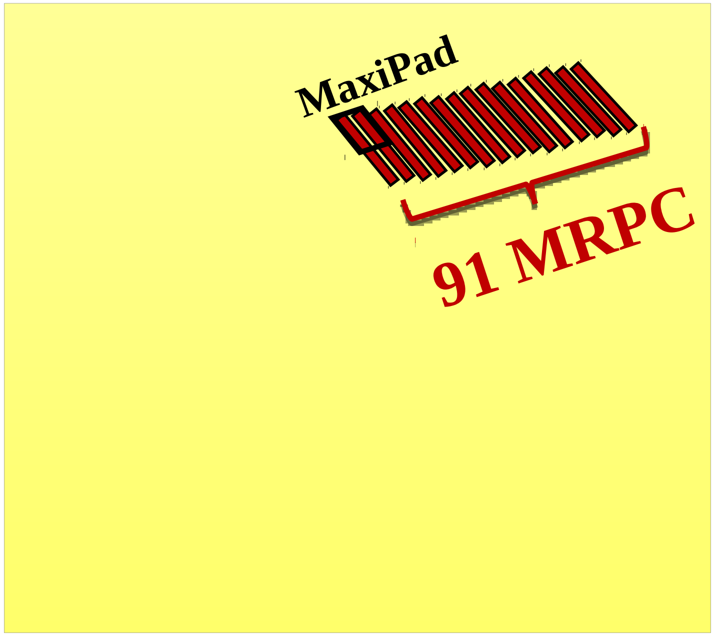
- e.g.: varying gain on Pb-Pb simulation
  - using same thresholds as in pp



TOF trigger MaxiPads

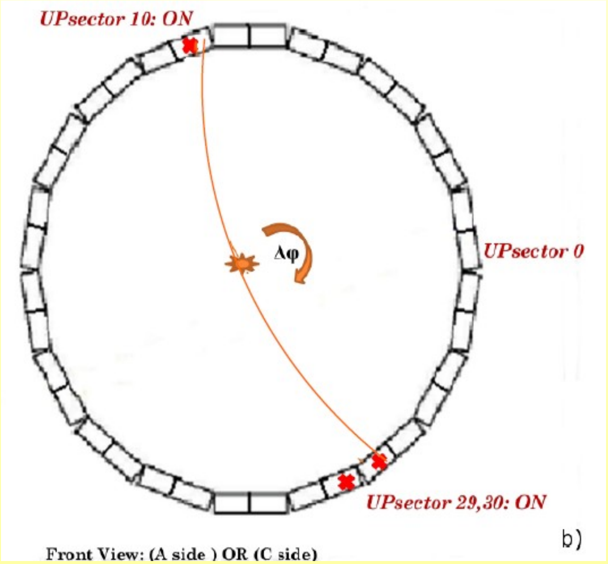


→ barrel divided into
46 (z) × 36 (φ) MaxiPads

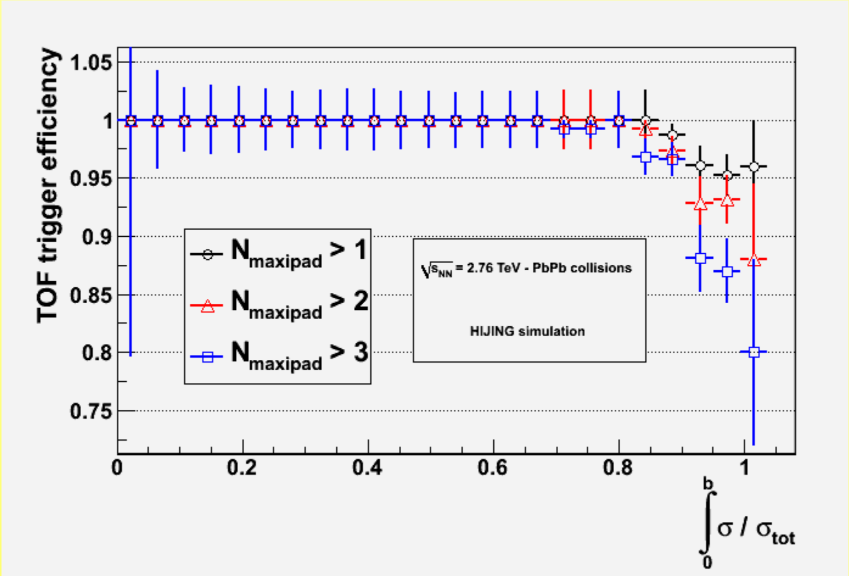


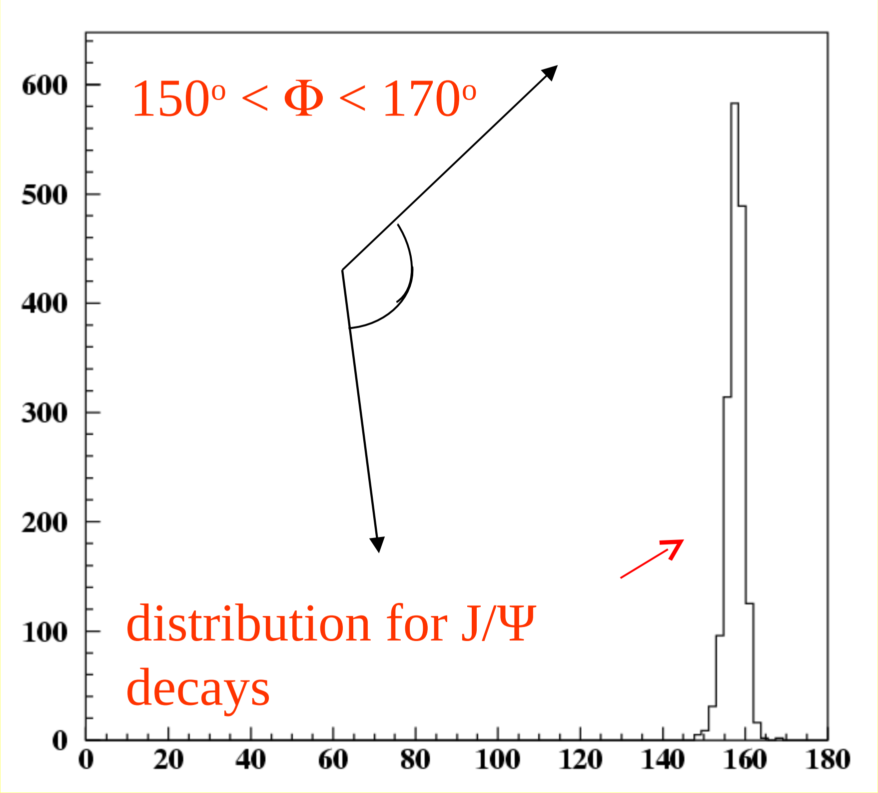
TOF Triggers

- Ultra-Peripheral J/Ψ
  - 2 MaxiPads
  - correlation in φ



- Interaction
  - condition on MaxiPad multiplicity

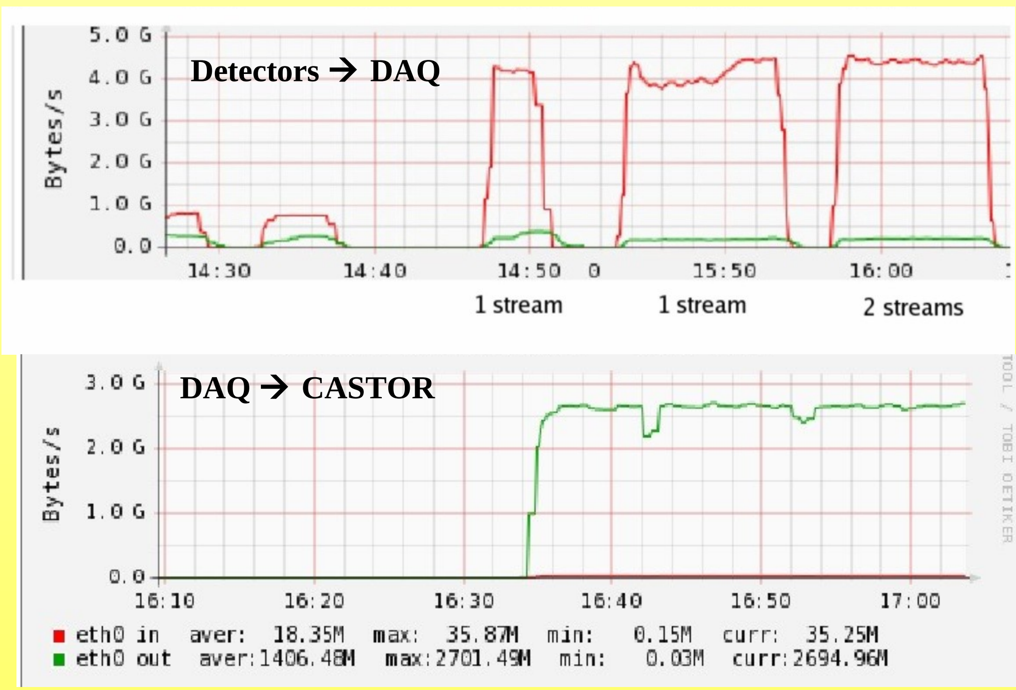




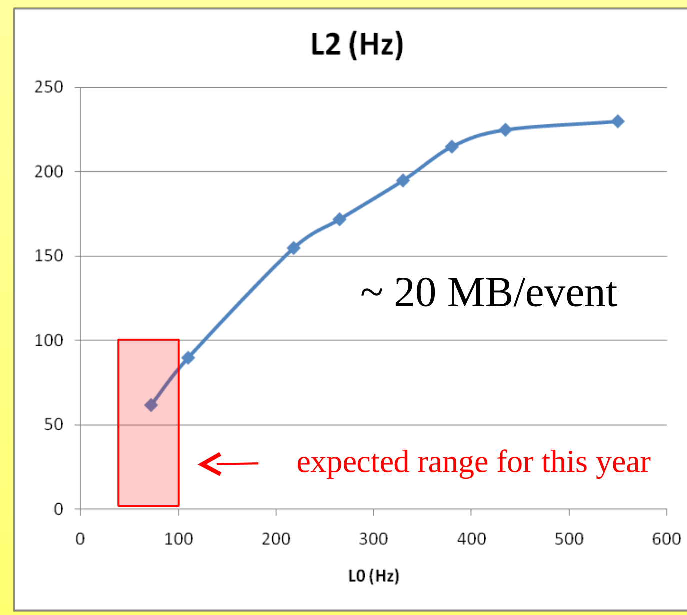
Angle between leptons ΔΦ(degrees)

High data rate tests

- extensive tests at Point 2 with artificially created Pb-Pb-like event sizes
  - verify correct operation of DAQ/Trigger
  - test data transfer bandwidths



Rate to DAQ vs L0 trigger rate



→at expected luminosity for this year HLT filtering is not needed

Heavy Ion Physics with ALICE

- **fully commissioned detector & trigger**
  - alignment, calibration available from pp

- **first 10^5 events:** global event properties
  - multiplicity, rapidity density
  - elliptic flow
- **first 10^6 events:** source characteristics
  - particle spectra, resonances
  - differential flow analysis
  - interferometry
- **first 10^7 events:** high-p_t, heavy flavours
  - jet quenching, heavy-flavour energy loss
  - charmonium production
- yield bulk properties of created medium
  - energy density, temperature, pressure
  - heat capacity/entropy, viscosity, sound velocity, opacity
  - susceptibilities, order of phase transition

First run Physics Reach?

global event properties

multiplicity

v2

HBT

bulk strangeness

with a p_T reach dependent on statistics…

particle correlations

nuclear modification factors

strange, identified particle spectra

a first glimpse of hard probes?

jets

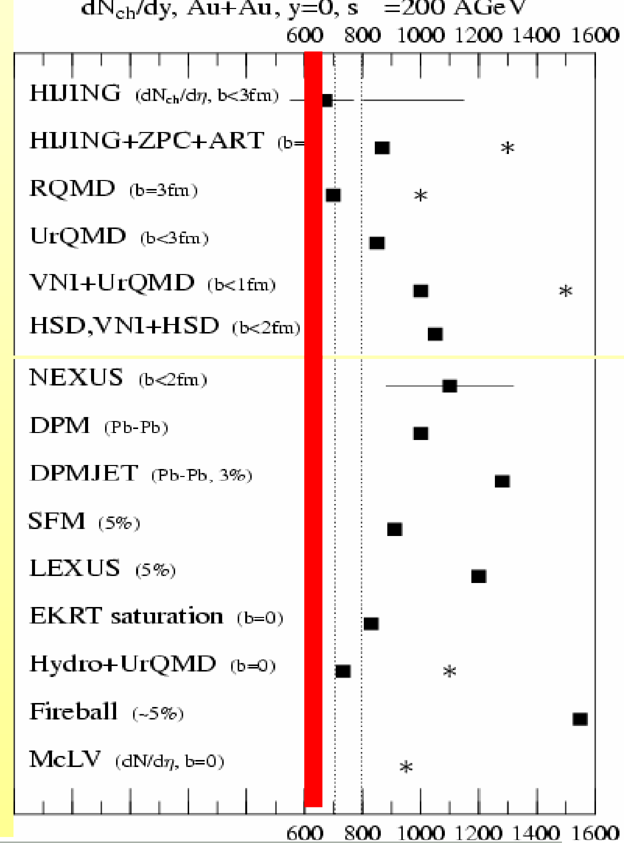
J/ψ

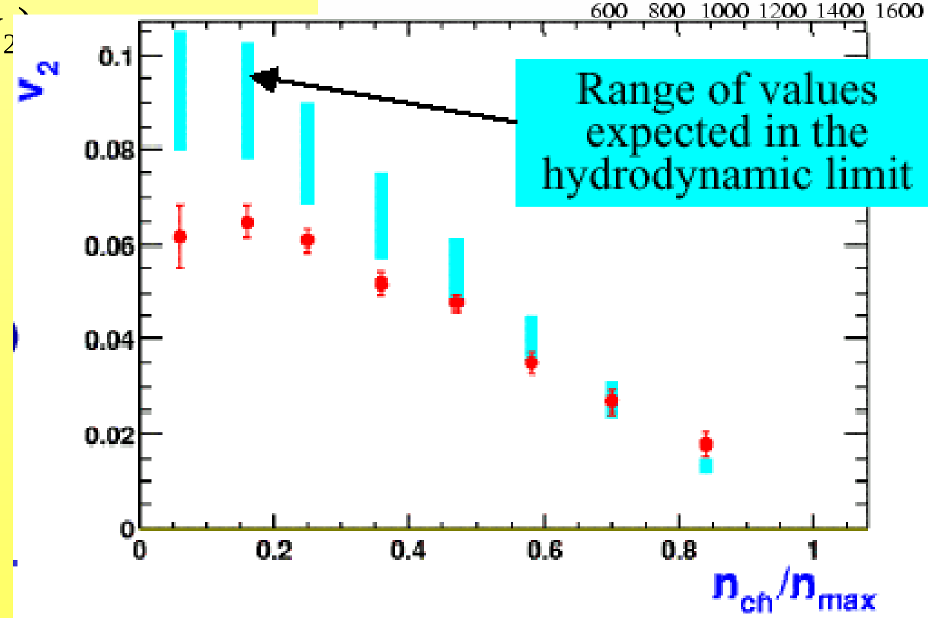
heavy flavour

surprises? (always there so far at each new AA energy)

‘Phyisics of the First 3 Minutes’

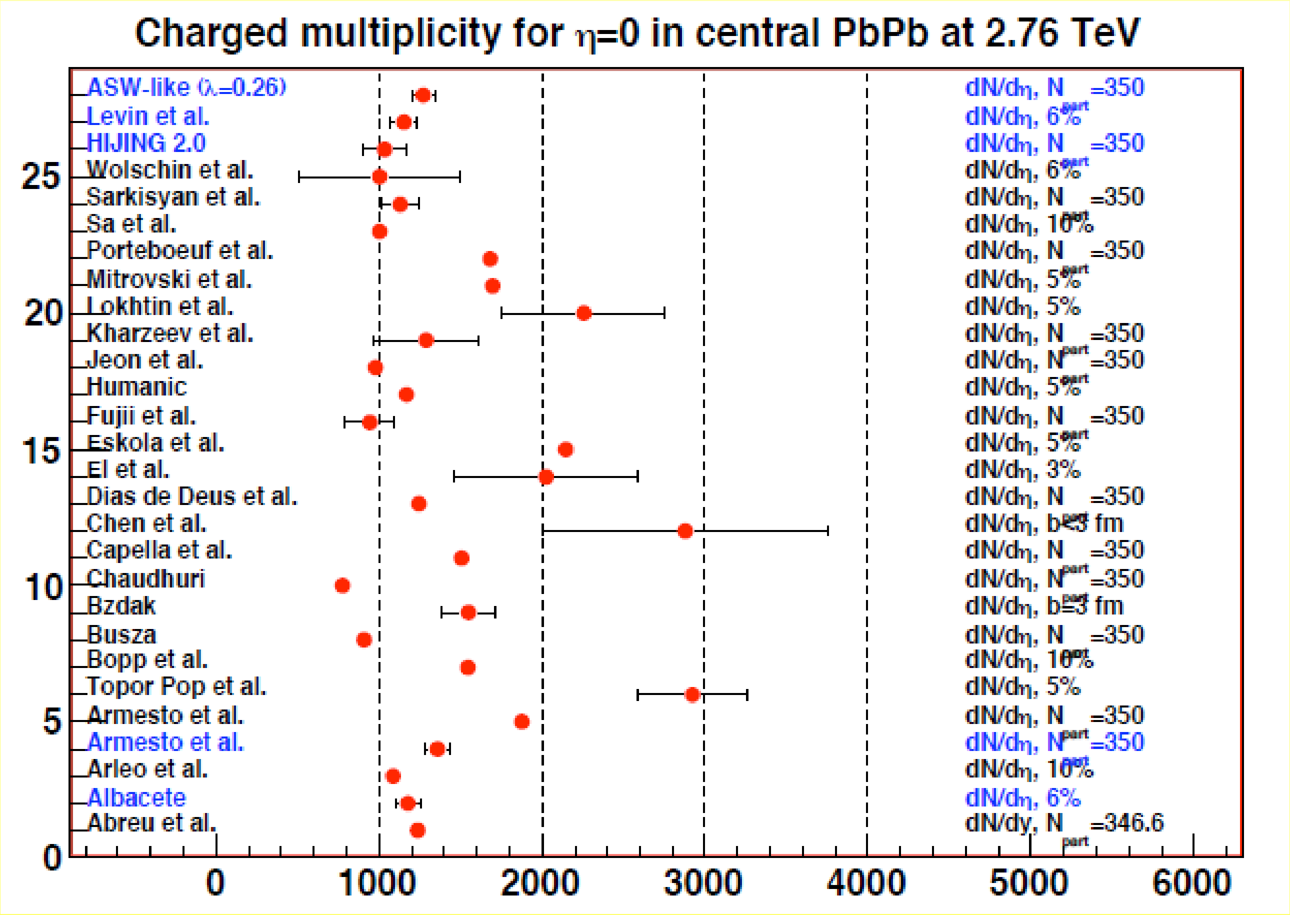
- Minimum Statistics needed:
  - few seconds at 1% design L
- **SPS in 1986**
  - first spectrum 1 week
    before official start of HI run !
- **RHIC in 2000:** first collisions June 12
  - 1st paper July 19, dNch/dη, excluding 90% of predictions
  - 2nd: Aug 24, 22k events, flow surprise (v_2
  - ~ 3 weeks run, very low L,
    > 10 PRL’s within < 1 year
    - RHIC was commissioned with HI !





Multiplicity

- connected to temperature, energy density, parton density,…
  - day 1 measurement → primary input to models
- considerable spread of predictions… and the possibility of surprises!



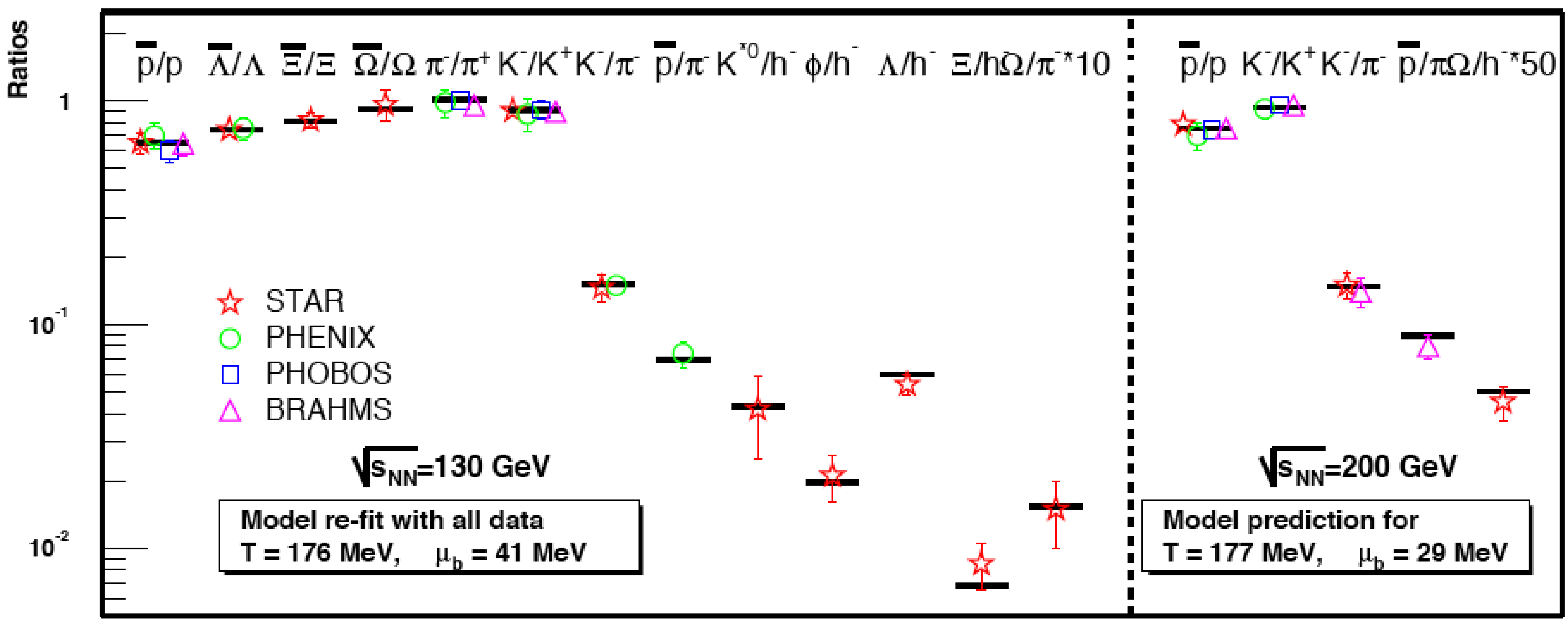
from Néstor Armesto
@ CERN TH Institute
3 September 2010

Day-1 Physics: Chemical composition

Particle composition can be described in terms of a statistical model (grand canonical ensemble) with 2 free parameters (thermalization temperature and bariochemical potential). Consistent with a thermalization of the system with **T ~ 170 MeV , μ_B ~ 30 MeV**

Limiting temperature reached for large sqrt(s).

$\chi_r^2 = 0.8$ $\chi_r^2 = 1.1$

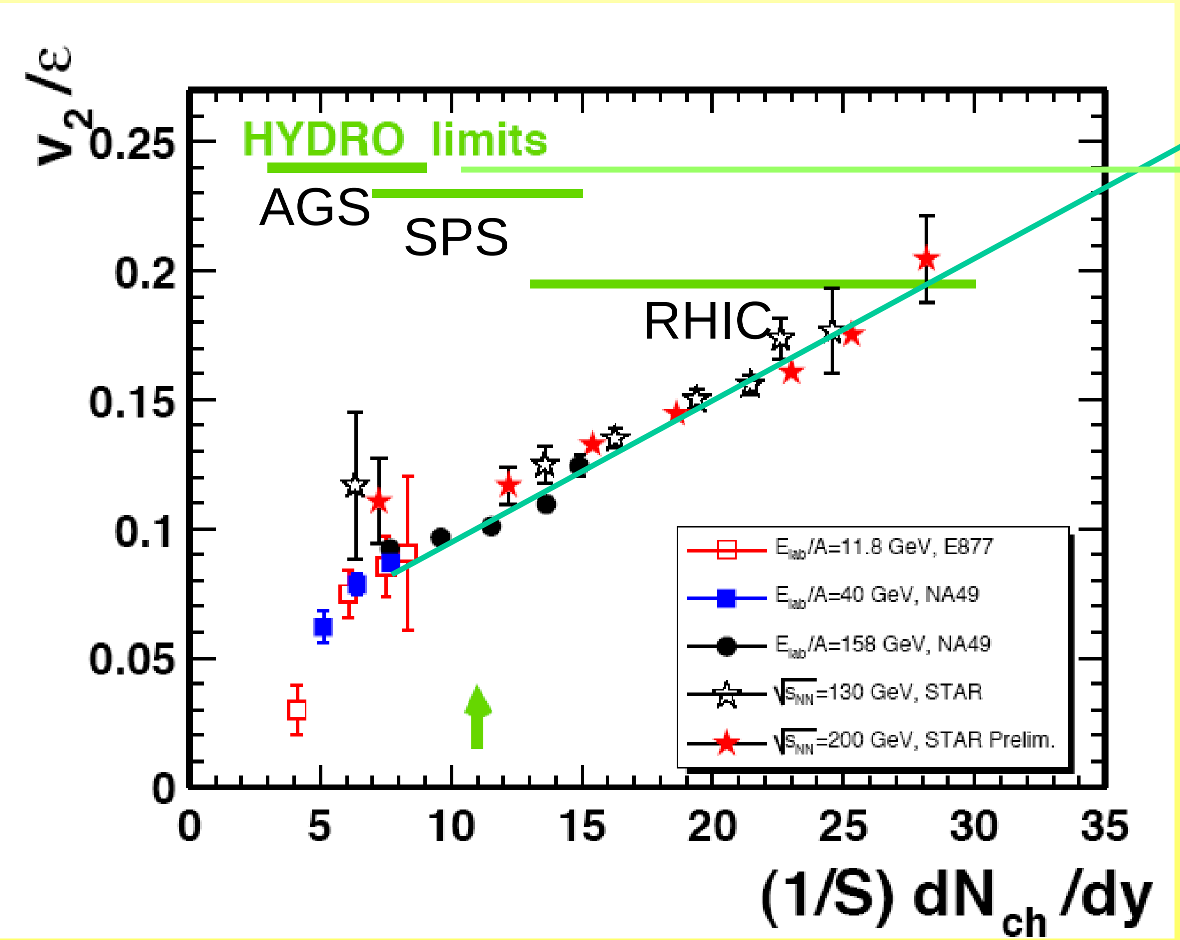


Braun-Munzinger et al., PLB 518 (2001) 41 D. Magestro (updated July 22, 2002)

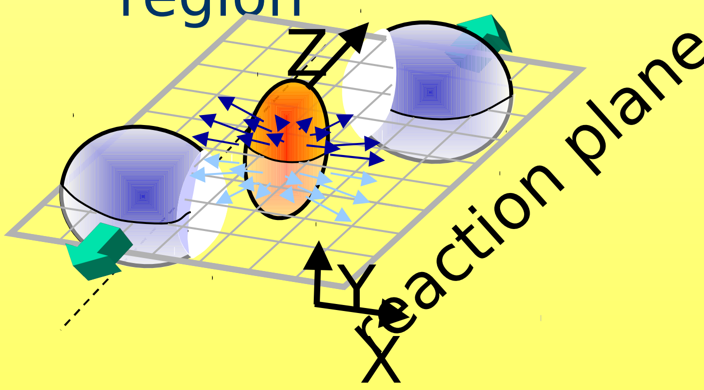
Day 1 Physics (10^5 events): Elliptic Flow

- One of the first answers from LHC
  - Experimental trend & scaling predicts large increase of flow
  - Hydrodynamics: modest rise

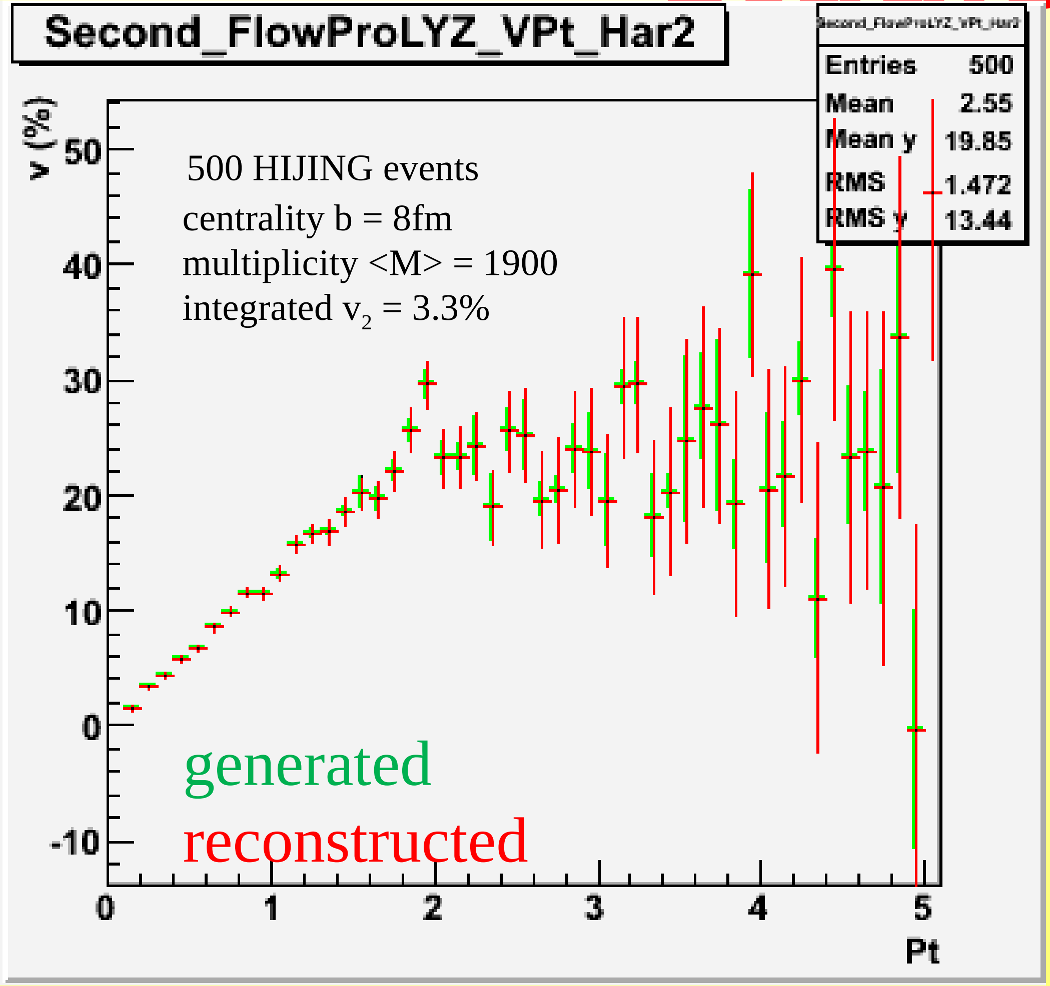
L
H
C



eccentricity vs. particle multiplicity in overlap region



v_2 measurement studies

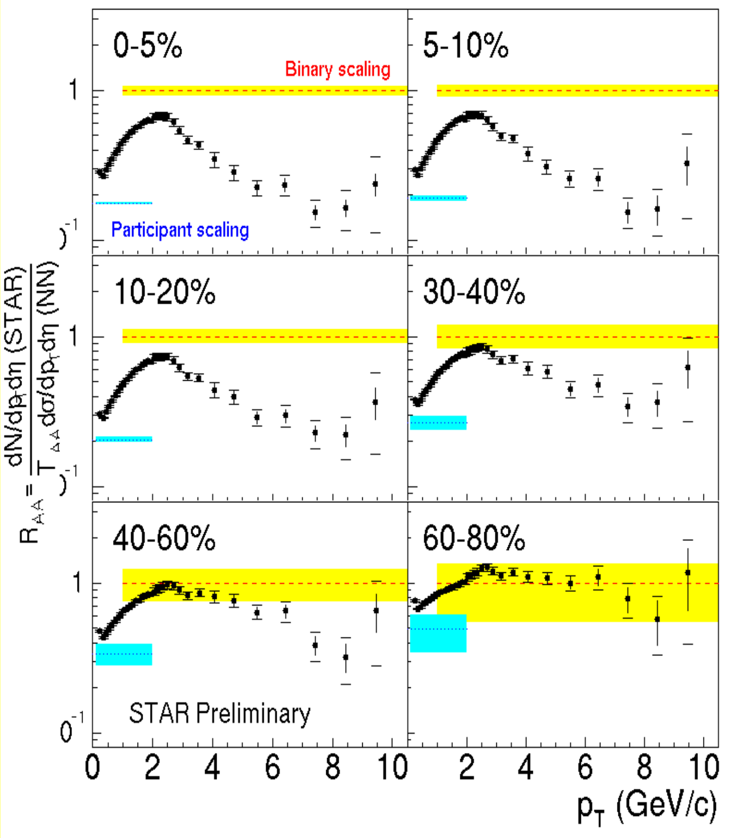


Standard event-plane method

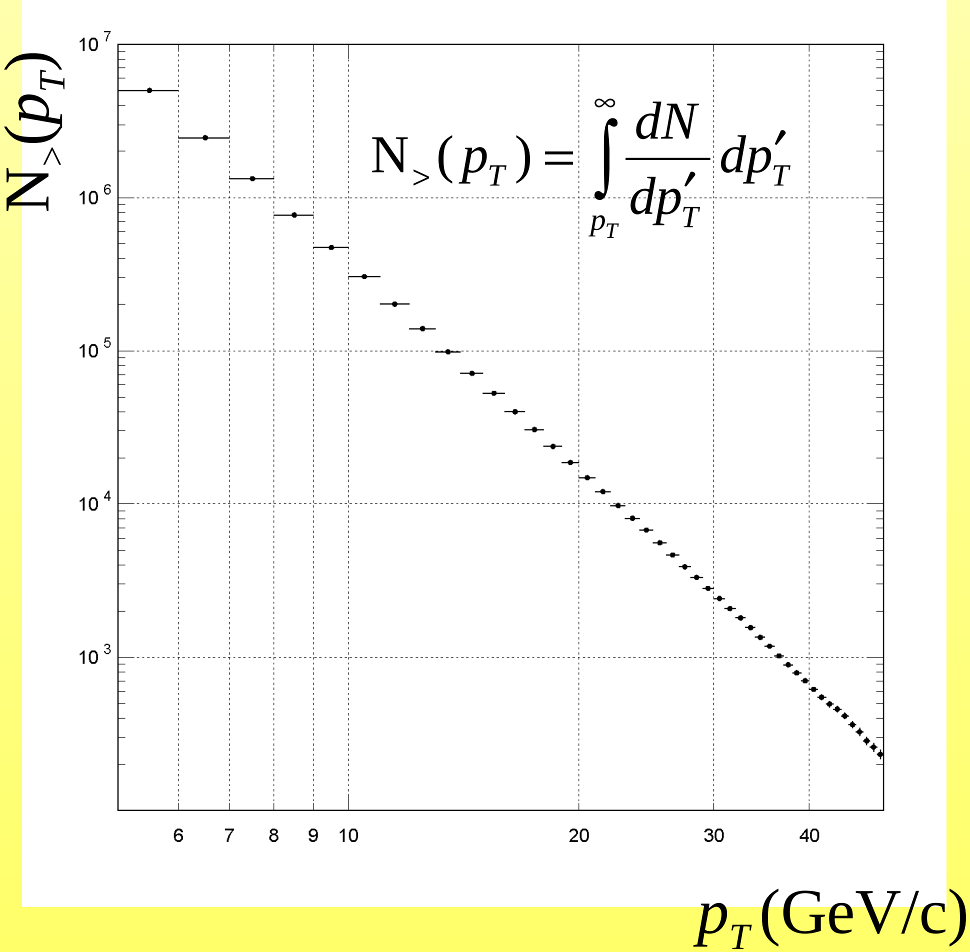
10^7 events → approach 20 GeV (asymmetry still there?)

Nuclear modification factor

- in Au-Au @ RHIC particle production suppressed by factor ~ 5 at high p_T w.r.t. binary-scaled p-p



- e.g.: expected reach in ALICE for 10^6 central (with no suppression):



Identified Particles: ρ, φ, K* , K^0_s, Λ, Ξ, Ω...

Measure:

- Hadrochemical Analysis
- medium modification of mass and widths

10^7 events:

p_t reach φ,K,Λ

~ 13-15 GeV

p_t reach Ξ,Ω

~ 9-12 GeV

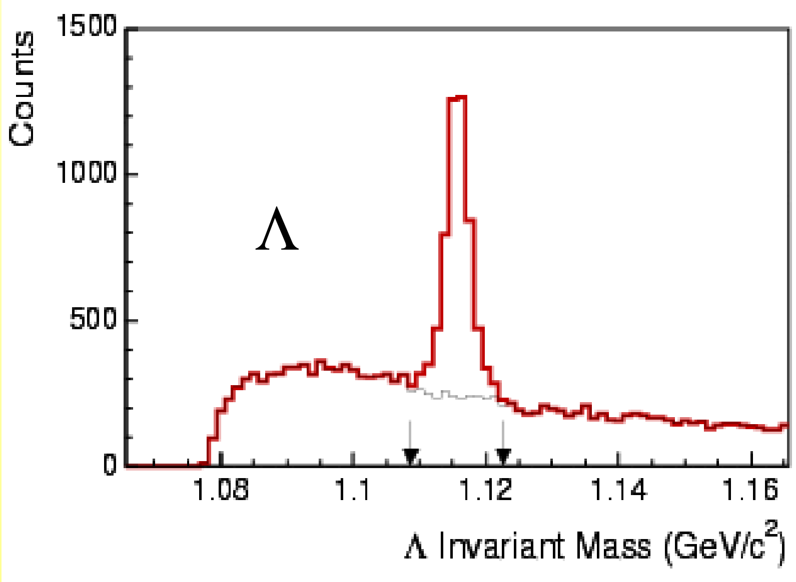
Reconstruction rates:

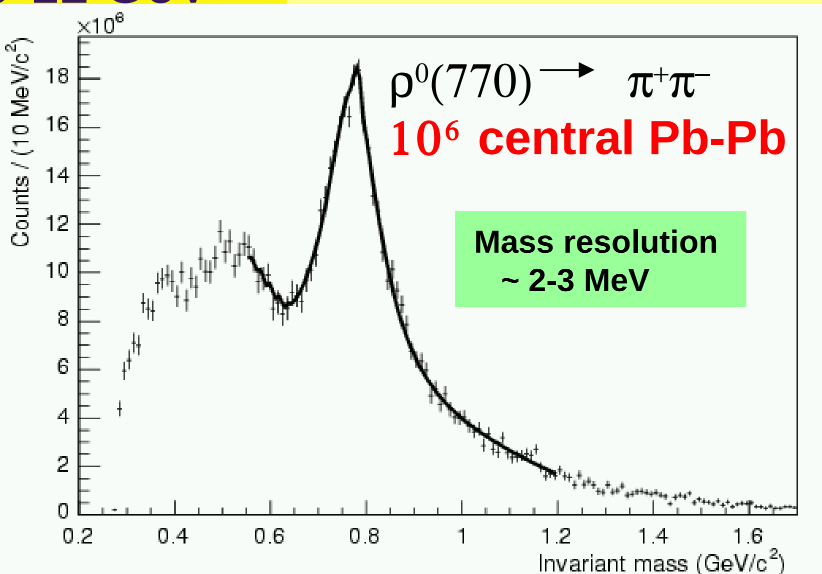
Λ: 13/event

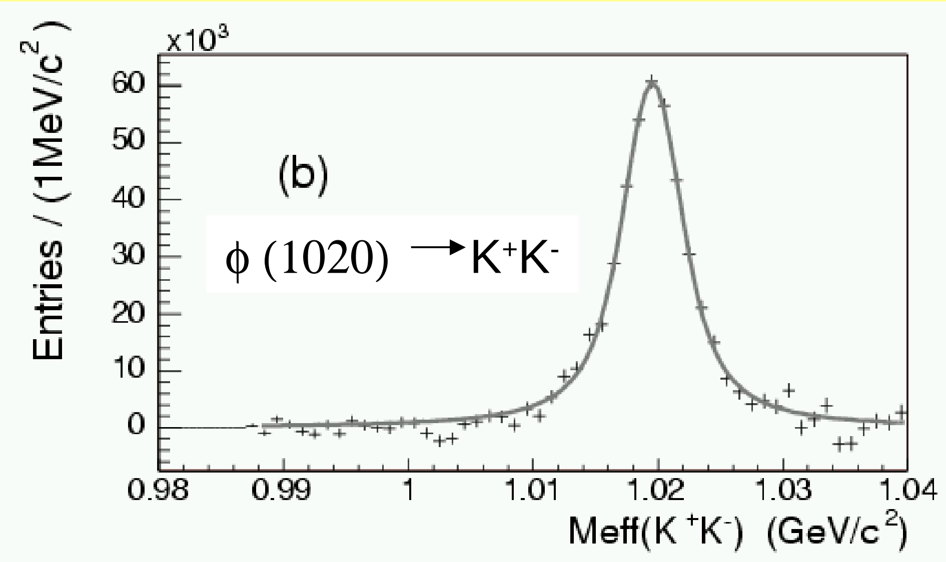
Ξ: 0.1/event

Ω: 0.01/event

p_T: 1 to 3-6 GeV

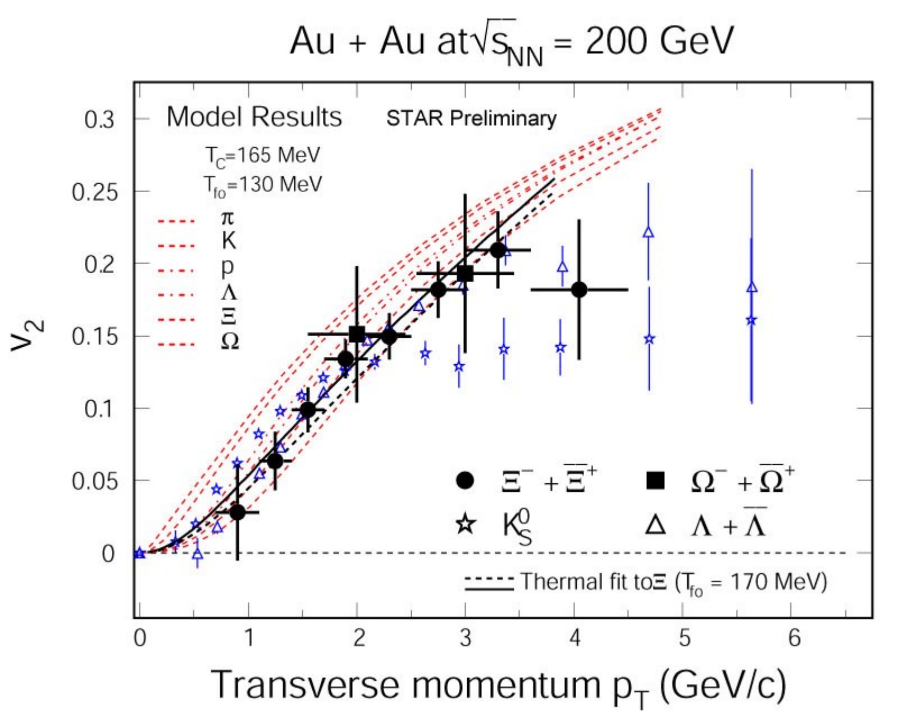


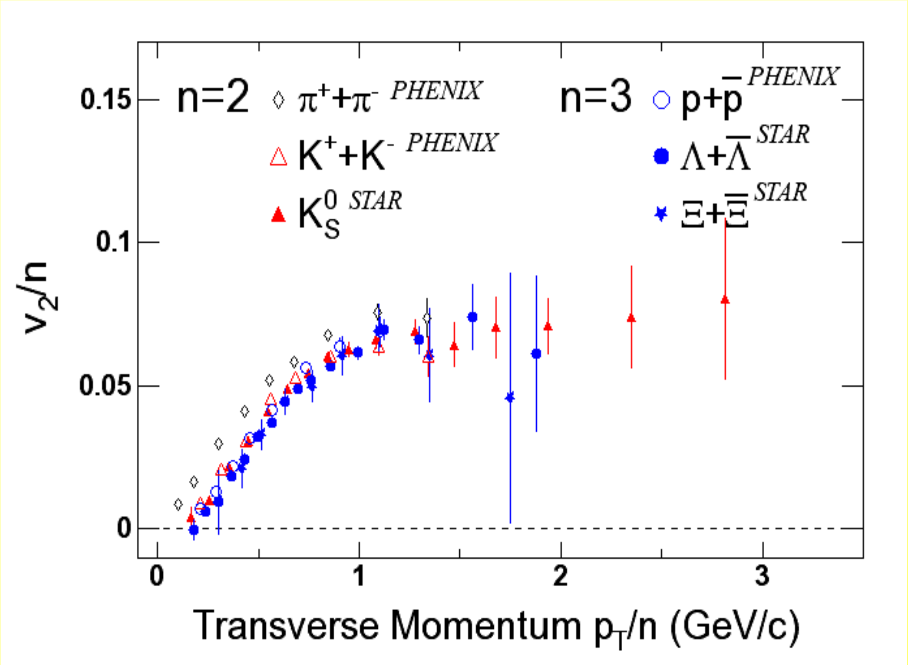




Identified particles v_2

- sensitive to hydrodynamics and recombination effects
  - e.g. @ RHIC: ~ scales with # of valence quarks

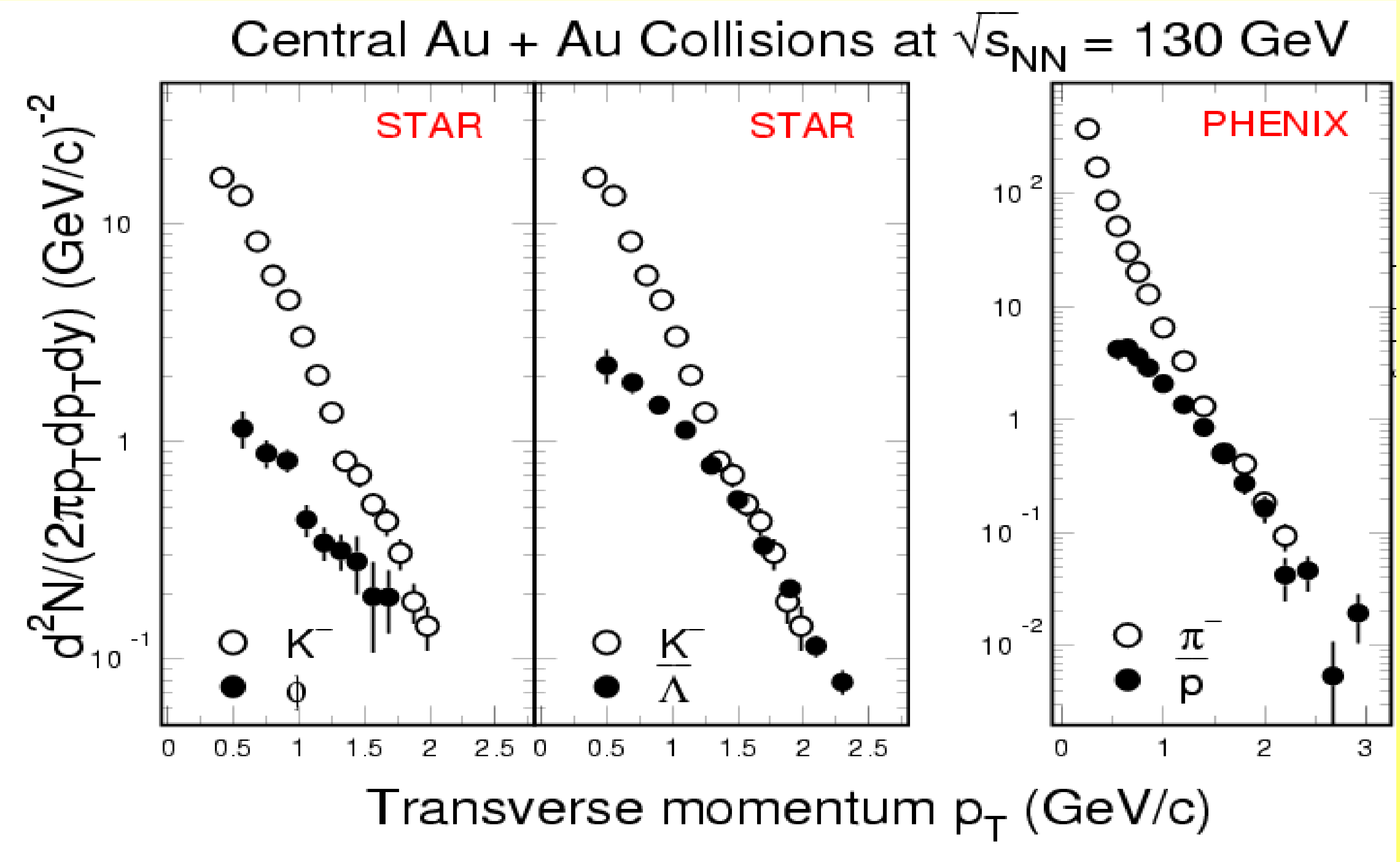




10^7 events → strange particles' v_2 out to ~ 10 GeV/c

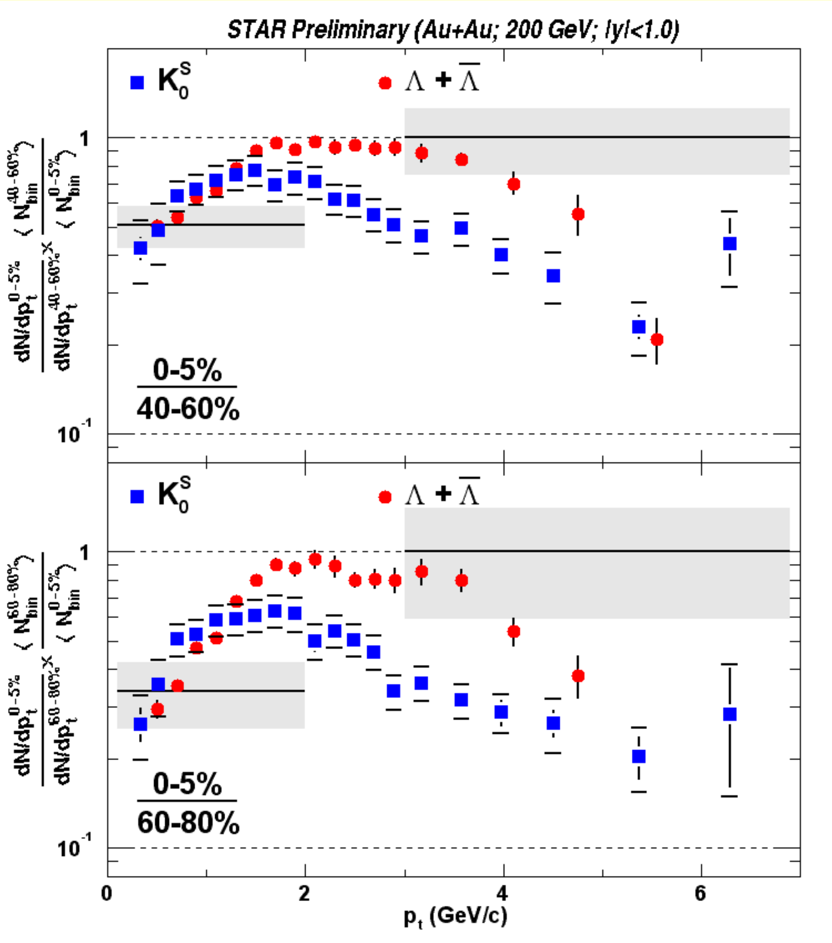
Identified particles p_T

- @ RHIC : as many π^- (K^-) as p (Λ) at $p_T \sim 1.5 \div 2.5$ GeV



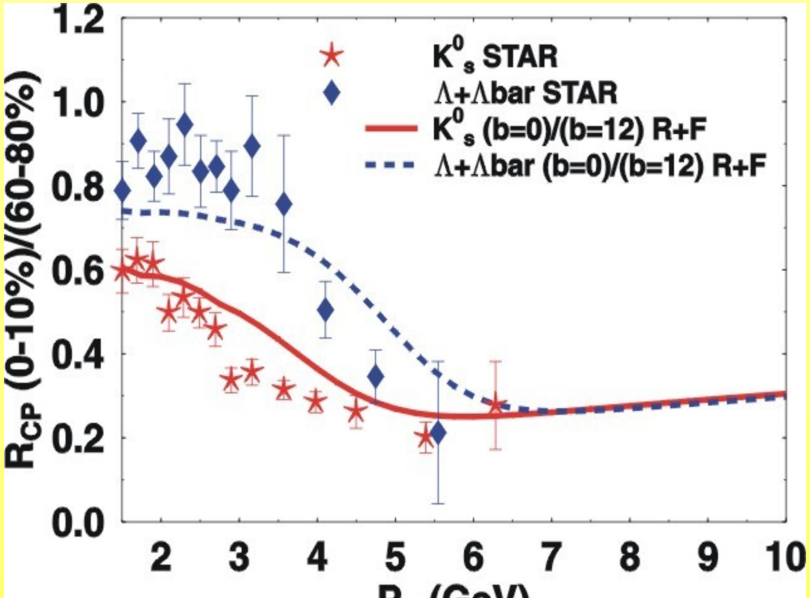
identified particles R_{cp}

- @ RHIC: suppression sets on at larger p_T for baryons



$$R_{cp} = \frac{\text{Yield}_{\text{AA, central}}}{\text{Yield}_{\text{AA, periph}}} \cdot \frac{\langle Ncoll \rangle_{\text{AA,periph}}}{\langle Ncoll \rangle_{\text{AA, central}}}$$

- recombination?



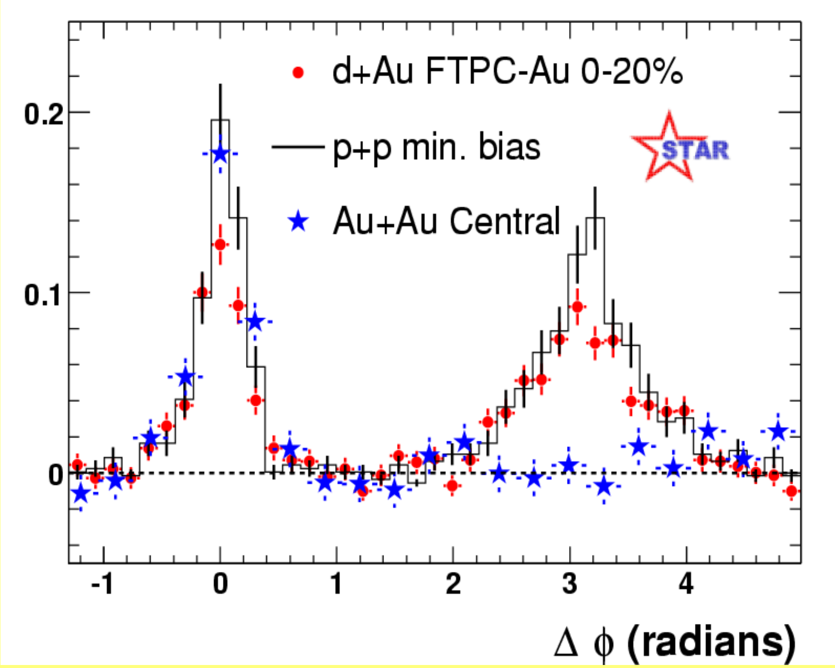
S.Bass @ SQM`04

e.g.: 10^6 central → Λ, K^0_s out to ~ 10 GeV

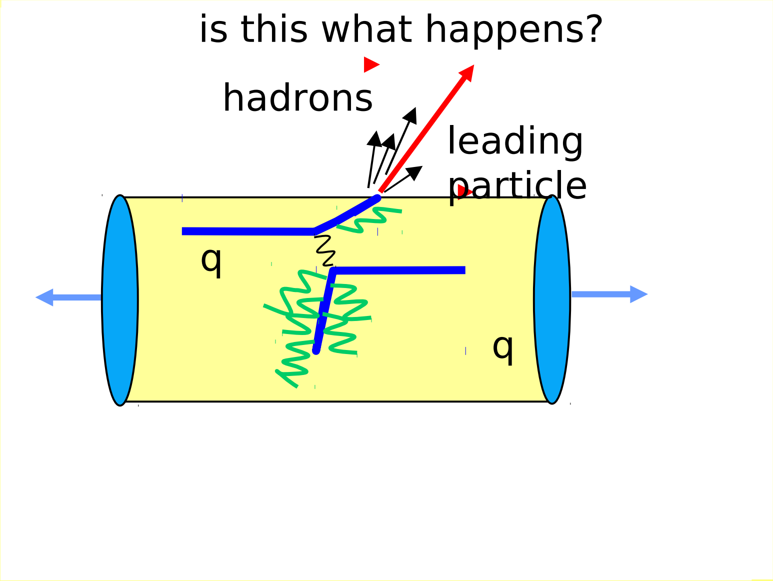
High p_T correlations

- e.g.: disappearance of away-side peak at RHIC

Adams *et al*., Phys. Rev. Let. 91 (2003) 072304



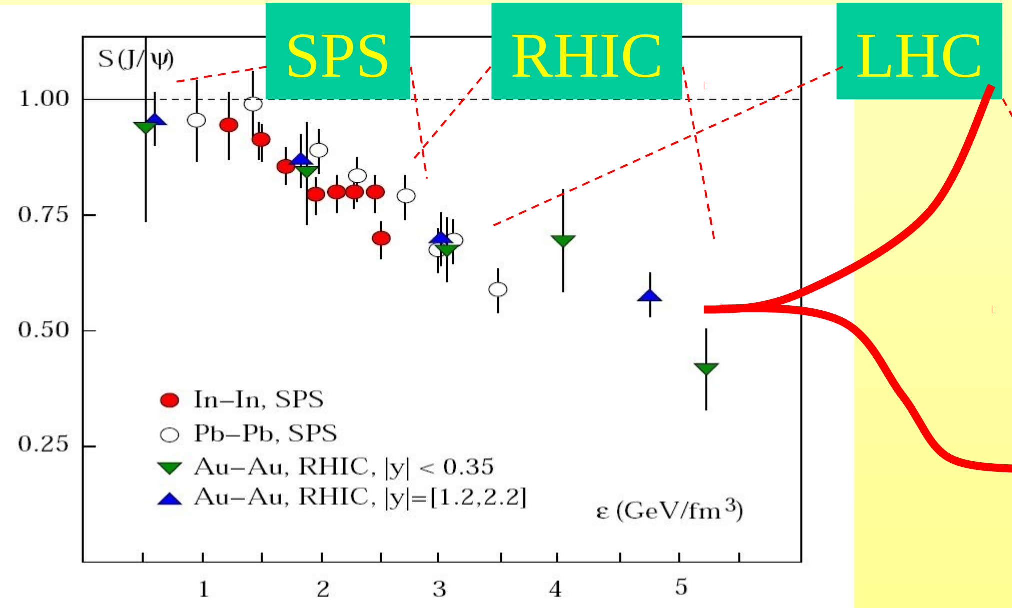
trigger particle: $4 < p_T < 6$ GeV/c
associated particles: $p_T > 2$ GeV/c



- STAR Au-Au sample ~ 1.5 10^6 central

Quarkonia

- present status:



more $c\bar{c}$ → reco dominates?

larger ε → J/ψ finally melts?

- very similar suppression at RHIC and SPS…
  - only ψ'and χ_c melt?
  - J/ψ melting compensated by $c\bar{c}$ recombination?

- performance critically dependent on ∫L
  eg: for 2 μb^{-1}, no suppression, no enhancement

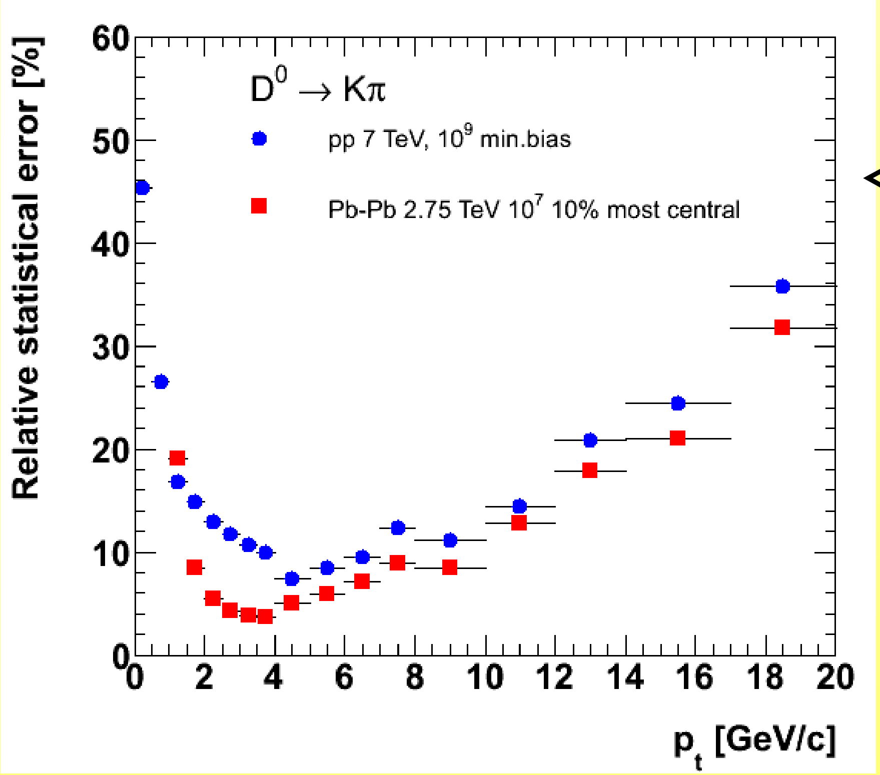
→ a few 1000s J/ψ
  say 5 centrality bins → significance ~ 15-20
  out to 6-7 GeV pT?

→ψ' marginal…

→a few 10s of Y at significance ~ 5?

Charm?

- heavy flavour: study colour charge and parton mass dependence of parton energy loss



- expected performance for <u>10^7</u> <u>central</u> Pb-Pb events at 2.75 TeV

- for <u>O(10^6)</u> central, ~ multiply errors by 3 → marginal…

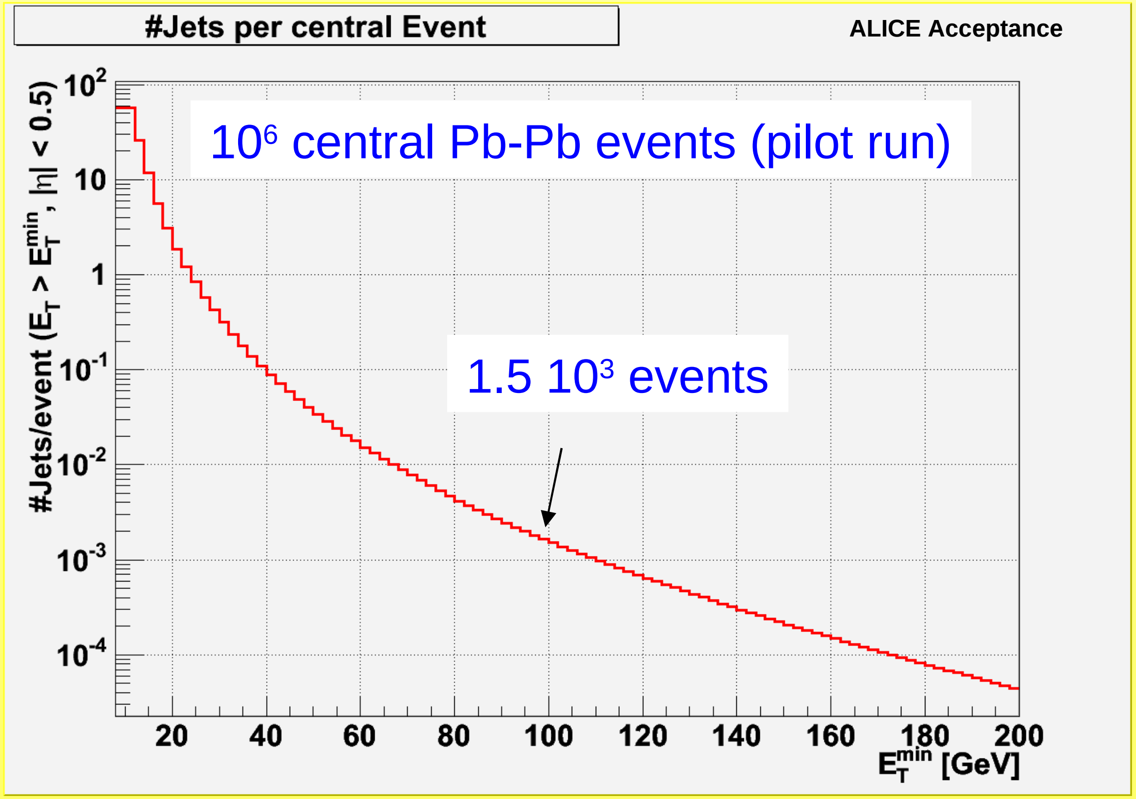
→ needs as much statistics as possible!

Jets

Jets are produced copiously…

2 | 20 | 100 | 200 | p_t (GeV)

100/event | 1/event | 10^3 in first 10^6 Pb-Pb events



10^6 central PbPb collisions

E_T threshold	N_{jets}
50 GeV	5×10^4
100 GeV	1.5×10^3
150 GeV	300
200 GeV	50

A first look at 2011

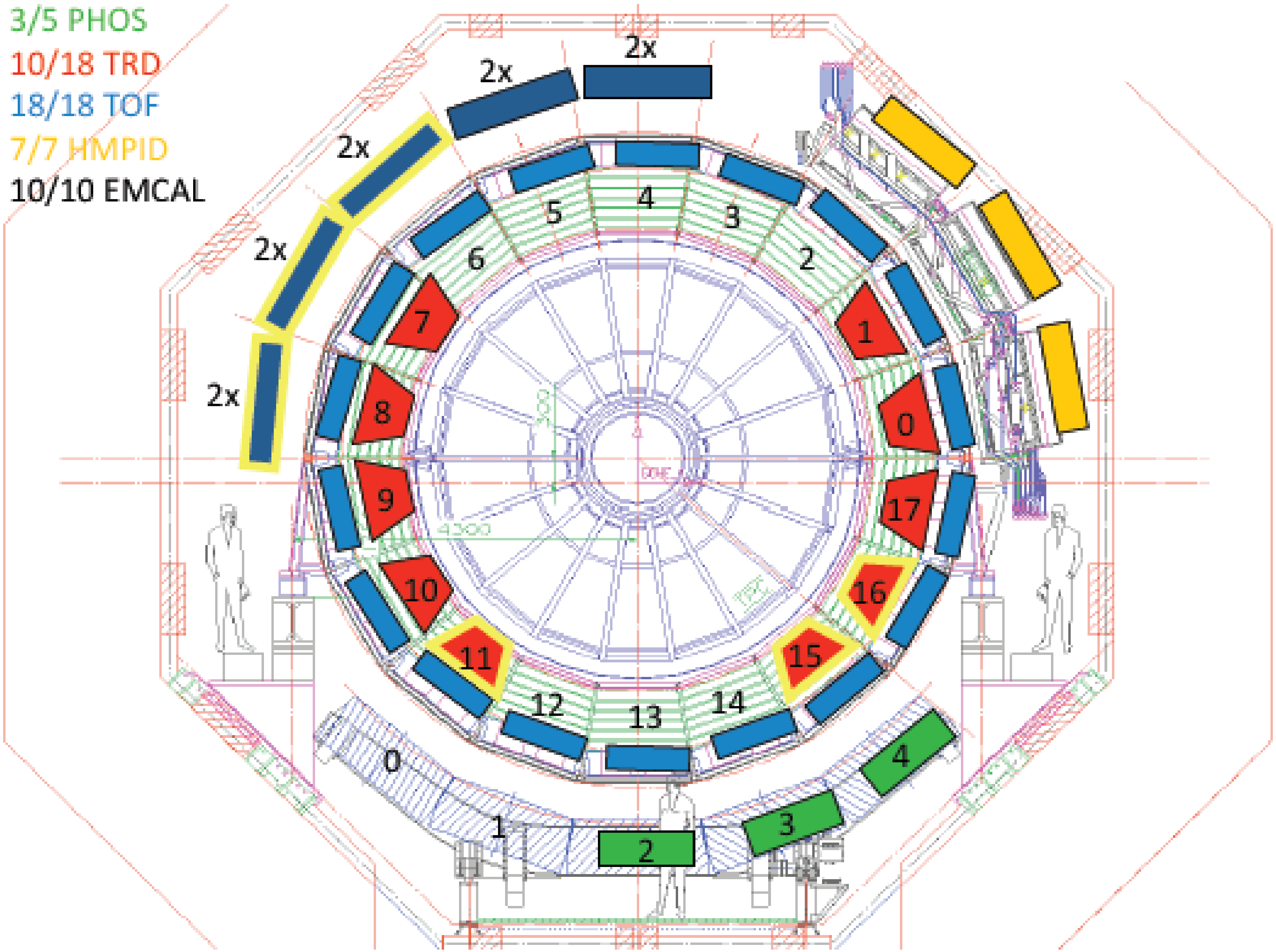
- Trigger
  - During the Winter shutdown, complete installation of full EMCAL and install 3 more TRD modules (-> 10/18)
  - Run 2011 will include photon, electron, and jet triggers, on top of muons
    - Move towards rare triggers
    - Increase luminosity in pp (to max tolerable level ov overlapping events in TPC)

~ 5 10^{30} cm^{-2} s^{-1} (~ 400 kHz min bias rate)

→ ~ 40 overlapping events in TPC

- HI
  - Higher Luminosity compared to 2010 (factor of 10 seems achievable)
  - FIRST full run (including charm, quarkonia)

ALICE 2011



3/5 PHOS
10/18 TRD
18/18 TOF
7/7 HMPID
10/10 EMCAL
2x
2x
2x
2x
2x
4
5
3
6
2
7
1
8
0
9
17
10
16
11
15
12
13
14
0
1
2
3
4

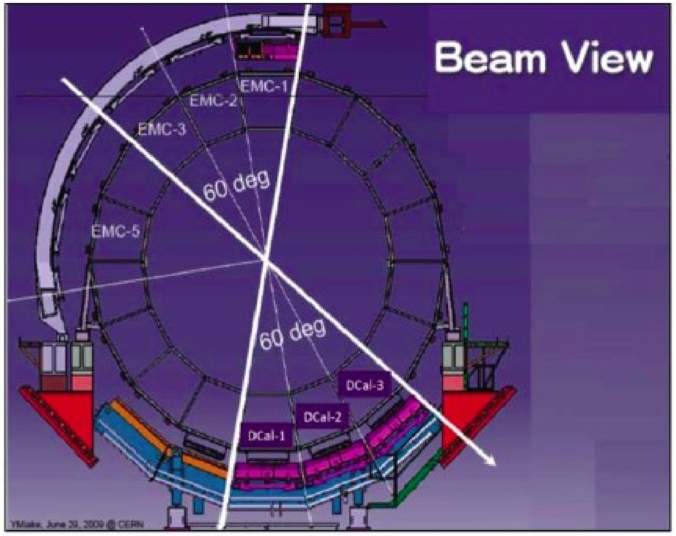
And later?

ALICE Upgrades (ongoing)

- A **program to upgrade some elements of ALICE is already ongoing**
- In fact ALICE has evolved considerably from its Technical Proposal, largely because of the new data from RHIC, which are also at the base of some of the future upgrade ideas. In particular
  - the **TRD** has been approved much later than the other central detectors
    - 7/18 installed
    - 3 more in winter 2010/2011
    - complete by 2012
  - a new **EMCAL** calorimeter (very important for jet-quenching) has been added recently
    - US project, with French and Italian involvement.
    - 4 SM installed in 2009 out of 11
    - Complete in winter shutdown 2010/2011
    - Further 6 SM on opposite side in phi (DCAL) approved
    - Complete by 2012

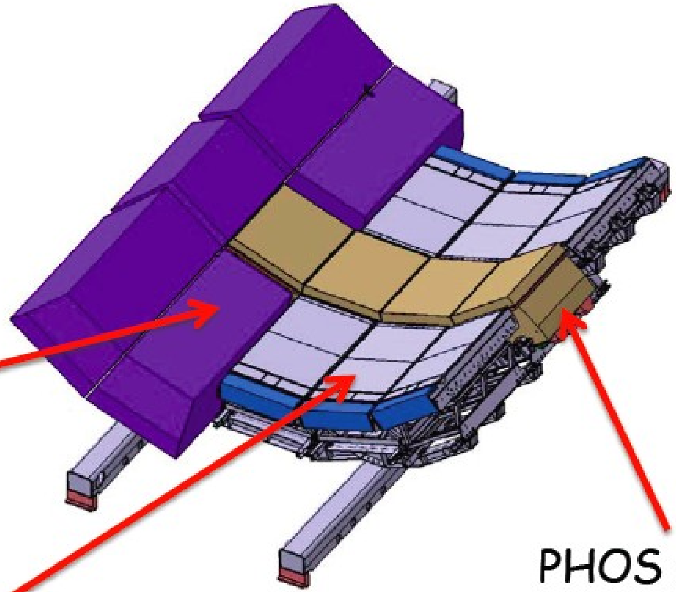
DCAL: Di-jet Calorimeter

A 60% **expansion** of EMCal acceptance arranged to permit back-to-back hadron-jet and jet-jet correlations



Incorporate PHOS and new Pb/Scint super modules to produce a single, large electromagnetic calorimeter patch back-to-back with EMCal

Acceptance $\Delta\eta \times \Delta\phi = 1.4 \times 0.7$



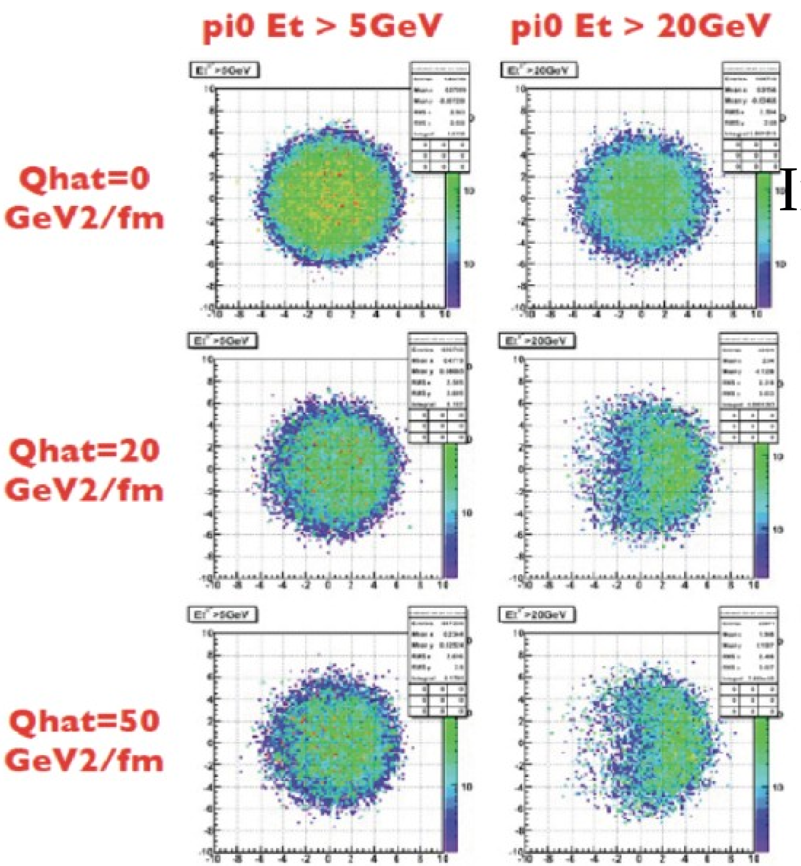
integration of VHMPID modules

New DCal super modules

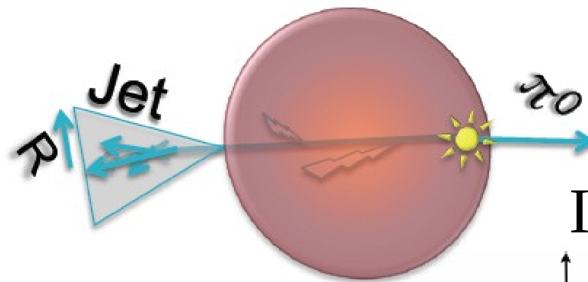
PHOS modules

Next generation measurement: controlled variation of jet path length

Calculation: qPYTHIA

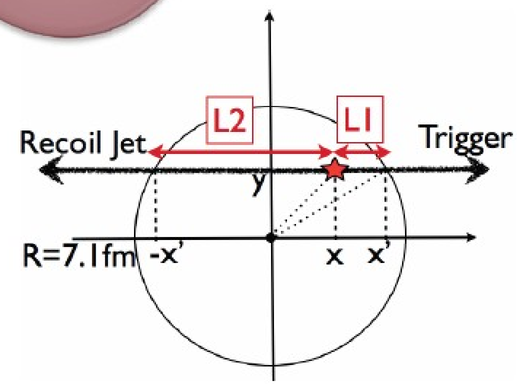


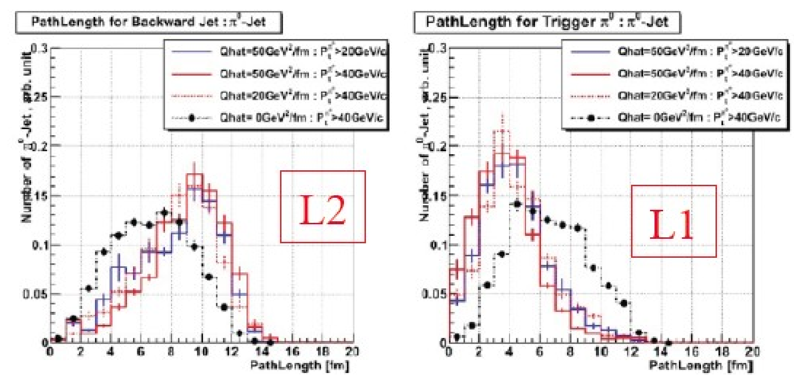
trigger



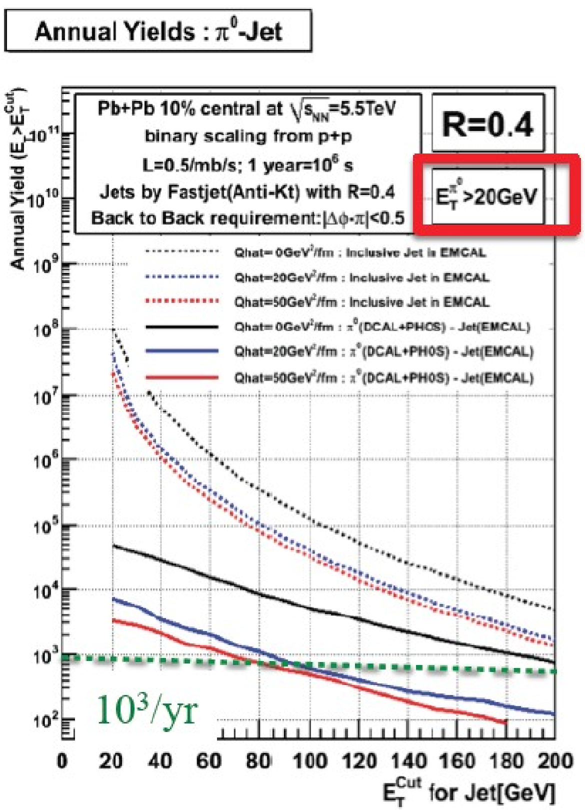
In DCal

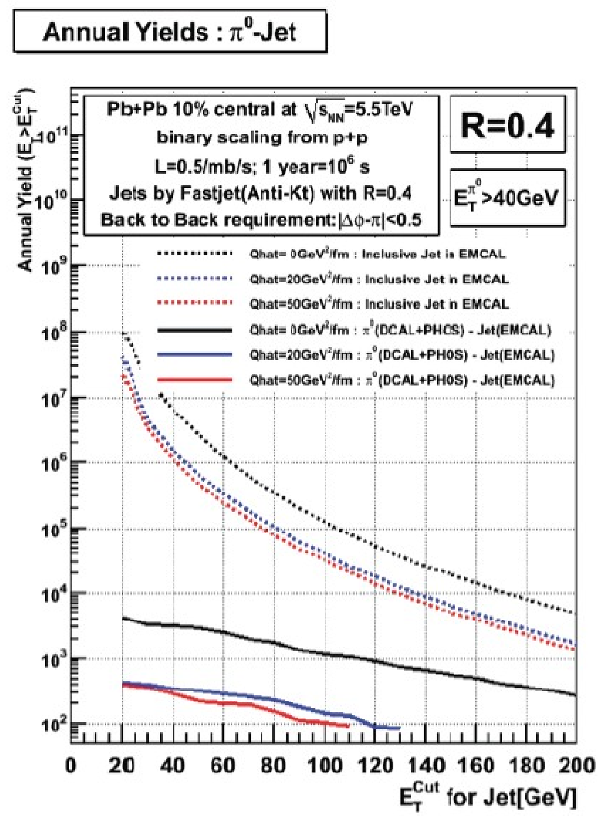
In EMCal

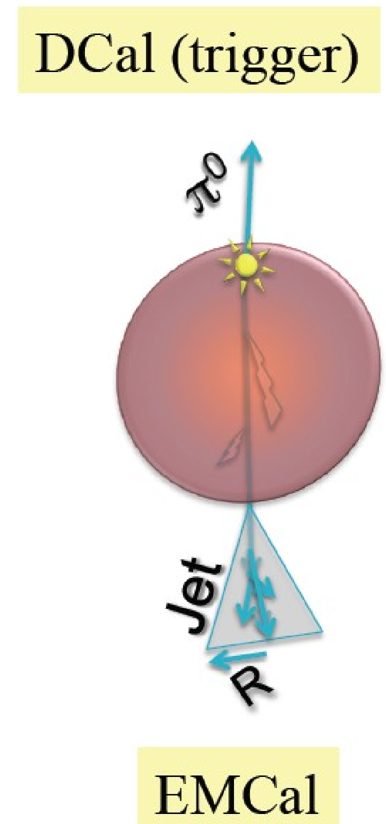




π^0+jet: coincidence rates

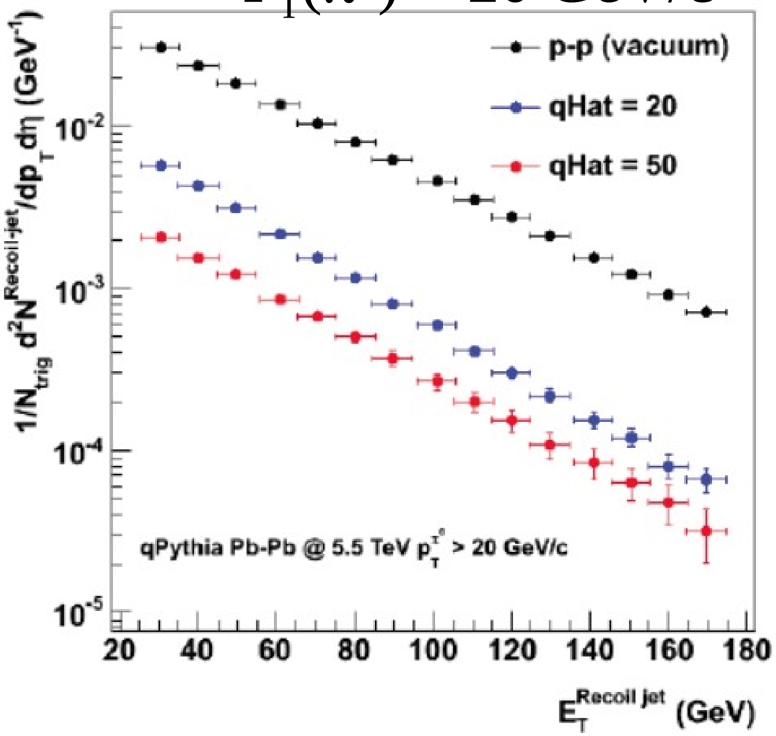






semi-inclusive jet spectrum

$P_T(\pi^o) > 20$ GeV/c



$P_T(\pi^o) > 40$ GeV/c

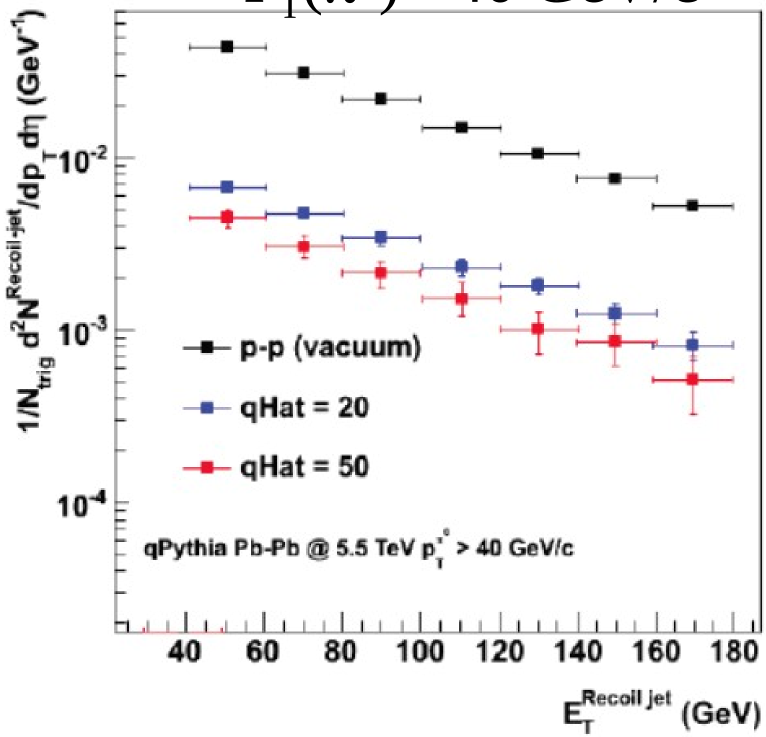


Figure II.13 Semi-inclusive jet spectrum measured in EMCal (anti-kT, R = 0.4), recoiling from a π^0 trigger in DCal above p_T thresholds of 20 GeV/c (left) and 40 GeV/c (right), for various qhat. Error bars show statistical errors expected for one year of running for Pb+Pb at 5.5 TeV (0.5 nb^{-1}).

π^0 (DCal)+jet (EMCal): jet I_{AA}

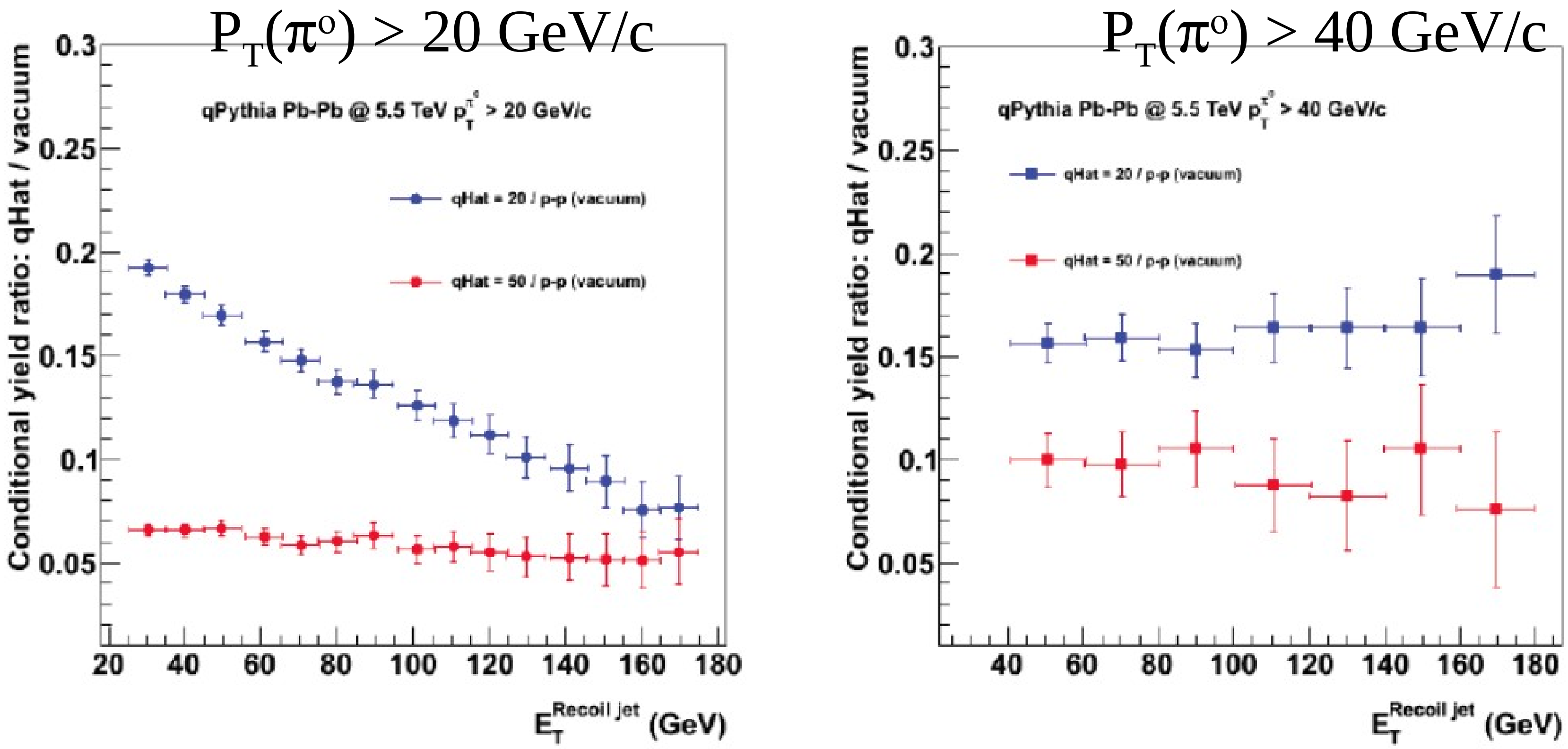
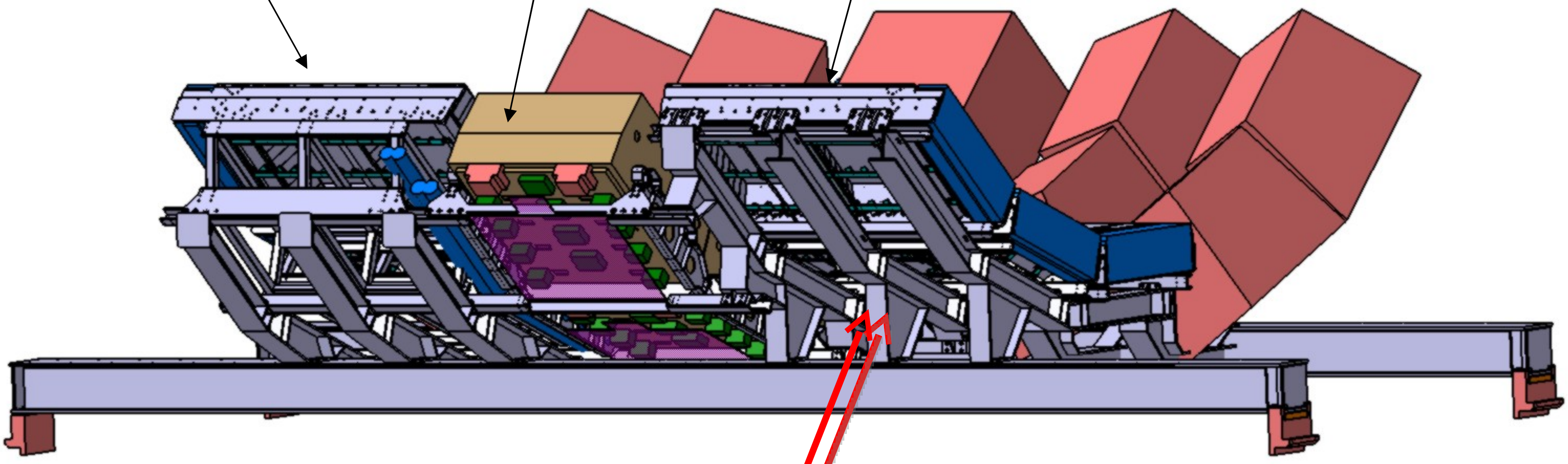


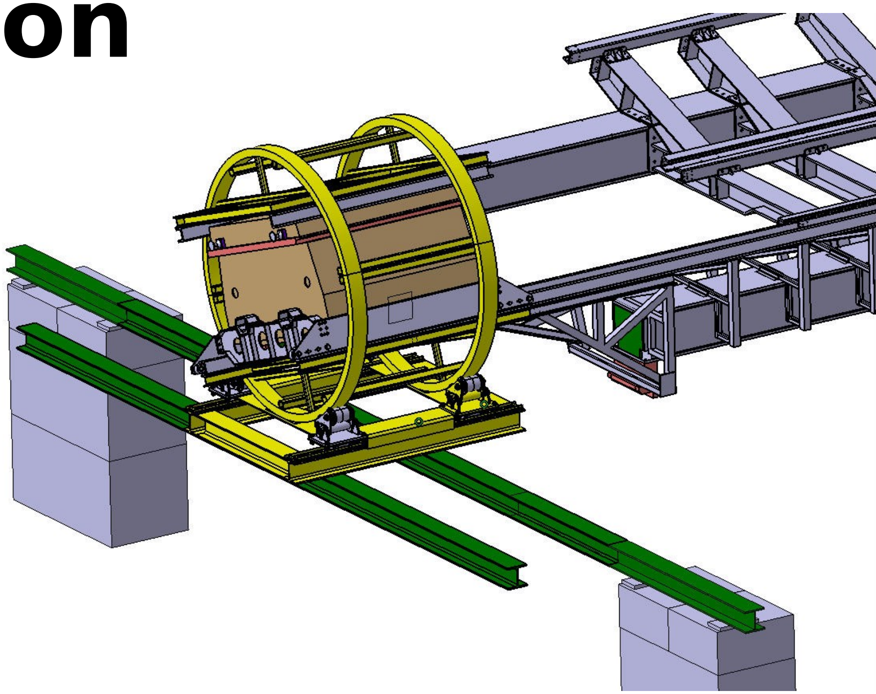
Figure II.14 Ratio of semi-inclusive jet spectra in Fig II.13 in the EMCal recoiling from a π^0 trigger in the DCal above p_T thresholds of 20 GeV/c (left) and 40 GeV/c (right), for qhat = 20 (blue) and 50 (red) relative to spectrum for qhat = 0. This corresponds to I_{AA} measured for di-hadrons. Error bars show statistical errors expected for one year of running for Pb+Pb at 5.5 TeV (0.5 nb^{-1}).

DCal+PHOS+VHMPID, Sideview



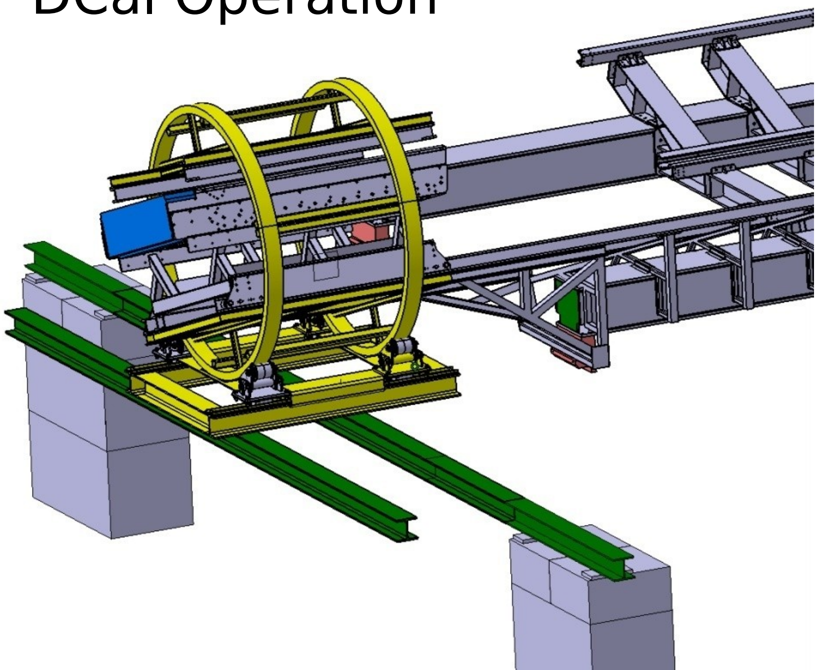
New common support structure for PHOS and DCal

Common DCal / PHOS Insertion Tooling



PHOS Operation

DCal Operation



Dcal Project organization (EMCAL + China and Japan)

China:
- Provide 1 DCal super module
- Proportional contribution of support structure costs
- Provide manpower for WLS fiber production for 3 SM in Frascati
- Proportional contribution of infrastructure, installation and integration costs
- Proportional contribution of electronics and trigger cost
- Proportional contribution to HLT and DAQ integration cost
- Provide proportional contribution to all shipping costs
- Proportional contribution of cosmic calibration manpower

France:
- Provide 0.5 DCal super modules (Nantes)
- Assemble and test all 2.5 EU and Asian strip modules (Nantes)
- Assemble and cosmic calibrate all DCal SMs: US, EU and Asian. (Grenoble)
- Provide engineering, design and fabrication oversight of support structure and installation tooling (Nantes)
- Proportional contribution of support structure costs
- Provide an advance of 200k euros toward the support structure cost in 2010
- DCal Installation oversight (Nantes)
- Proportional contribution of infrastructure, installation and integration costs
- Proportional contribution to HLT and DAQ integration cost
- Proportional contribution of electronics and trigger cost
- Provide proportional contribution to all shipping costs
- Proportional contribution of cosmic calibration manpower

Italy:
- Provide facilities, expertise and manpower for WLS fiber bundle assembly for EU and Asian modules (Frascati)
- provide module assembly tooling to Wuhan (two stations) (Frascati)
- provide module assembly tooling to Tsukuba (one station) (Catania & Frascati)
- Provide module assembly facilities, expertise and manpower for modules and strip modules for 0.5 Japanese SM (Catania)
- Provide facilities, expertise and manpower for all EU and Asian APD assembly and calibration (Catania)
- Contribution to US group of 2 DCal crates (Catania)
- Contribution of cosmic calibration manpower

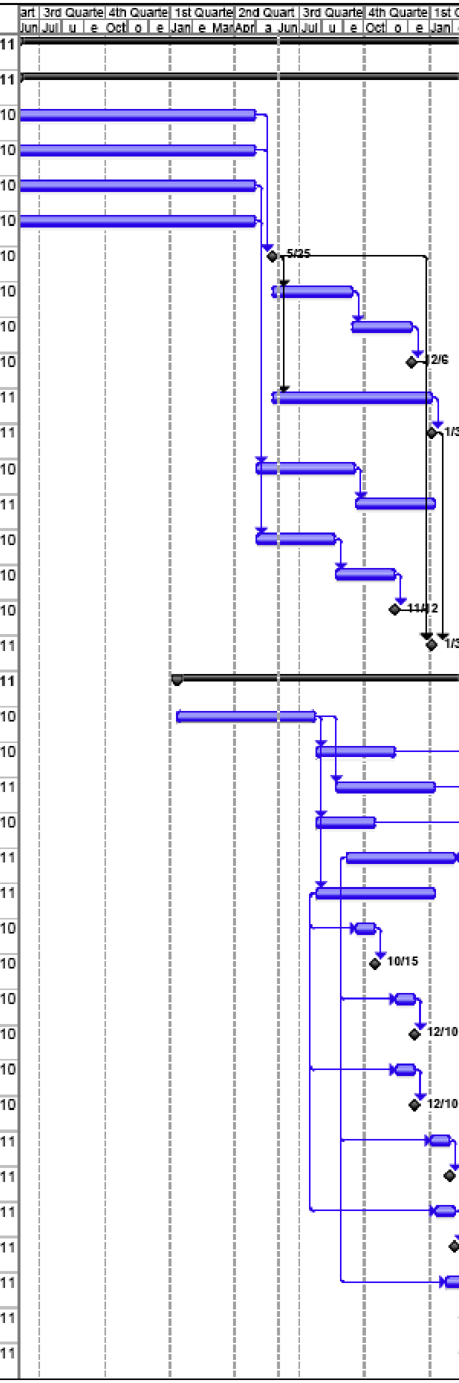
Japan:
- Provide 1.5 DCal super modules (1 SM assembled in Japan, and for 0.5 in Catania)
- Provide manpower for APD assembly and calibration for 3 SM
- Proportional contribution of support structure costs
- Proportional contribution of infrastructure, installation and integration costs
- Proportional contribution of electronics and trigger cost
- Proportional contribution to HLT and DAQ integration cost
- Provide proportional contribution to all shipping costs
- Proportional contribution of cosmic calibration manpower

USA:
- ALICE DCal Project Management
- ALICE DCal Project Technical Coordination
- Provide module assembly tooling to Tsukuba (one station)
- Provide LED calibration fibers for the full DCal
- Provide APD plastic parts, fiber plastic parts
- Provide oversight of electronics procurement, installation and testing
- Provide 3 DCal super modules
- Proportional contribution of support structure costs
- Proportional contribution of infrastructure, installation and integration costs
- Proportional contribution of electronics and trigger cost
- Proportional contribution to HLT and DAQ integration cost
- Provide proportional contribution to all shipping costs
- Proportional contribution of cosmic calibration manpower (From all US Labs)

DCAL cost and schedule

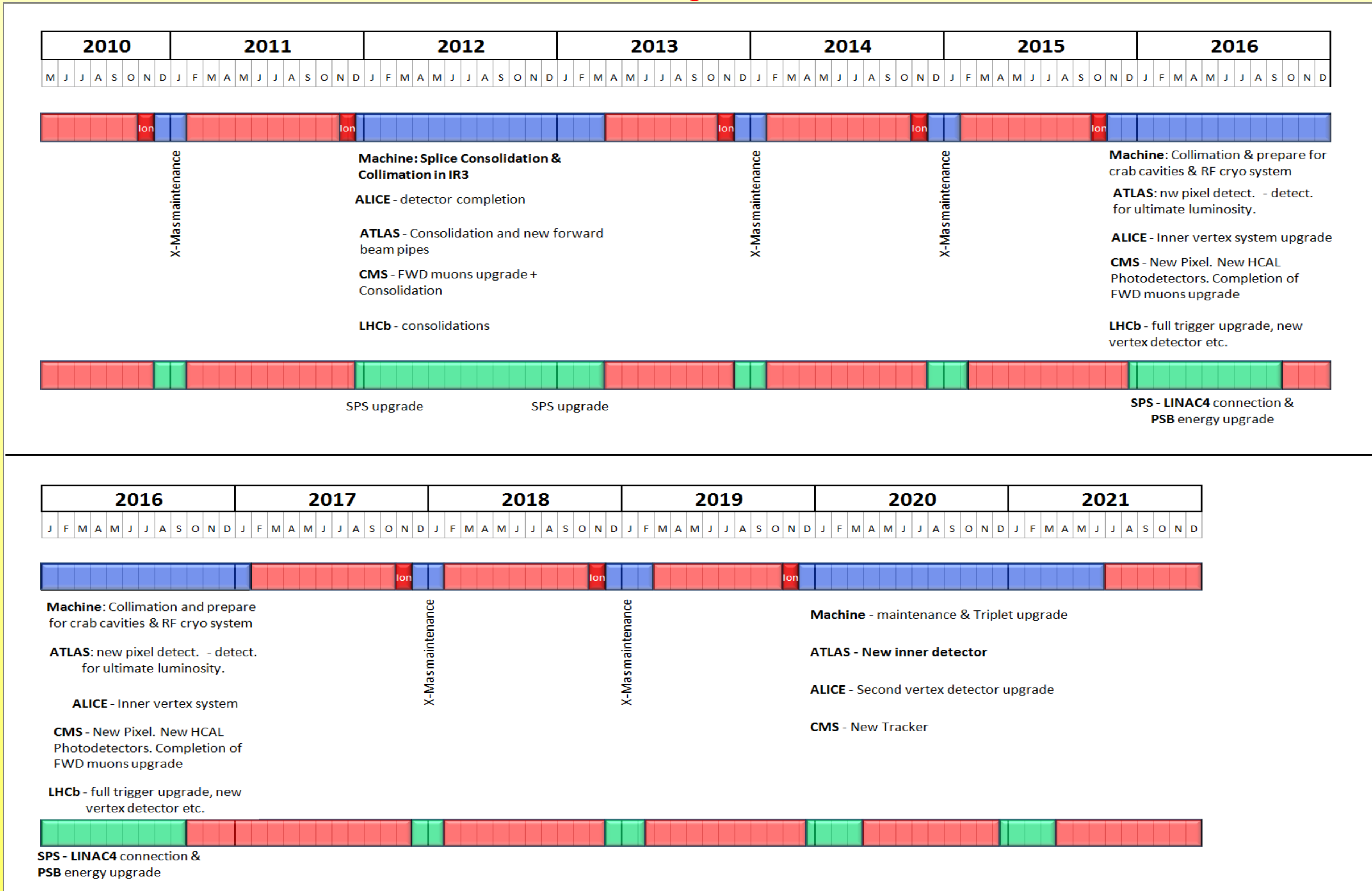
Completion February 2011

ID	Task Name	Finish
1	**DCal Supermodule No. 1 Ready for Installation**	**Fri 2/18/11**
2	**DCal Integration Into Alice**	**Fri 2/18/11**
3	Support Rails Design	Fri 4/30/10
4	Support Cradle Design	Fri 4/30/10
5	Insertion Tooling Preliminary Design	Fri 4/30/10
6	Dcal Utilities/Services Integration Preliminary Design	Fri 4/30/10
7	Design Review	Tue 5/25/10
8	Rails Material Procurement	Mon 9/13/10
9	Rail Fabrication	Mon 12/6/10
10	Rails Available for Installation	Mon 12/6/10
11	Support Cradle Farication	Mon 1/3/11
12	Support Cradle Ready for Installation	Mon 1/3/11
13	Insertion Tooling Final Design	Fri 9/17/10
14	Insertion Tooling Fabrication	Fri 1/7/11
15	Utilities/Services Integration Final Design	Fri 8/20/10
16	Utilities/Services Fabrication	Fri 11/12/10
17	Services Ready for Installation	Fri 11/12/10
18	DCal Integration Is Ready	Mon 1/3/11
19	**DCal Supemodule Production**	**Fri 2/18/11**
20	Material Procurement	Fri 7/23/10
21	Module Assembly in Japan	Fri 11/12/10
22	Module Assembly in China	Fri 1/7/11
23	Module Assembly in France	Fri 10/15/10
24	StripModule Assembly In Nantes	Fri 2/4/11
25	Module and Stripmodule production at WSU	Fri 1/7/11
26	Dcal SM No. 1 Assembly at Grenoble (USA)	Fri 10/15/10
27	DCal Supermodule No. 1 Ready for Installation	Fri 10/15/10
28	Dcal SM No. 2 Assembly at Grenoble (Japan)	Fri 12/10/10
29	DCal Supermodule No. 2 Ready for Installation	Fri 12/10/10
30	Dcal SM No. 3 Assembly at Grenoble (USA)	Fri 12/10/10
31	DCal Supermodule No. 3 Ready for Installation	Fri 12/10/10
32	Dcal SM No. 4 Assembly at Grenoble (Japan-Fran	Fri 1/28/11
33	DCal Supermodule No. 4 Ready for Installation	Fri 1/28/11
34	Dcal SM No. 5 Assembly at Grenoble (USA)	Fri 2/4/11
35	DCal Supermodule No. 5 Ready for Installation	Fri 2/4/11
36	Dcal SM No. 6 Assembly at Grenoble (China)	Fri 2/18/11
37	DCal Supermodule No. 6 Ready for Installation	Fri 2/18/11
38	**Dcal Supermodule Production Is complete**	Fri 2/18/11



DCAL System	Estimated Cost (kCH) 6 Supermodules
Mechanical Components production	1,744
Electronics Production	1,047
DCal Service Integration	174
Rails and Support Structure	436
Insertion Tooling	140
Total Shipping Cost	419
DCal total cost	3,959

The 10 year LHC technical Plan



ALICE Program

- Baseline Program:
  - initial Pb-Pb run in 2010 (1/20th design L, i.e. ~ 5 x 10^{25})
  - 2-3 Pb-Pb runs (medium -> design Lum. L ~ 10^{27}, 2.75 TeV -> 5.5 TeV) **integrate ~ 1nb^{-1}** at least at the higher energy
  - 1-2 p A runs (measure cold **nuclear** matter **effects**, e.g. shadowing)
  - 1-2 low mass ion run (**energy density & volume** dependence) typ. ArAr
  - **continuous running with pp** (comp. data, genuine pp physics)
- **-> Baseline Program fills the 5 runs till 2015 and could ~ fill the 8 "HI runs" to ~ 2019**
- Following or included:
  - lower energies (energy dependence, thresholds, RHIC, pp at 5.5 TeV)
  - additional AA & pA combinations
- NEXT:
  - program and priorities to be decided based on results, but
    - **Increase int. Luminosity** by an order of magnitude (to **~ 10nb^{-1})** is the most likely option
      - Address rare probes (statistics limited: example with 1nb^{-1} :J/Y: excellent, Y': marginal, Y: ok (14000) , Y': low (4000), Y'': very low (2000))

Timeline

- **2010-2012:** complete the approved detector configuration by adding modules of PHOS, **TRD** and **EMCal** (plus the 6-module *extension* **Dca**l). During the same period, upgrade R&D and design definition effort will continue to progress.
  - *Critical for any design definition are the first Heavy Ion data to be taken in November 2010*
- **2011:** Decisions on upgrade plans in terms of physics strategy, based on analysis of the first data, detector feasibility, results of the R&D, funding availability, and approval by LHCC.
- Must target the 2016 and 2020 shutdowns

Major Constraint:
Installation of a new beampipe and new ITS detector

From past experience we can get a good estimate of the needed time:

Opening the experiment and moving the TPC to parking position	**11 weeks**
Disconnecting and removing ITS and beampipe	**6 weeks**
Moving ITS to the surface and perform modifications	**x weeks**
Reinstallation of new beampipe, ITS detector, commissioning	**16 weeks**
TPC to IP and closing the experiment	**15 weeks**
	=========
Total time without contingency->	**48 +x weeks**

Whether we just replace the Silicon Pixel Detector (x=0 weeks) or whether we also modify the Silicon Drift Detector or Silicon Strip Detector is still not decided. This would add at least (x=10 weeks).

→ For the ALICE beampipe and tracker upgrade we need an absolute minimum of 1 year.

UPGRADE priorities

- The Upgrade plans, in order to be credible, need a “flagship” project with a strong Physics case, the others can proceed in the shadow, but might not drive the approval
- Plans cannot avoid facing the issue of having a plan for ALICE at higher rates
  - Motivation for further pp runs
  - Base for increased-luminosity running in PbPb
  - Main issue are **triggers** and related readout (might require a different readout scheme for several detectors, with major interventions on the electronics)
  - HOW? Several Possibilities, still to be studied
    - Increased/improved EMCAL
    - New ITS with topology triggering capability
    - …

Upgrades (future)

Upgrade ideas for >= 2012. Objectives:

Extend the Physics reach (independent on L)

Improve the rate capability (in view of higher PbPb L)

- High rate upgrade:
  - increase rate capability of TPC (faster gas, increased R/O speed)
  - → rare hard probes (ϒ, γ-jet, …)
- DAQ & HLT upgrades:
  - → more bandwidth, more sophisticated and selective triggers
- Particle id upgrade:
  - extend to p_T range for track-by-track identification to O(20) GeV/c
  - → new physics interest, based on RHIC results
- Forward upgrades:
  - new detectors for forward physics (tracking & calorimetry)
  - → low-x in pA, AA
  - → Extend ALICE coverage for diffractive Physics
- Vertex upgrade:
  - 2nd generation vertex detector (closer to beams)
  - → heavy flavour baryons, fully reconstructed B, …

Impact on the beampipe

STATUS

- Studies to define the projects progress
- R&D programs have been launched and are vigorously pursued:
  - Fast drift and fast readout for TPC
  - Enhanced capacity DAQ
  - Hadron Identification up to over 20 GeV
  - High density Calorimetry
  - Low-mass, high-resolution pixel detectors

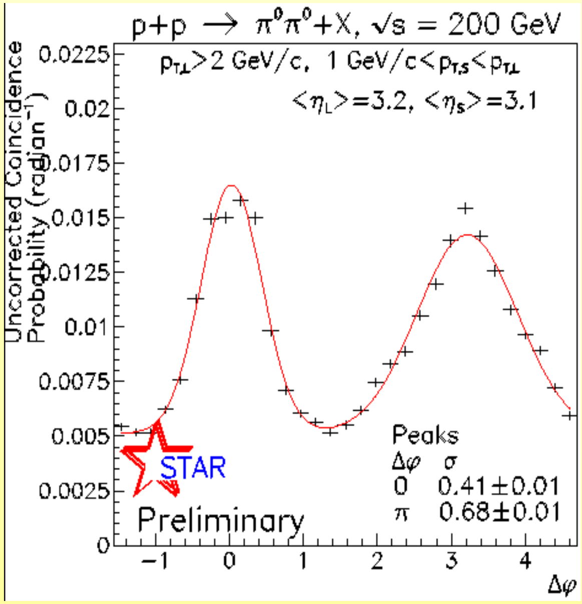
FoCal Physics Motivation

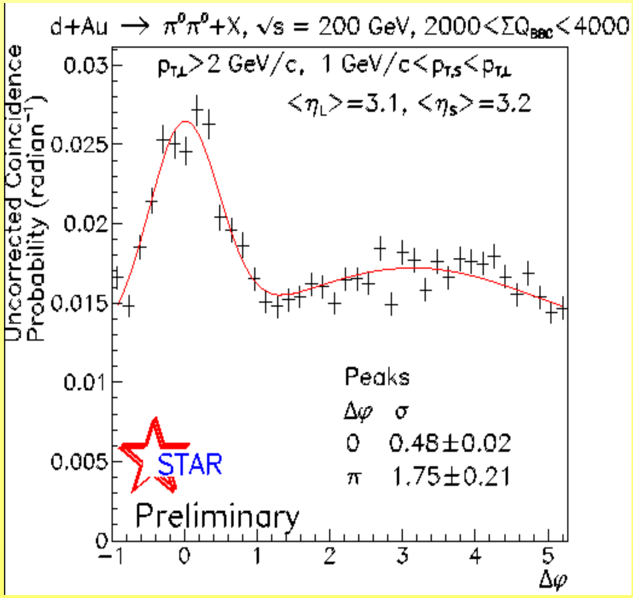
- Study low-x parton distributions
  - implies large rapidities

$$x \approx \frac{p_T}{\sqrt{s}} \exp(-y) \approx \frac{p_T}{\sqrt{s}} \exp(-\eta)$$

- Main physics issues:
  - gluon saturation (pA)
  - elliptic flow (AA)
    - rapidity gap reduces non-flow
  - long-range rapidity correlations: ridge (AA)
  - …

- Provide forward ($\eta > 3$) coverage for identified particle measurements
  - EM calorimeter for photons, neutral pions (eta?), jets
  - Requires high granularity (lateral and longitudinal)
- Favoured technology: SiW
- **Phased approach**
  - **Phase 1: inside magnet, $\eta < 4.5$**
  - **Phase 2: outside magnet, $\eta > 4.5$**



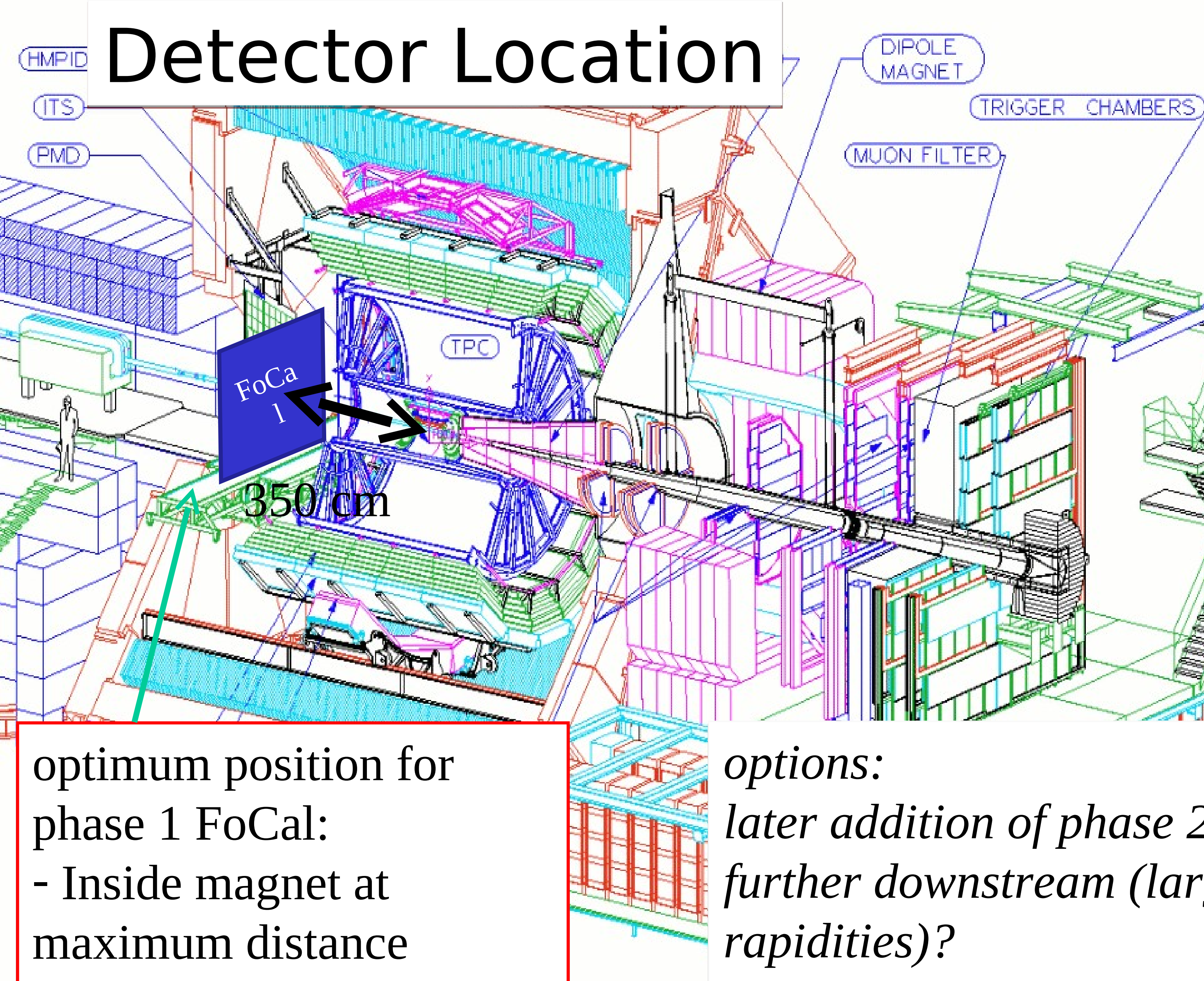


Akio Ogawa et al.

Signals of gluon saturation

- At forward forward rapidities:
  - Single hadron suppression
  - De-correlation of recoil yield
- Interesting observations at RHIC, consistent with gluon saturation
  - Still too low p_T! Reference measurement not describable by pQCD?
  - Limited by small saturation scale
- Measurements at LHC advantageous
  - Larger kinematic reach (smaller x)!
  - Larger saturation scale: larger p_T possible!

Detector Location



optimum position for phase 1 FoCal:
- Inside magnet at maximum distance (before T0, flange, etc.)

options:
later addition of phase 2 detector further downstream (larger rapidities)?
detector integrated in muon absorber?

Institutes/Current Activities

- Tokyo (simulation, electronics R&D, prototype tests, 10x10 mm^2 pads)
- Kolkata + collaborating Indian institutes (simulation, Si-strips)
- Utrecht/Nikhef (simulation)
- Yonsei (prototype tests)
- Prague, Jyväskylä
- *expression of interest: Bergen, Copenhagen, Nantes, Oak Ridge, …*

Design Decisions

- technology: Si-W sandwich
  - active layers pads and/or strips
- location: 3.5 m from vertex (replacing PMD)
  - alternative option to be studied: integrate in muon absorber
- pad size: 10 x 10 mm^2 or smaller
- tower geometry
  - bring services to back of detector

Open Design Issues

- exact granularity?
  - Driven by overlap probability in heavy ion collisions
    - Needs November data on Multiplicity
  - information on longitudinal shower development
- dynamic range?
  - depends on granularity
  - consequences for front-end electronics
- electronics/integration
  - front-end electronics: only preamp/shaper or also ADC, integrated in Si layers?
  - modify existing design?

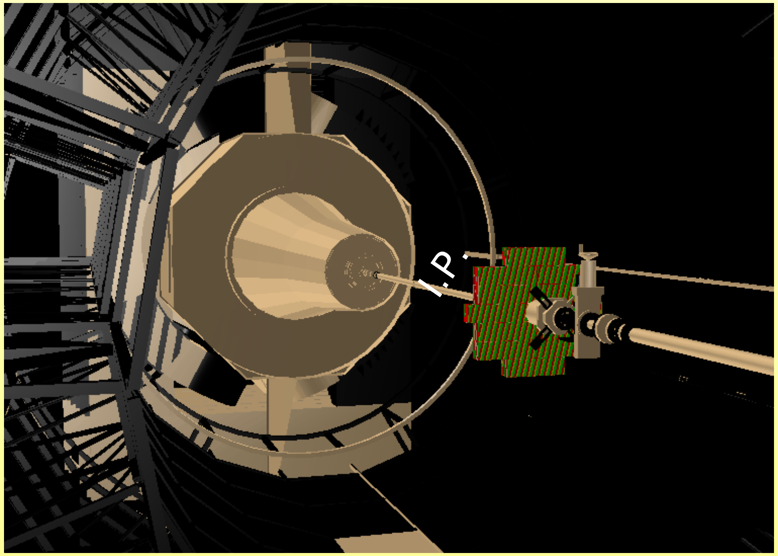
Timeline (tentative)

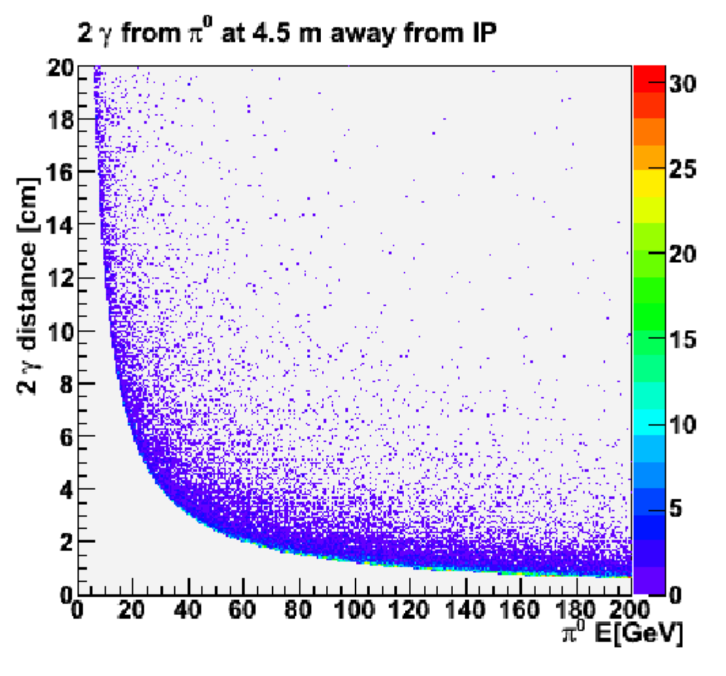
2010	crucial design decisions: granularity, dynamic range, eta coverage establish options for front end electronics prepare Letter of Intent
2011	detailed simulations and mechanics design: number of layers, exact thickness, necessary gaps, etc. electronics R&D, construction of physics prototype
2012	physics prototype in beam (test beam or physics beam?) continue electronics R&D
2013	production, tests
2014	production, tests
2015	detector installation

Cost Estimates (tentative)

	max	min
radius [cm]	75	75
layers	30	21
pad size [cm^2]	0.5x0.5	1x1
# of channels	2 120 000	371 000
mechanics, cooling etc.	2 000 k€	2 000 k€
tungsten	380 k€	270 k€
Si sensors	5 300 k€	3 700 k€
read-out	5 300 k€	930 k€
total	12 980 k€	6 900 k€

Si - W Tracking Calorimeter





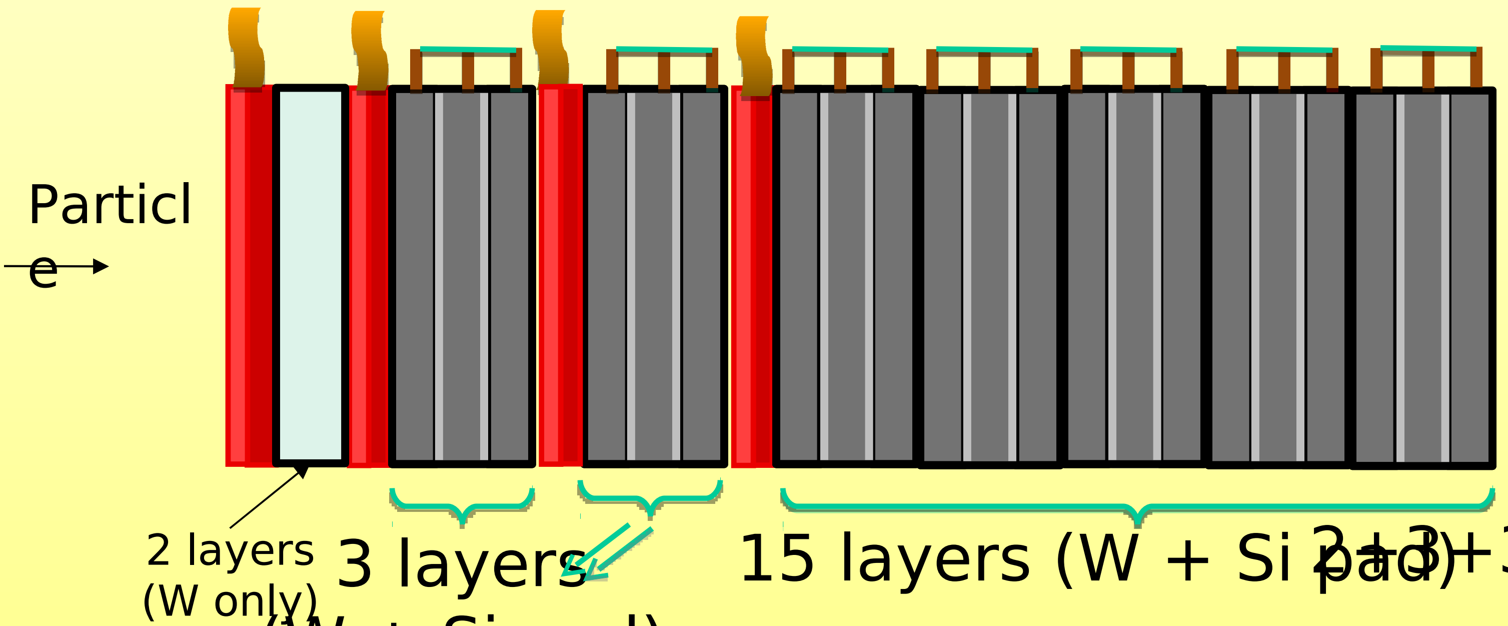
Capability for p-p, p-A and A-A collisions

- Pb-Pb collisions will define the granularity
- π^0 measurement up to 200 GeV/c momentum

Requirements

- Small Moliere radius
- Capability of two photon separation at short distance less than 1 cm

Forward Calorimeter: Silicon – W Calorimetry



2+3+3+15 = 23 X

X-Y Si Strip

- 0.3 mm thickness
- 3 layers
- Strip size 0.5 mm
- Detector depth 5.5 mm

First Layer acts as Charged particle VETO

Si Pad + W

- Si thickness 0.3 mm
- Si size 1 cm x 1cm
- W thickness 3.5 mm

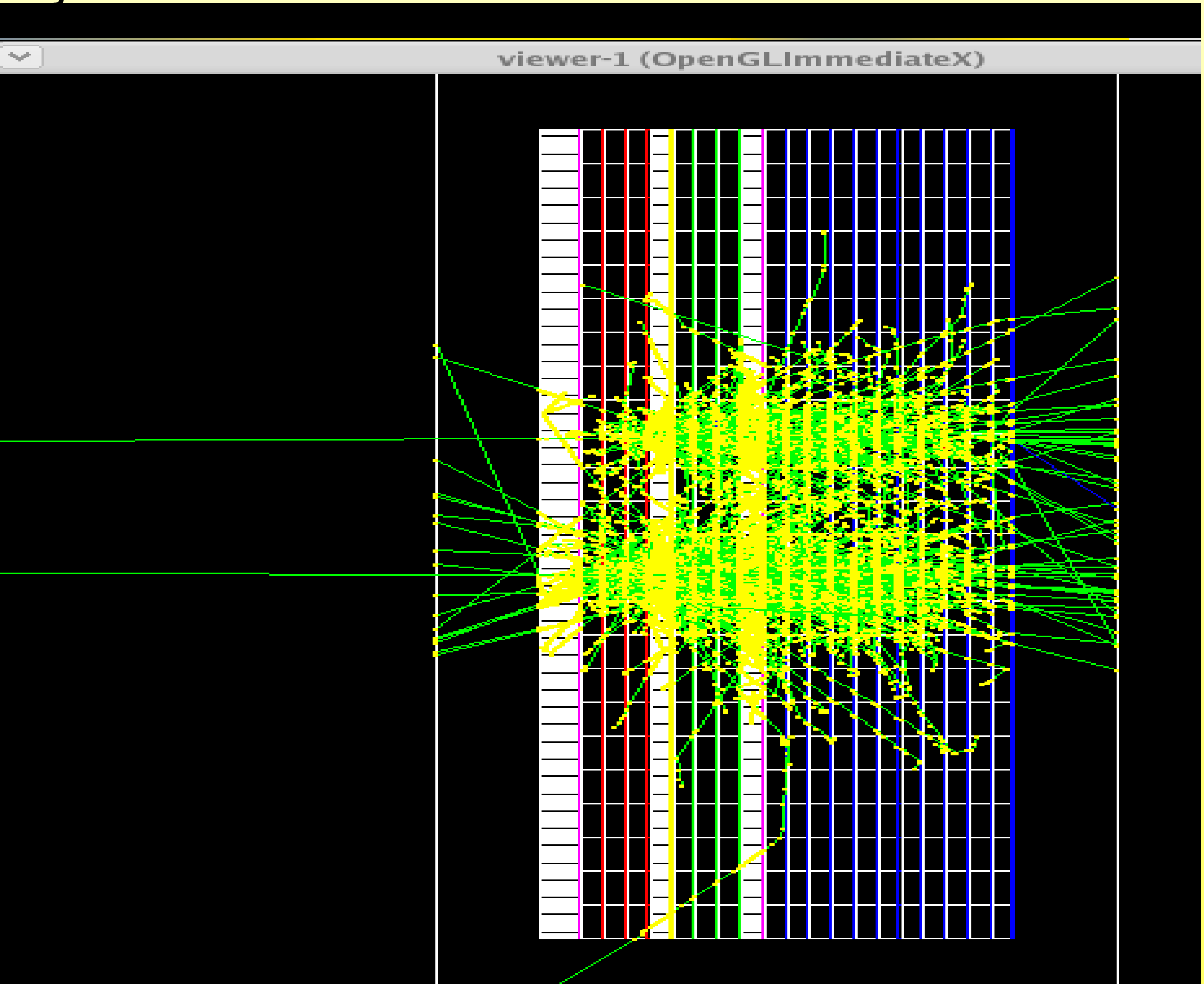
Only Tungsten (W)

- W thickness 3.5 mm

About 20/sqrt(E) (%) resolution

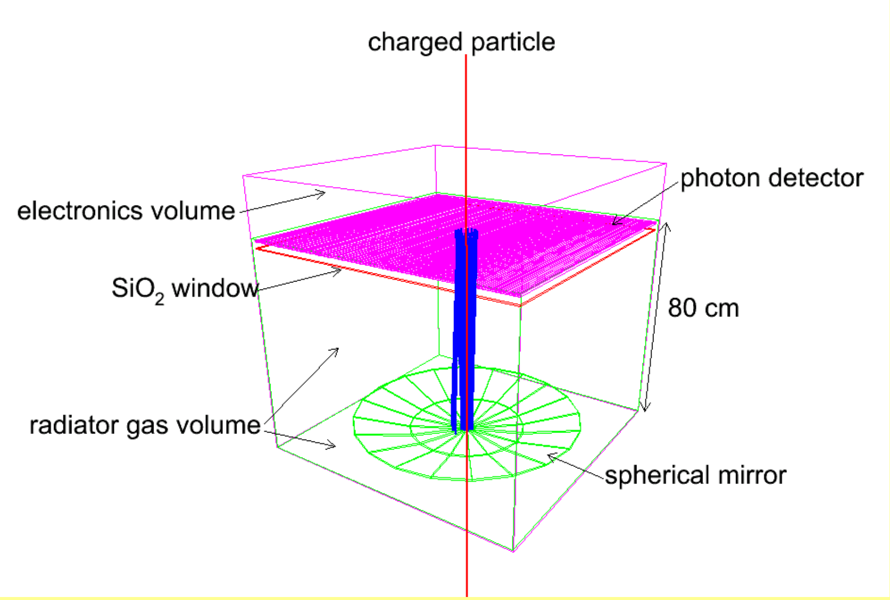
Geometry Implementation in Geant

anjib Muhuri

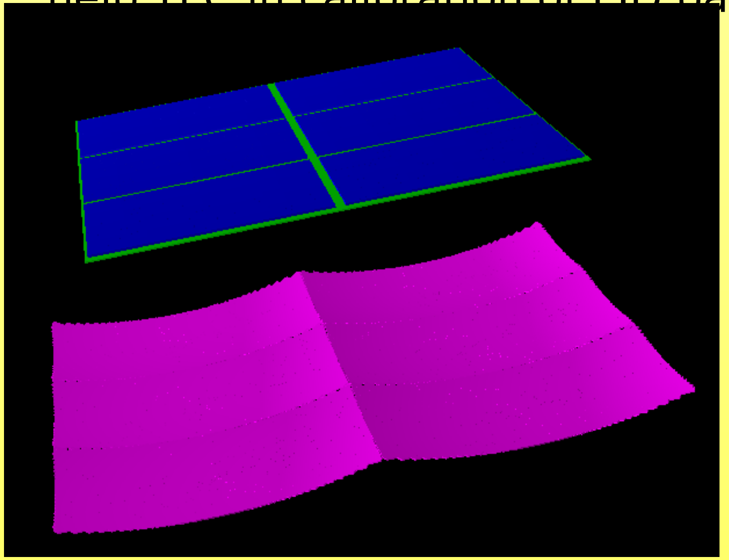


- Detector at 350cm from IP
- 10 GeV/c π^0 decaying to 2γ
- Cluster Centers separated by ~4cm

Extending ALICE PID capability: The VHMPID project



- RHIC results: importance of high momentum particles as hard probes and the need for particle identification in a very large momentum range, in particular protons.
- The VHMPID (Very High Momentum PID) detector will extend the track-by-track identification capabilities of ALICE up to ~ 26 GeV/c
- The VHMPID will also represent a tool to help TPC in calibration of PID based on



- It is a RICH in focusing geometry using 80 cm C_4F_{10} gaseous radiator, segmented spherical mirror and CsI-based photodetector (with MWPC or Thick-GEM)
- Same HMPID FEE, based on Gassiplex chip
- Most of the design derived from HMPID know-how, issues needing R&D:
  - CsI-TGEM reliability over large area
  - Pad cathode segmentation and structure
  - Large area quartz windows segmentation and fixation

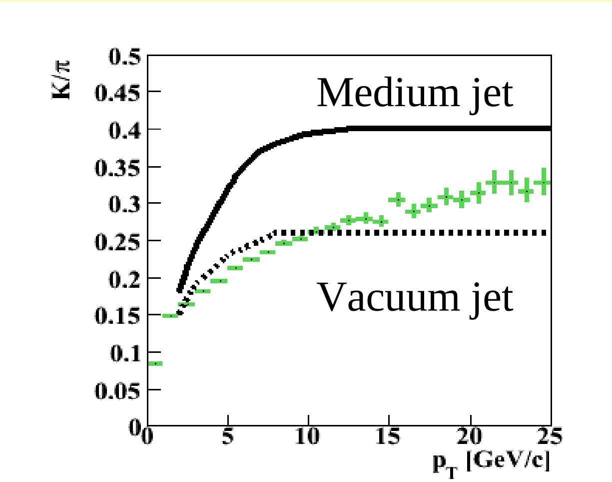
Specific hadro-chemistry predictions

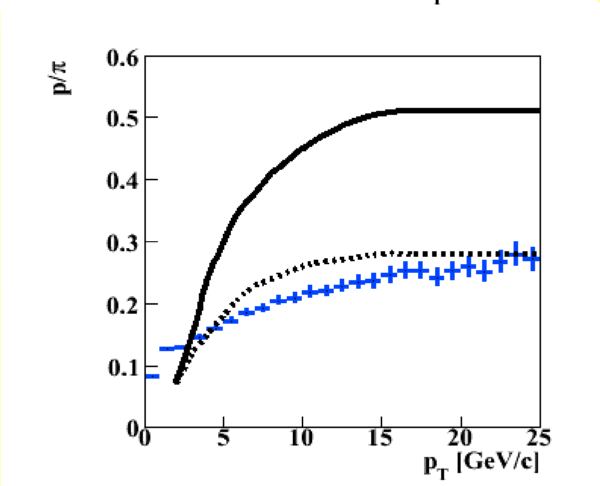
In-medium partonic energy loss through enhanced gluon splitting

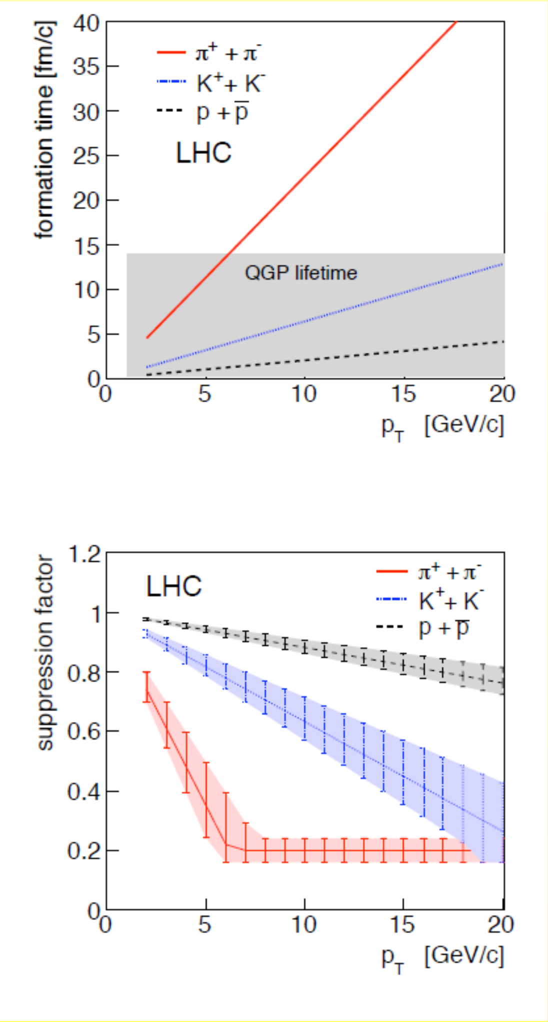
Sapeta-Wiedemann (arXiv:0707.3491)

In-medium hadronization through early recombination

Bellwied-Markert (arXiv:1005.5416)







symbols are PYTHIA pp with
Realistic stat. error bars

The VHMPID collaboration

- **Instituto de Ciencias Nucleares Universidad Nacional Autonoma de Mexico, Mexico City, Mexico**

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- **Universita' degli Studi di Bari and INFN Sezione di Bari, Bari, Italy**

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- **Eotvos University, Budapest, Hungary**

D. Varga

- **Chicago State University, Chicago, IL, USA**

E. Garcia

- **Yale University, New Haven, USA**

J. Harris, N. Smirnov

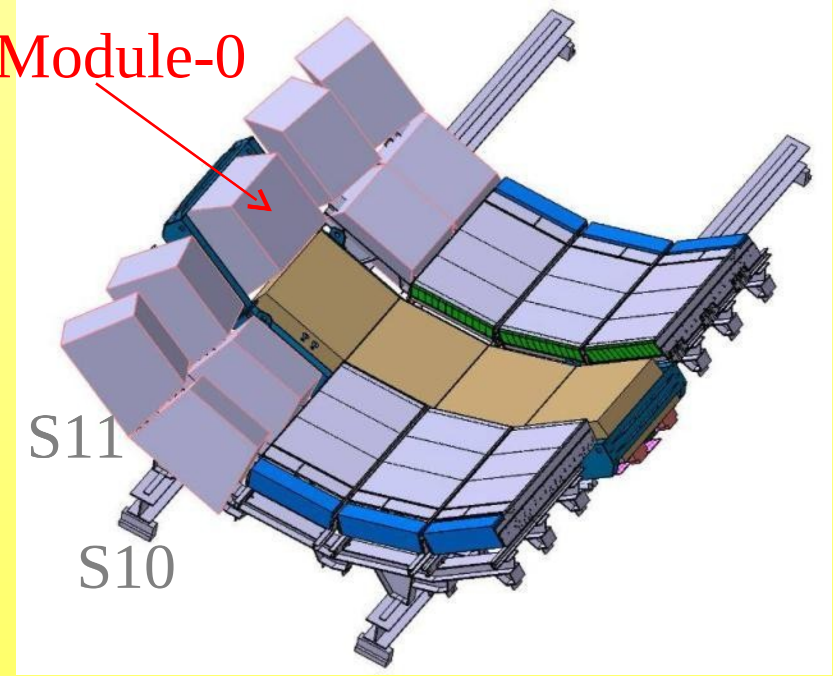
- **Pusan National University, Pusan, Korea**

In-Kwon Yoo, Changwook Son, Jungyu Yi

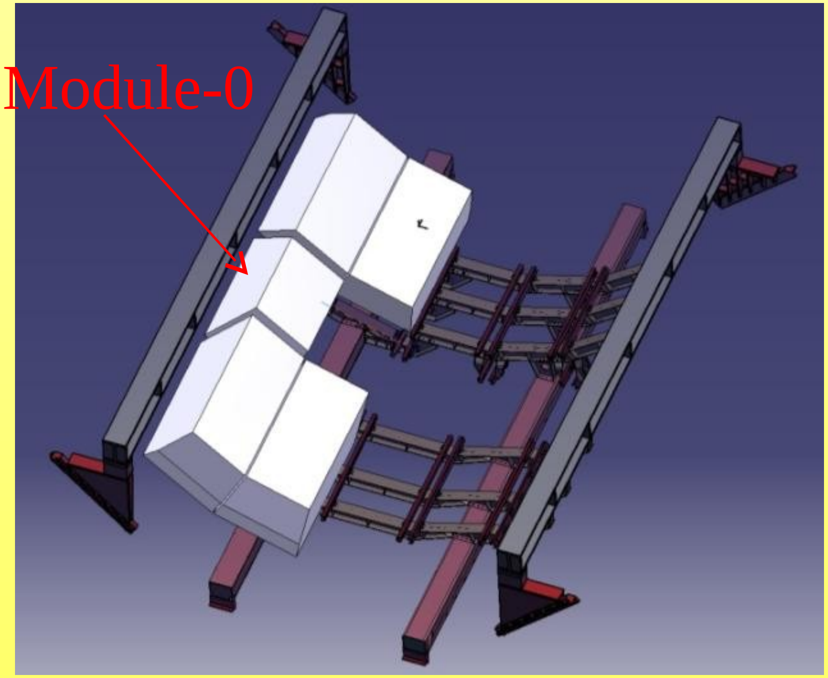
Integration in ALICE

- Design constraint: exploit all available space to maximize acceptance
- Tilted single modules: problems with different clearance in S10 and S11, acceptance ~ 8% wrt to TPC in $|\eta| < 0.5$ (jet fully contained)
- "Super-modules" layout: h=130 cm everywhere, acceptance ~ 12%
- Module-0 size doubled acceptance (~ 3%) due to new PHOS support structure (i.e. no cradle in S11)

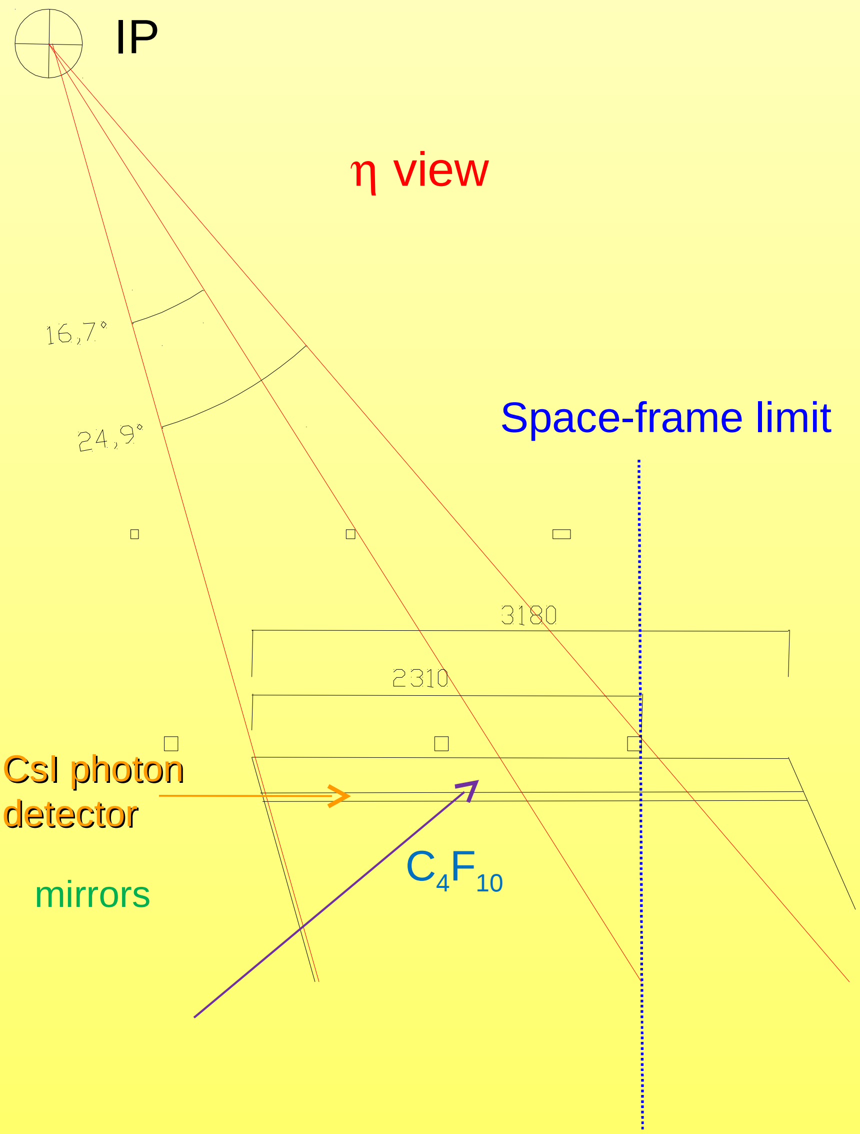
2009 layout: projective geometry

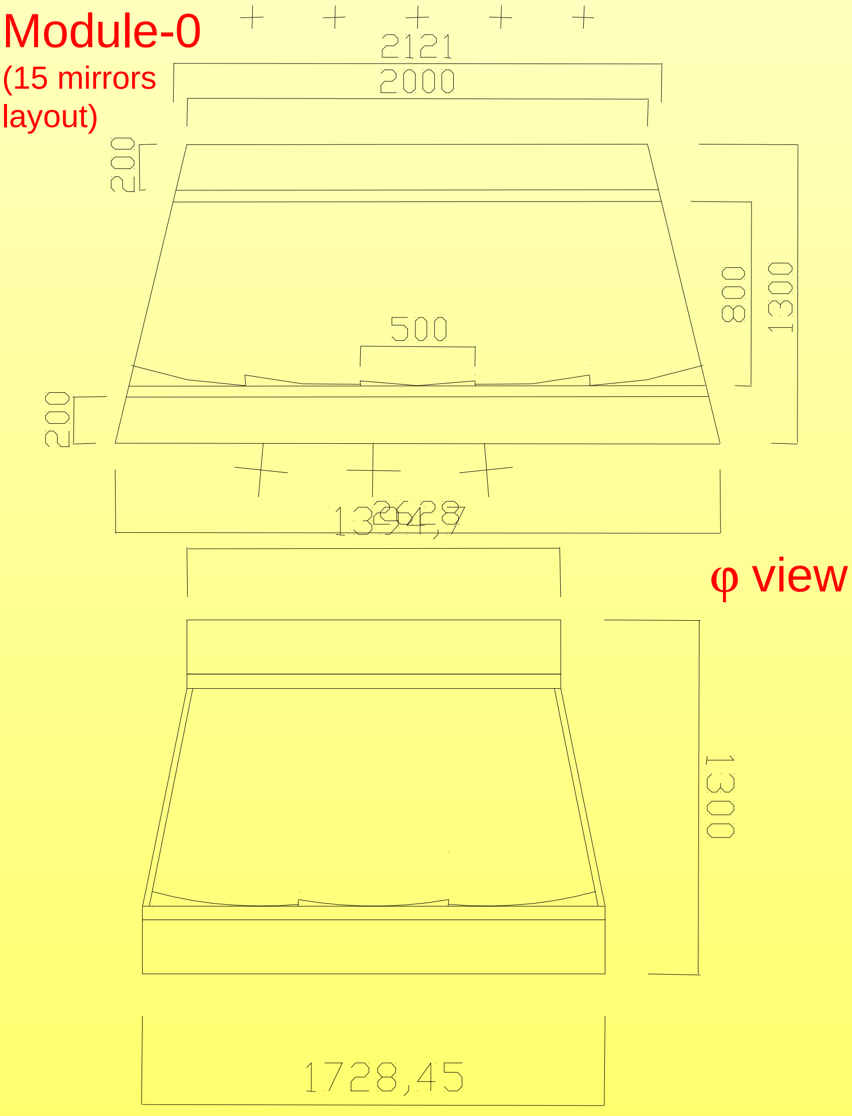


new layout, super-modules

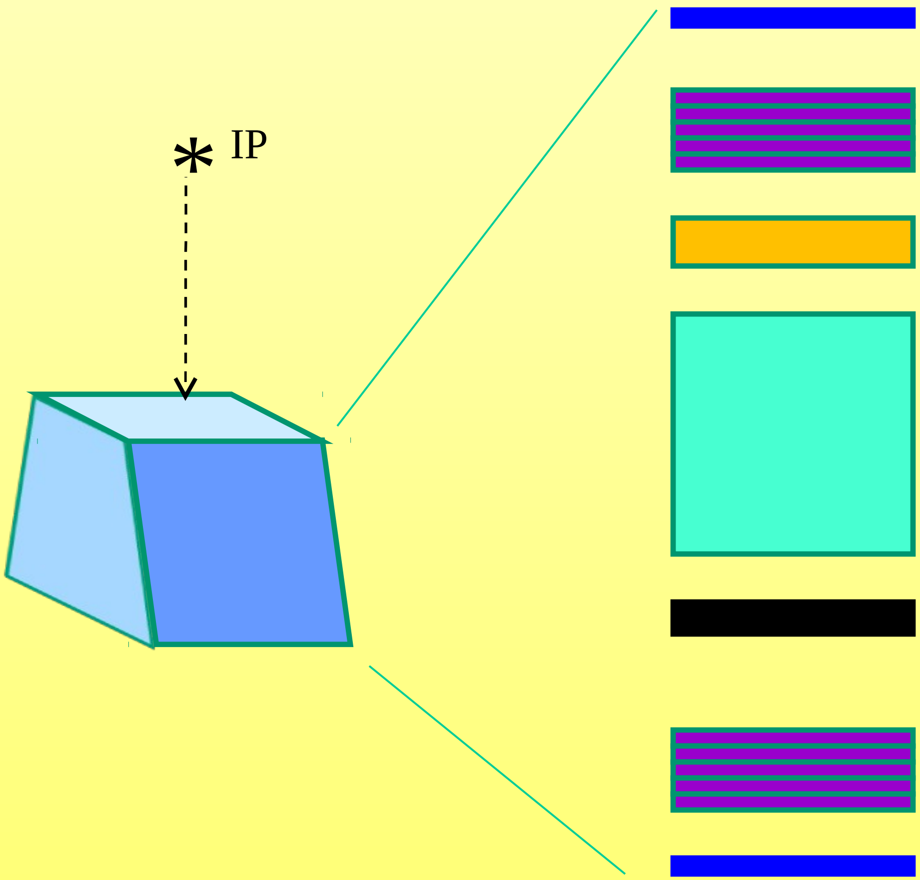


Supermodule layout





Module-0 layout



Cooling+cover: 3cm

Trigger A + MIP layer: 16cm

Photon-detector+FEE: 8cm

C_4F_{10} radiator: 80 cm

Mirror+cover: 4cm

Trigger B + MIP layer: 16cm

Cooling+cover: 3cm

Total: 130 cm

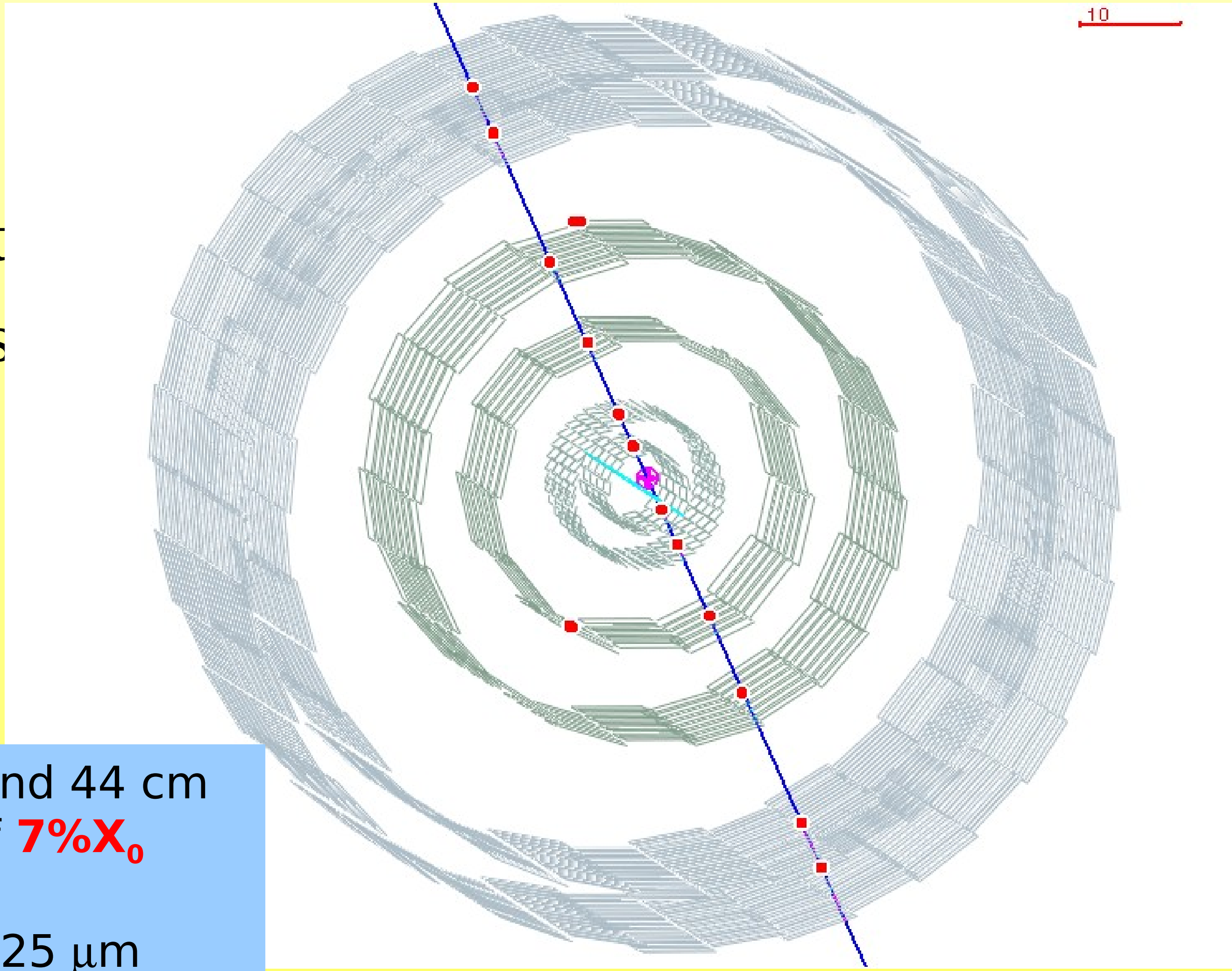
Beam tests program

Period A	1-19 Jul	PS/T10	TGEM
Period B	16-30 Aug	PS/T10	HPTD
Period C	27 Sept-11 Oct	PS/T10	Small prototype
Period D	1-8 Nov	SPS/H4	HPTD+Small prototype

Module-0 production planning

Inner Tracking System upgrade

- Present 6 detector layers based on three silicon technologies:
  - SPD (pixels)
  - SDD (Si Drift
  - SSD (Si strips
- Unique level-zero trigger (fast OR)



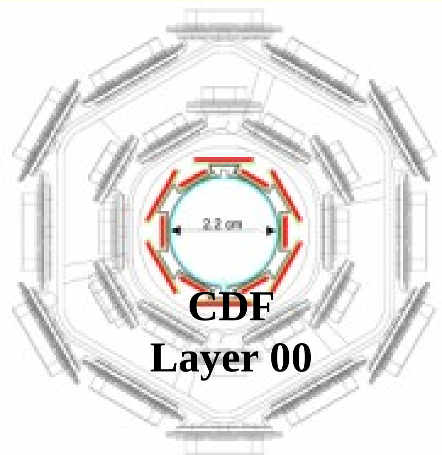
Radii: **4**, 7, 15, 24, 39, and 44 cm
Total material budget of **7%X_0**
(normal incidence)
Pixel size 50 μm times 425 μm
Beam pipe radius 2.98 cm

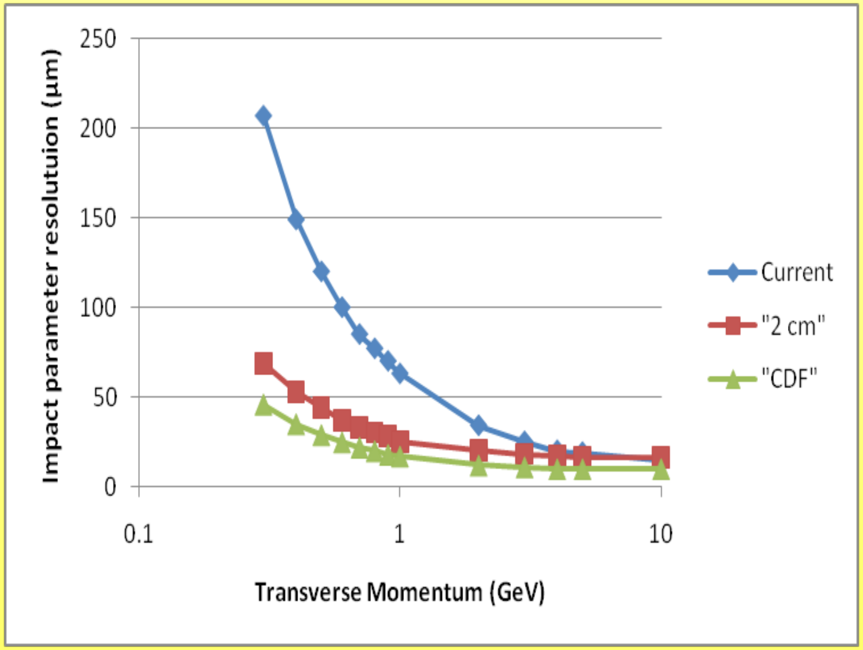
Inner Tracking System upgrade

- Goal: a factor of 2 improvement in impact parameter resolution
- Secondary goal: improve stand-alone tracking capability
- Improving the impact parameter resolution by a factor 2 or better will:
  - Increase sensitivity to charm by factor 100;
  - Give access to charmed baryons (baryon/meson ratio in charm sector – main issue is understanding of recombination);
  - Allow study of exclusive B decays;
  - Allows first measurement of total B production cross section down to zero P_T;
  - Improve flavor tagging.

Inner Tracking System Upgrade

- **Detector Layout and Technology:**
  - 6/7 cylindrical layers
  - First layer as close as possible to the interaction point: smaller and thinner beam-pipe (present 29/0.8mm) **goal: at least O(20mm) radius or smaller**
  - Extend the use of pixel detectors to larger radii (replace SDD, slowest det in ITS)
    - strips where pixels not affordable
    - re-use of the existing pixel and/or strip layers being considered
  - Extremely low material budget, trigger capability, granularity, fast readout
  - New mechanics and cooling
- **Target dates defined by the LHC shutdown schedule: 2016**





ITS Upgrade Time-scale (very tentative!)

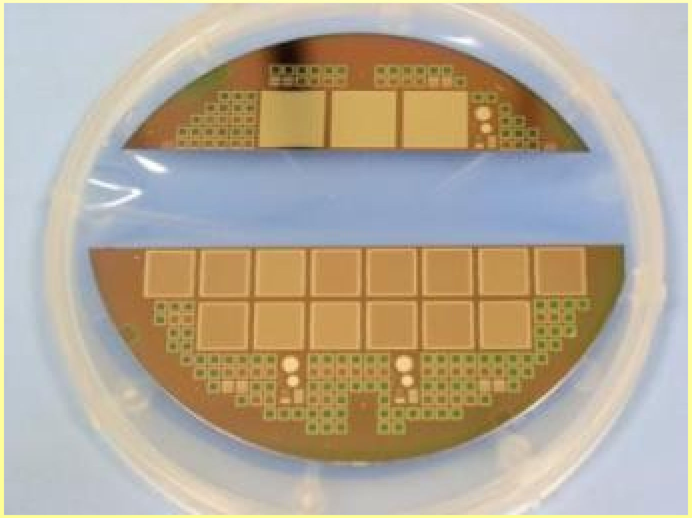
- **R&D phase: 2010-2012**
  - Explore two Pixel technologies:
    - Hybrid pixel detectors: “state of the art”
      - low cost bump-bonding
      - new sensor type (3D, edgeless planar)
      - further thinning (SPD: 200 μm sensor + 150 μm FEE)
    - Monolithic pixel detectors: Mimosa and LePix
      - larger detector areas at considerably lower cost
  - Layout Studies and Technical Design report
- **Production and pre-commissioning: 2013-2015**
- **Installation and commissioning: 2016**
- **VERY AGGRESSIVE SCHEDULE!**
  - Will require careful planning, synergies with other projects (PANDA/CBM? STAR? MEDIPIX?), and possibly a two-stage approach (2016 and 2020)
  - Effort to get already in 2016 the smallest possible radius beampipe

R&D Progress

- Hybrid Pixels:
  - ☞ Investigating possible application of hybrid silicon pixel detectors by studying possibilities to reduce the material budget
  - ☞ 3 main targets defined
    - Thinning studies of chip wafers (150 μm in ALICE SPD, is 50-100 μm feasible?)
    - Thin silicon sensors (reduce the thickness from 200 um to 150 um, non-linear yield problem!)
    - Reduce the need for overlaps between modules (active edge, 3D sensor technologies)
- Lepix:
  - Submission in 90nm finalized March 2010, prototypes expected back now
    - Several issues: ESD, special layers and mask generation, guard rings
  - 7 chips submitted :
    - 4 test matrices C90_MATRIX1_V0…C90_MATRIX4_V0
    - 1 diode for radiation tolerance C90_DIODE_V0
    - 1 breakdown test structure C90_VBRDOWN_V0
    - 1 transistor test: already submitted once in test submission C90_TESTC90_V1
  - Very significant testing effort for which we need to prepare (measurement setup, test cards…)

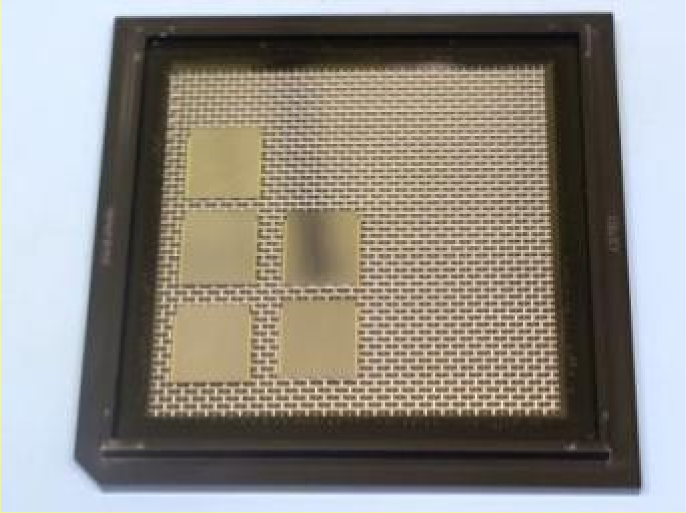
Happening … 3D assemblies

FBK 3D sensor wafer



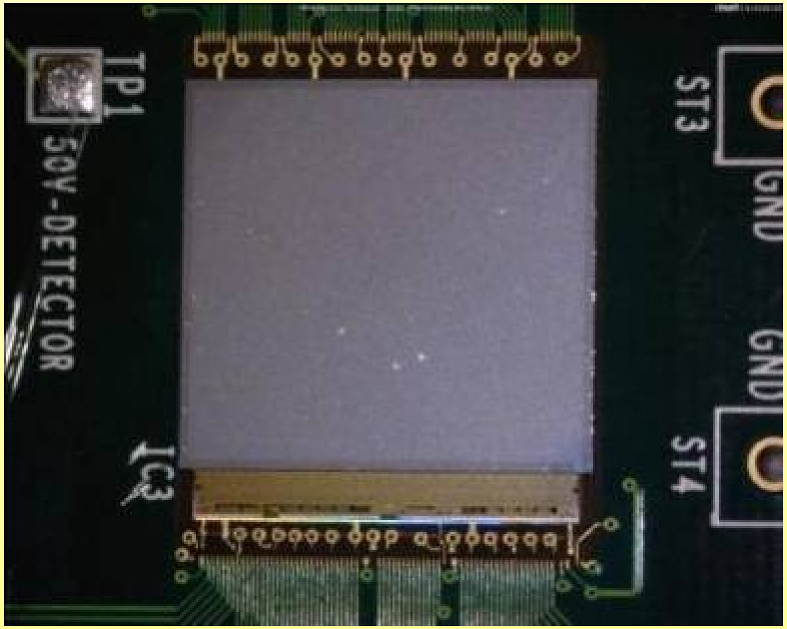
Details of the SPD-ALICE-3D sensor

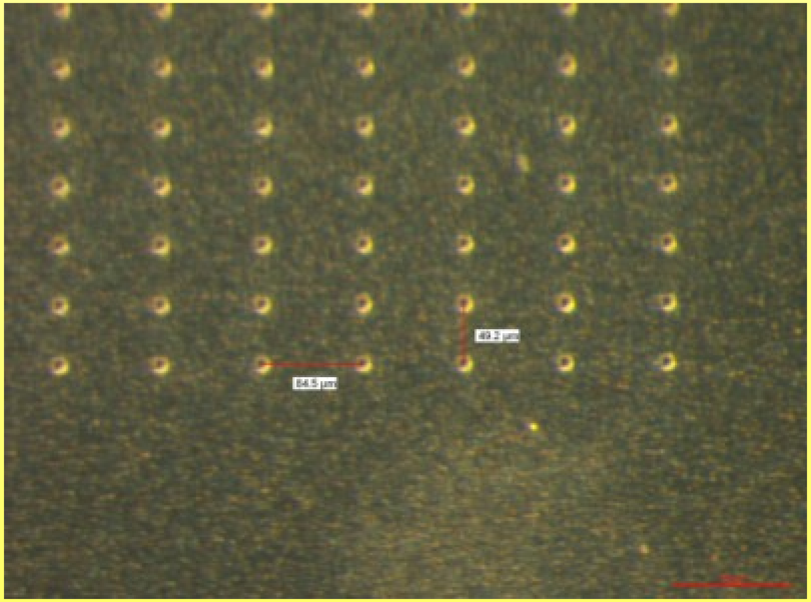
5 single chip assembly:
SPD-ALICE-3D + ALICE1LHCb

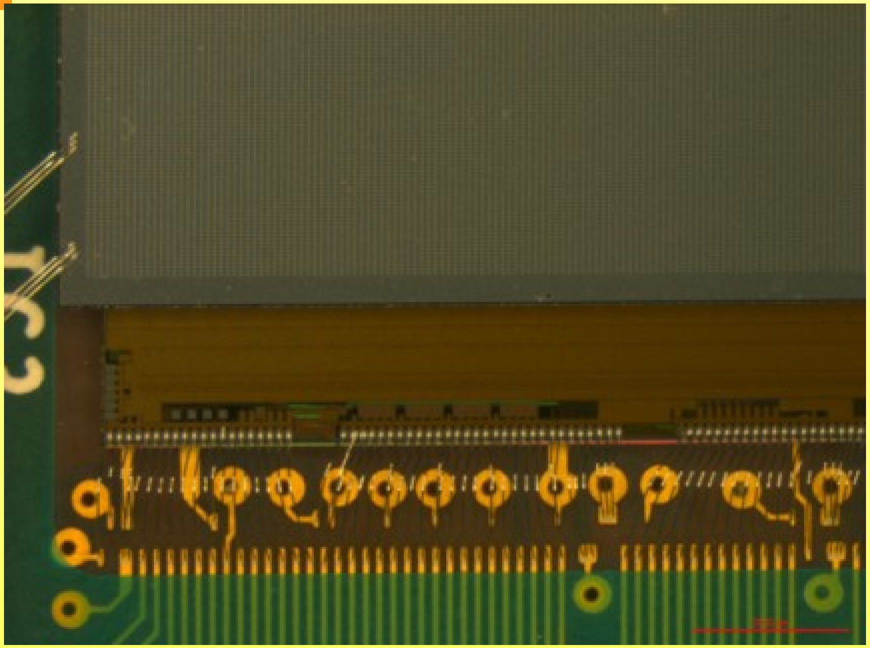


3D prototype

Single chip assembly glued and wire-bonded to the test card







… and a lot more …

- Detectors to improve tagging of diffractive events via rapidity gaps (with Mexican leadership)
- DAQ upgrade
- Trigger
- Forward tracking
- TPC rate capability
- …

Conclusion

- ALICE has finally started its journey in Physics, after 20 years of preparation.
- It was worth the effort!
  - The detector performs beautifully
  - Results are plentyful
  - Soon will have Heavy Ions
- ALICE Physicists have not lost creativity and ingenuity along the way, and are already working on how to do more and better
- A very, very exciting time ahead of us! … and Mexico is in the frontline!