MPD-NICA y MexNICA

Mario Rodríguez Cahuantzi
Facultad de Ciencias Físico Matemáticas, BUAP

Seminario de Altas Energías (ICN/IF-UNAM)

03/03/2021

This talk is based on:

Core meets corona: a two-component source to explain Lambda and anti-Lambda global polarization in semi-central heavy-ion collisions, Alejandro Ayala, E. Cuautle, Maria Elena Tejeda-Yeomans, M. Rodriguez-Cahuantzi, Jordi Salinas, et al (30.03.2020). Physics Letters B, 810 (2020) 135818

Electric charge estimation using a SensL SiPM doi: doi.org/10.1088/1748-0221/15/09/P09008, 2020 JINST 15 P09008, C.H. Zepeda-Fernández, L.F. Rebolledo-Herrera, M. Rodiguez-Cahuantzi, E. Moreno-Barbos. arXiv: 2005.14226

A beam-beam monitoring detector for the MPD experiment at NICA, doi: 10.1016/j.nima.2019.163150, Nuclear Instruments and Methods in Physics Research A, Alejandro Ayala, Luis Manuel Montano, V.Z. Reyna Ortiz, M. Rodríguez Cahuantzi, A. Villatoro Tello, et al 953 (2020) 163150

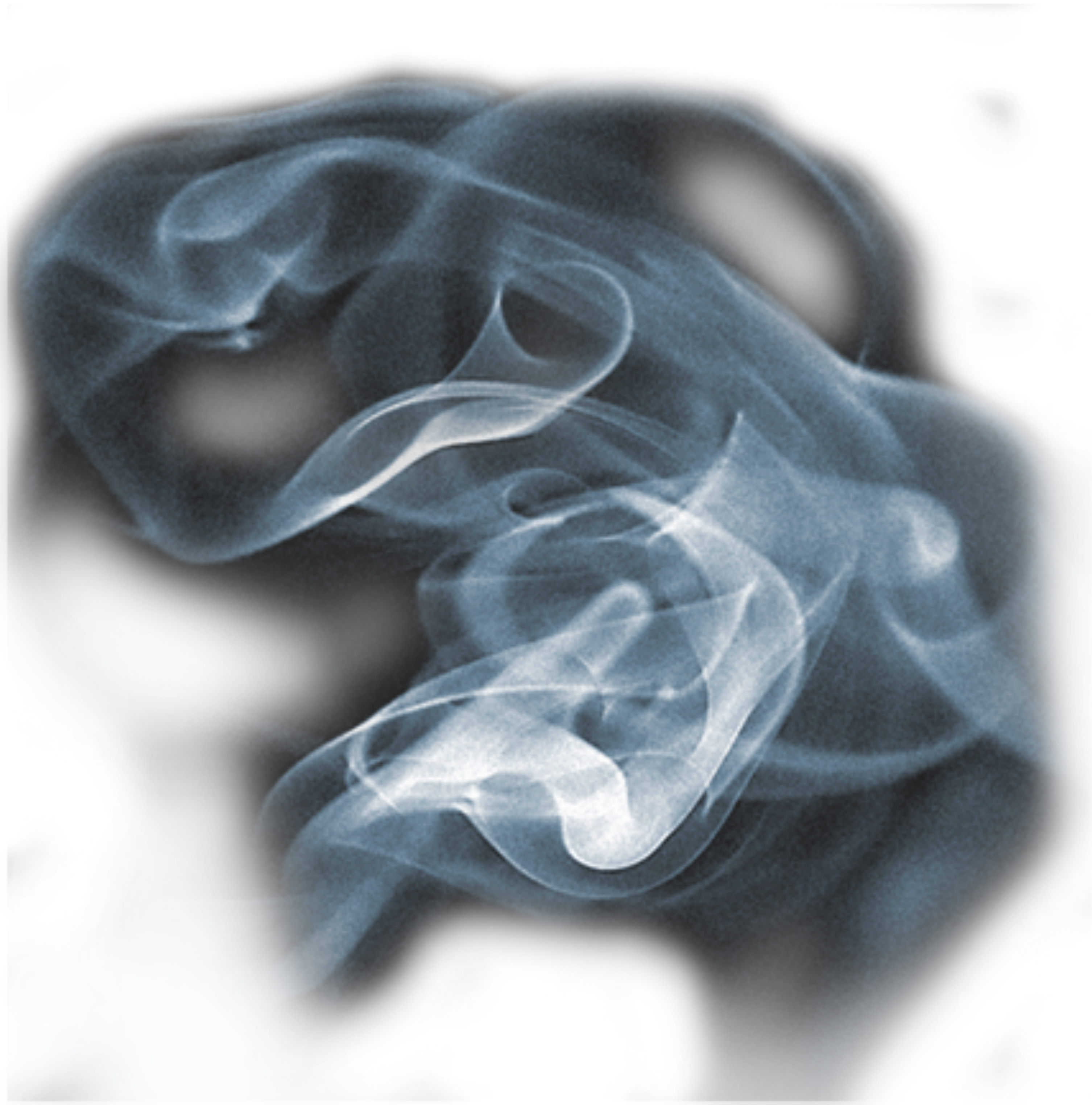
Hyperons from Bi+Bi collisions at MPD-NICA: Preliminary analysis of production at generation, simulation and recontruction level. Accepted for publication. To appear in the Journal of Physics of Elementary Particles and Atomic Nuclei, Year 2021, Volume 3. Alejandro Ayala, Eleazar Cuautle, Isabel Dominguez, M. Rodriguez-Cahuantzi, Ivonne Maldonado, Maria Elena Tejeda-Yeomans (23.10.2020) arXiv: 2010.12593

The conceptual design of the miniBeBe detector proposed for NICA-MPD 2021 JINST 16 P02002 , Ramon Acevedo Kado, Mauricio Alvarado, Alejandro Ayala, Marco Alberto Ayala, Wolfgang Bietenholz, Dario Chaires, Eleazar Cuautle, Isabel Dominguez, Alejandro Guirado, Ivonne Maldonado, Julio Maldonado, Eduardo Moreno-Barbosa, P.A. Nieto Marin, Miguel Enrique Patino, Lucio Rebolledo, Mario Rodriguez-Cahuantzi, D. Rodriguez-Figueroa, Valeria Z. Reyna Ortiz, Guillermo Tejeda-Munoz, Maria Elena Tejeda-Yeomans, Luis Valenzuela-Cazares, C.H. Zepeda-Fernandez, arXiv: 2007.11790

Introduction

SOLID

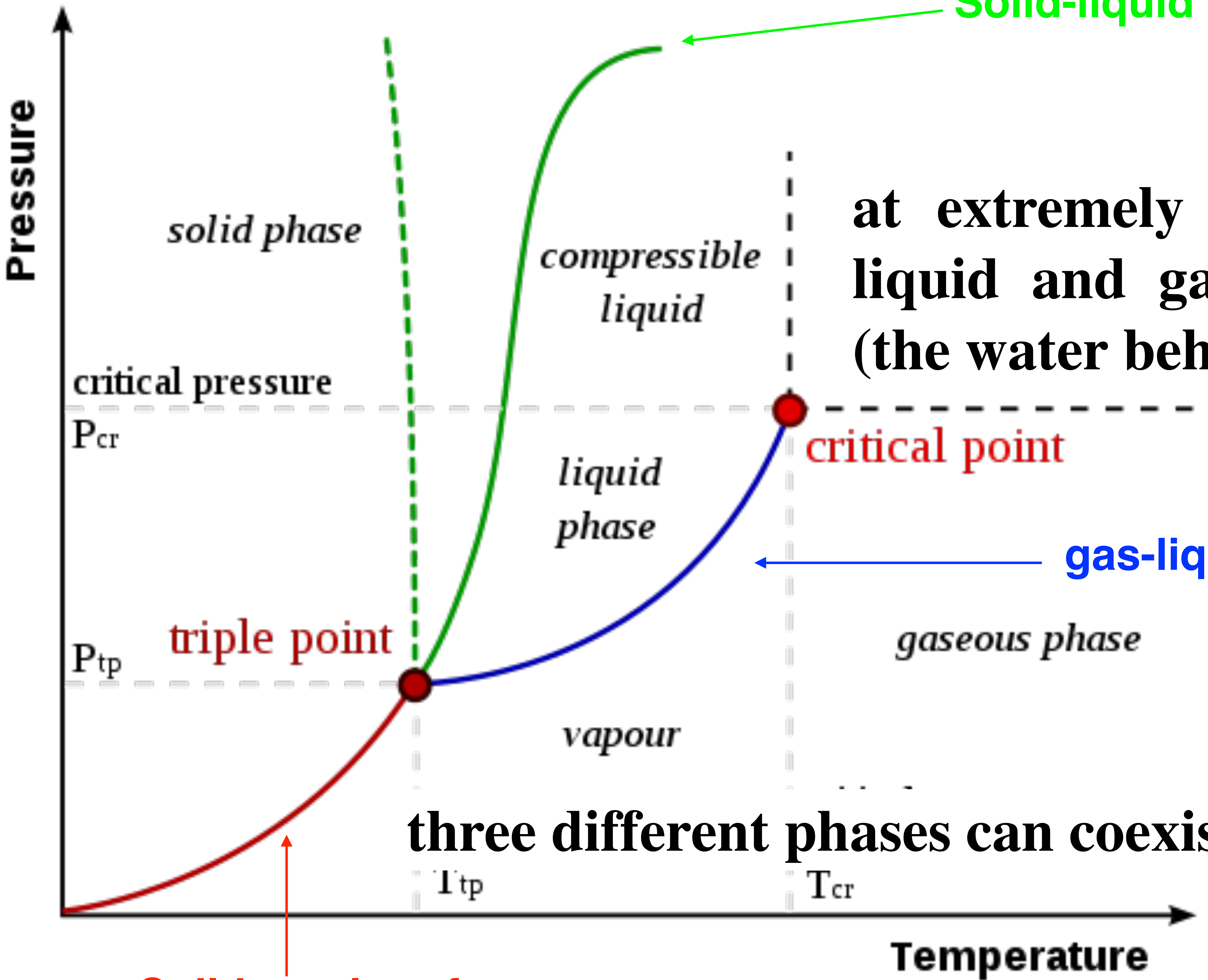
LIQUID



GAS

Introduction

BUAP



Solid-liquid interface

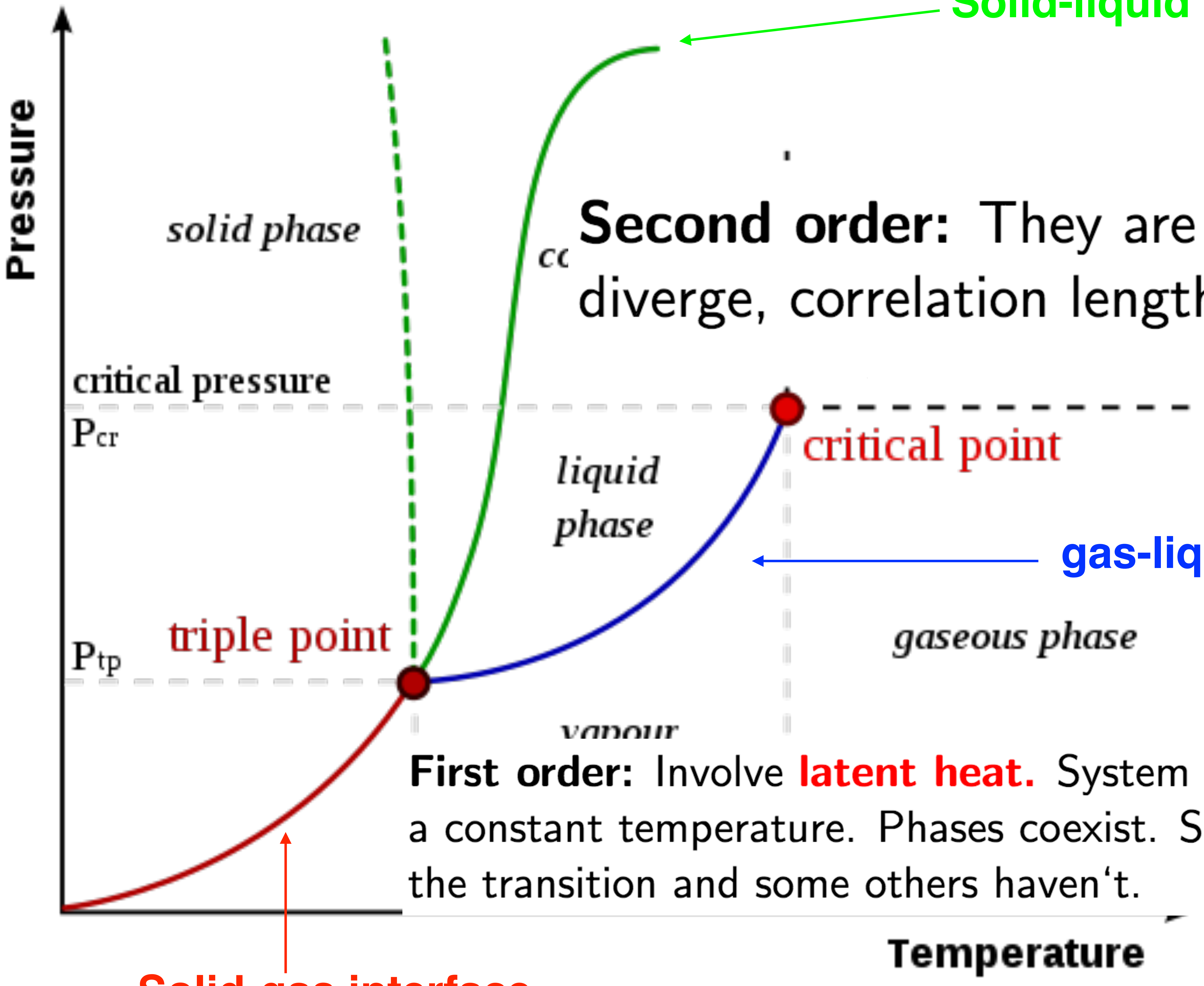
gas-liquid interface

Solid-gas interface

at extremely high temperatures and pressures, the liquid and gaseous phases become indistinguishable (the water behaves like a gas and liquid)

three different phases can coexists (like opalescent)

Introduction

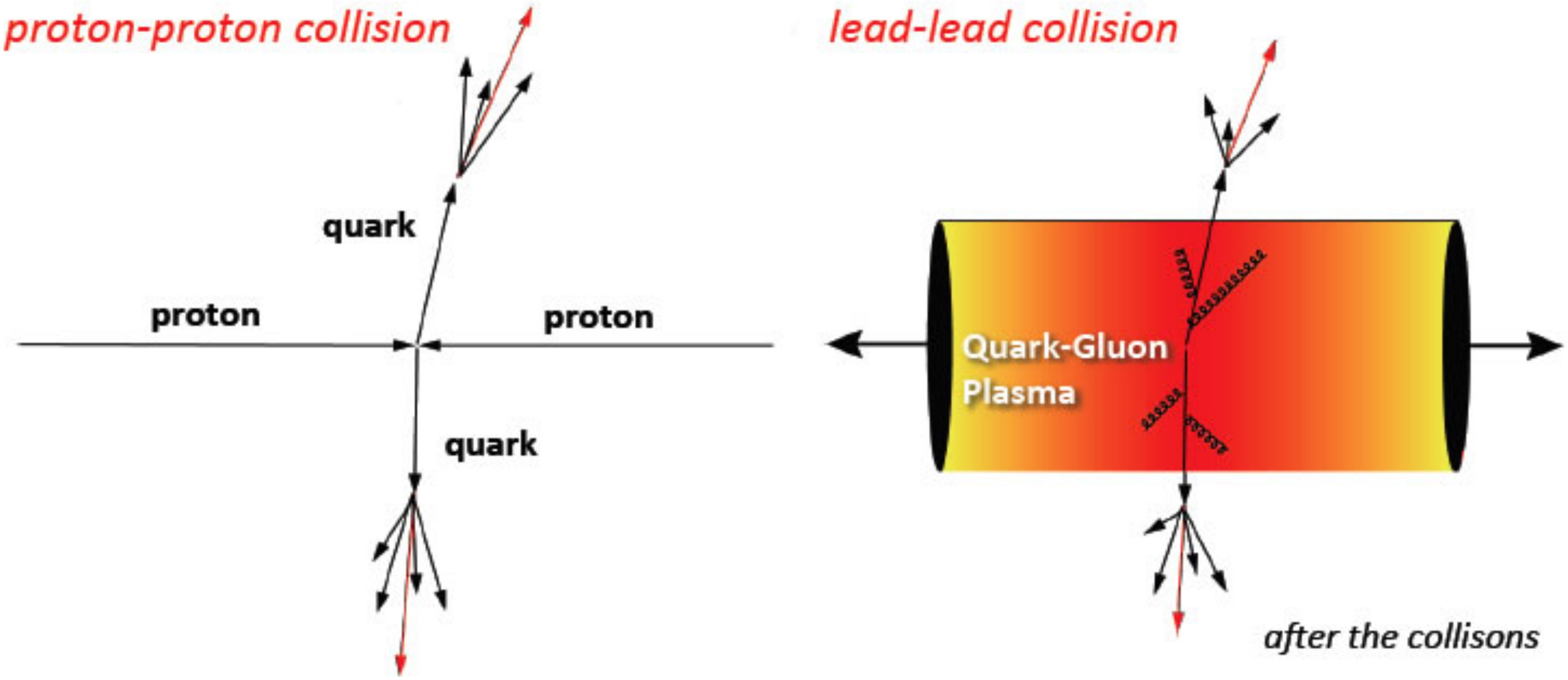


Second order: They are **continuous** transitions. Susceptibilities diverge, correlation lengths become large.

First order: Involve **latent heat.** System absorbs or releases heat at a constant temperature. Phases coexist. Some parts have competed the transition and some others haven't.

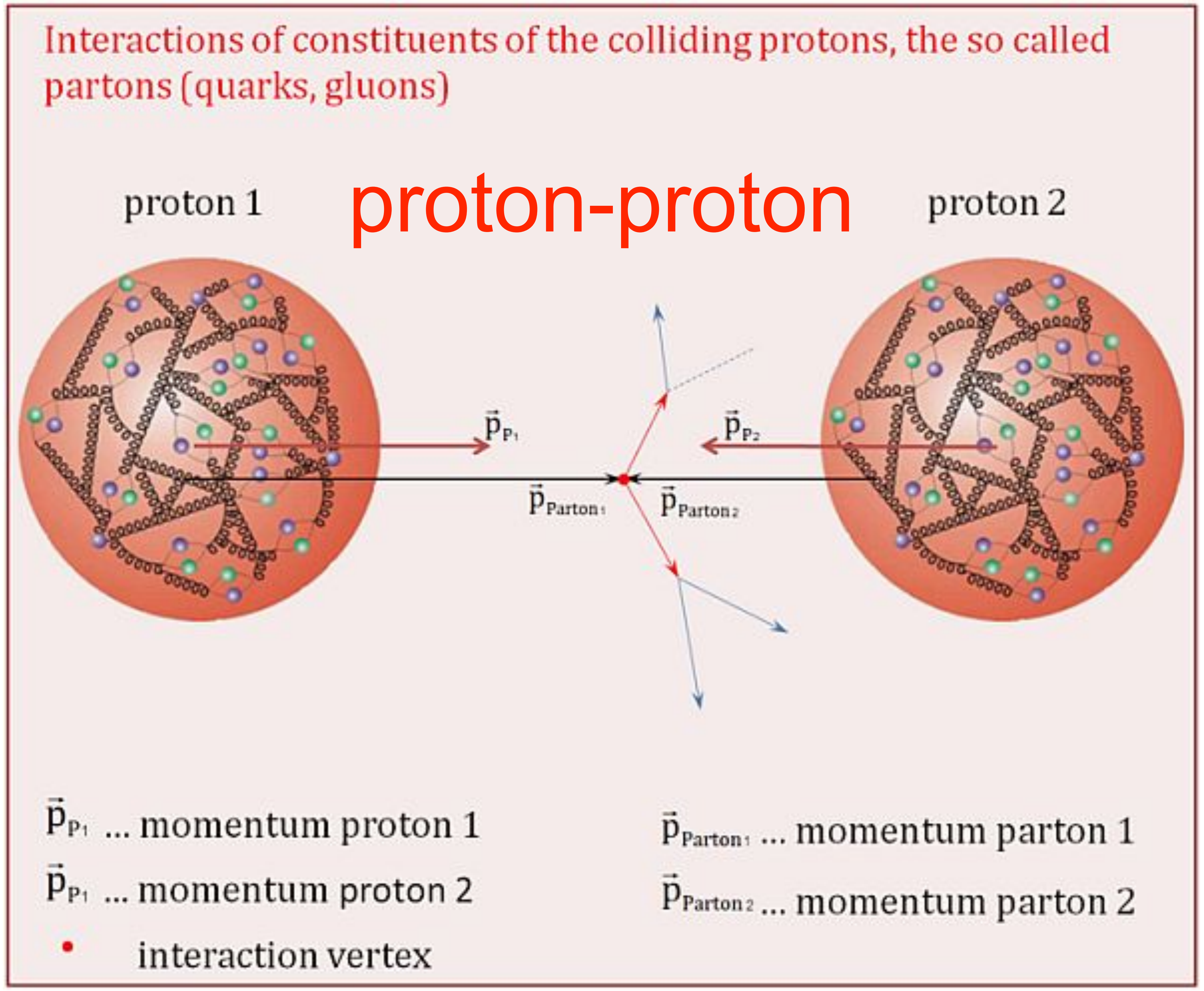
Introduction

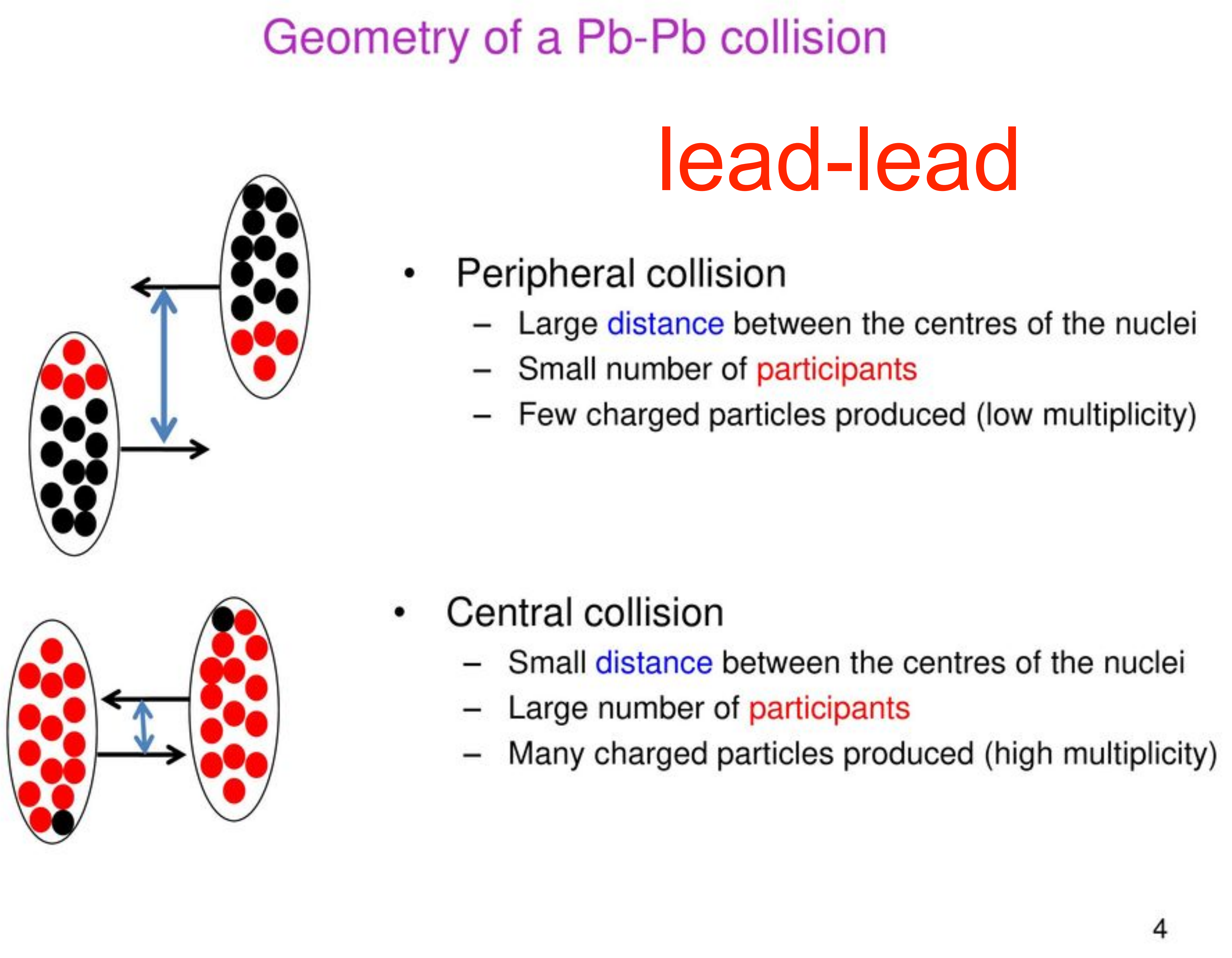
Heavy-ion physics allows us to study QCD matter under extreme conditions of high temperature and energy density.



Introduction

Heavy-ion physics allows us to study QCD matter under extreme conditions of high temperature and energy density.

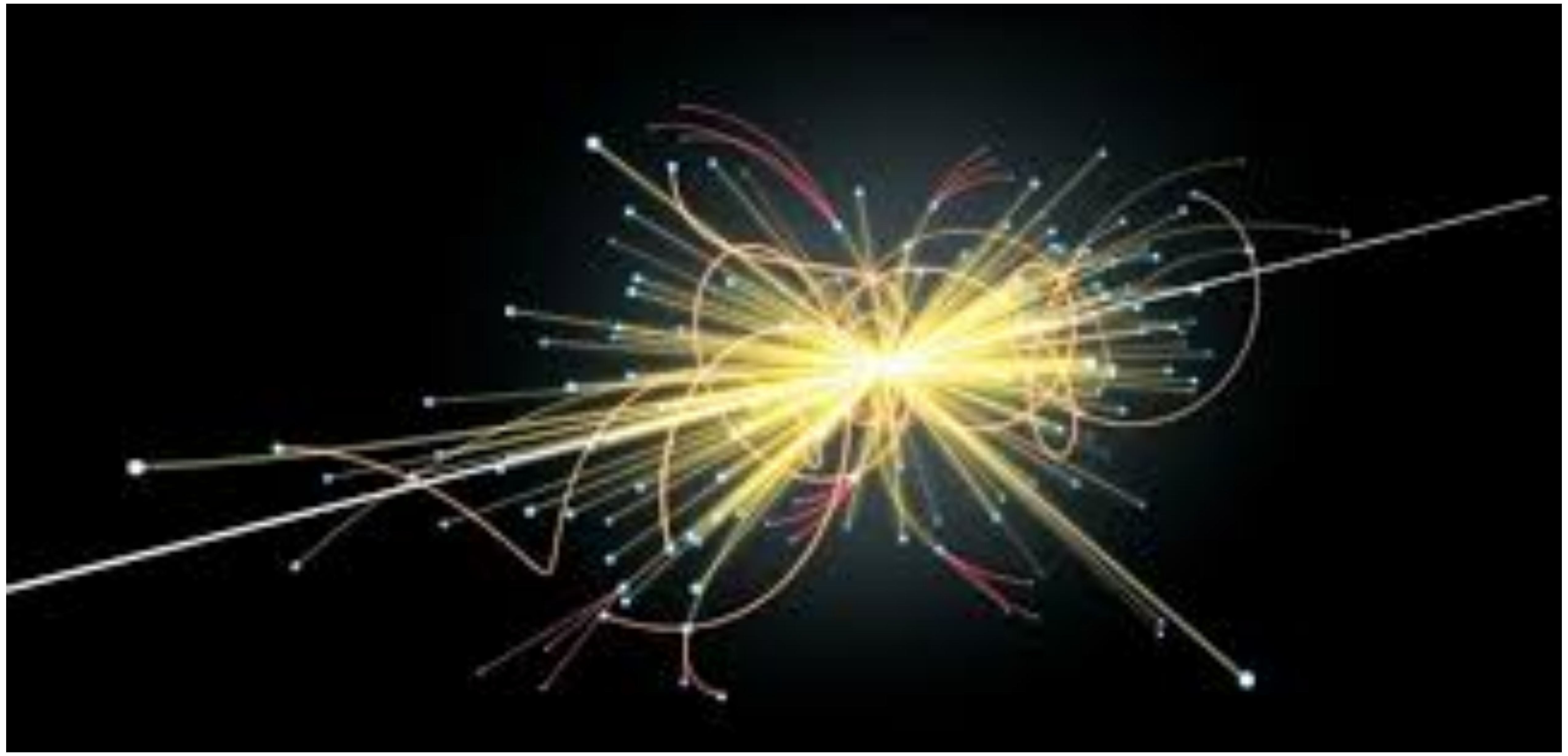




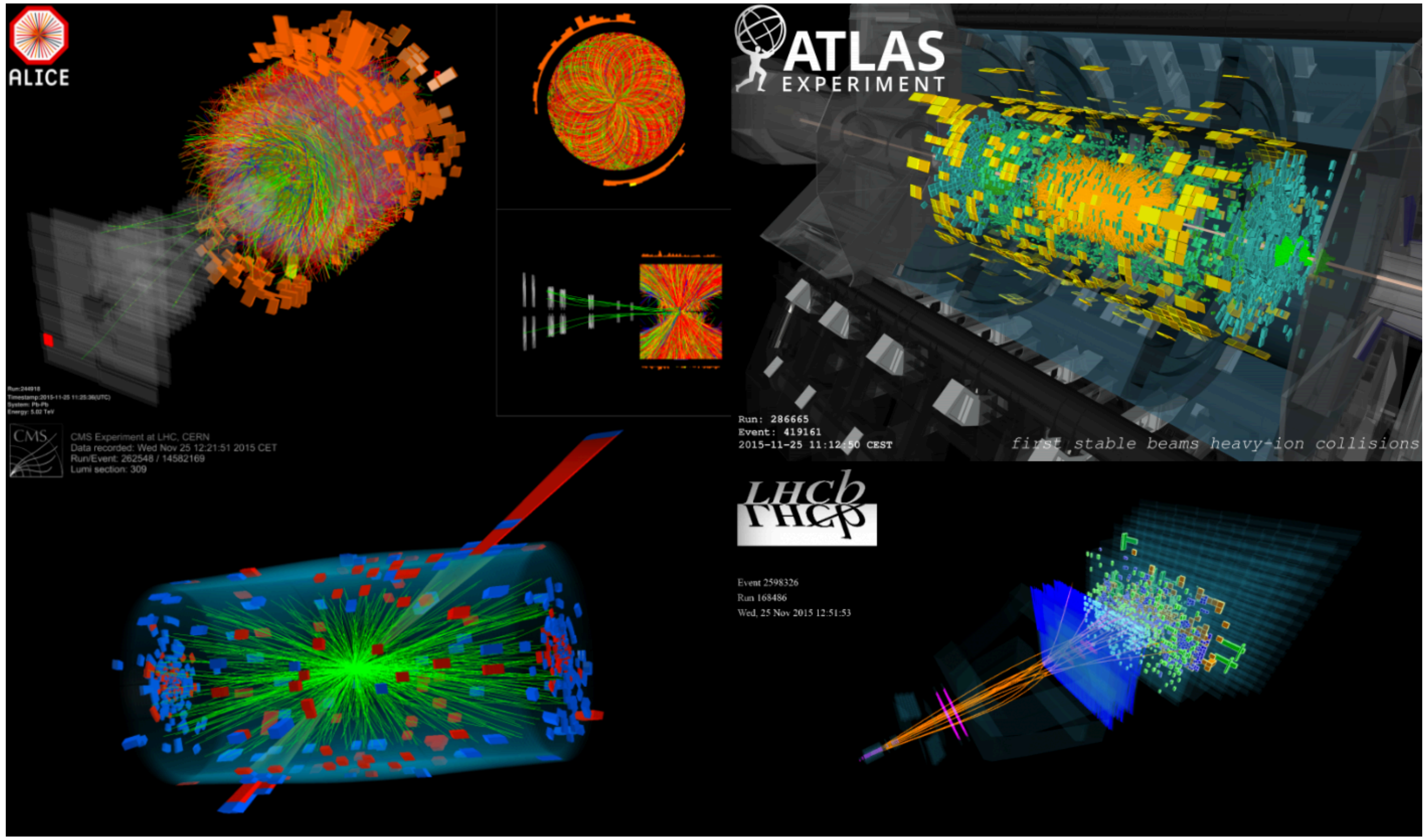
Introduction

Heavy-ion physics allows us to study QCD matter under extreme conditions of high temperature and energy density.

proton-proton

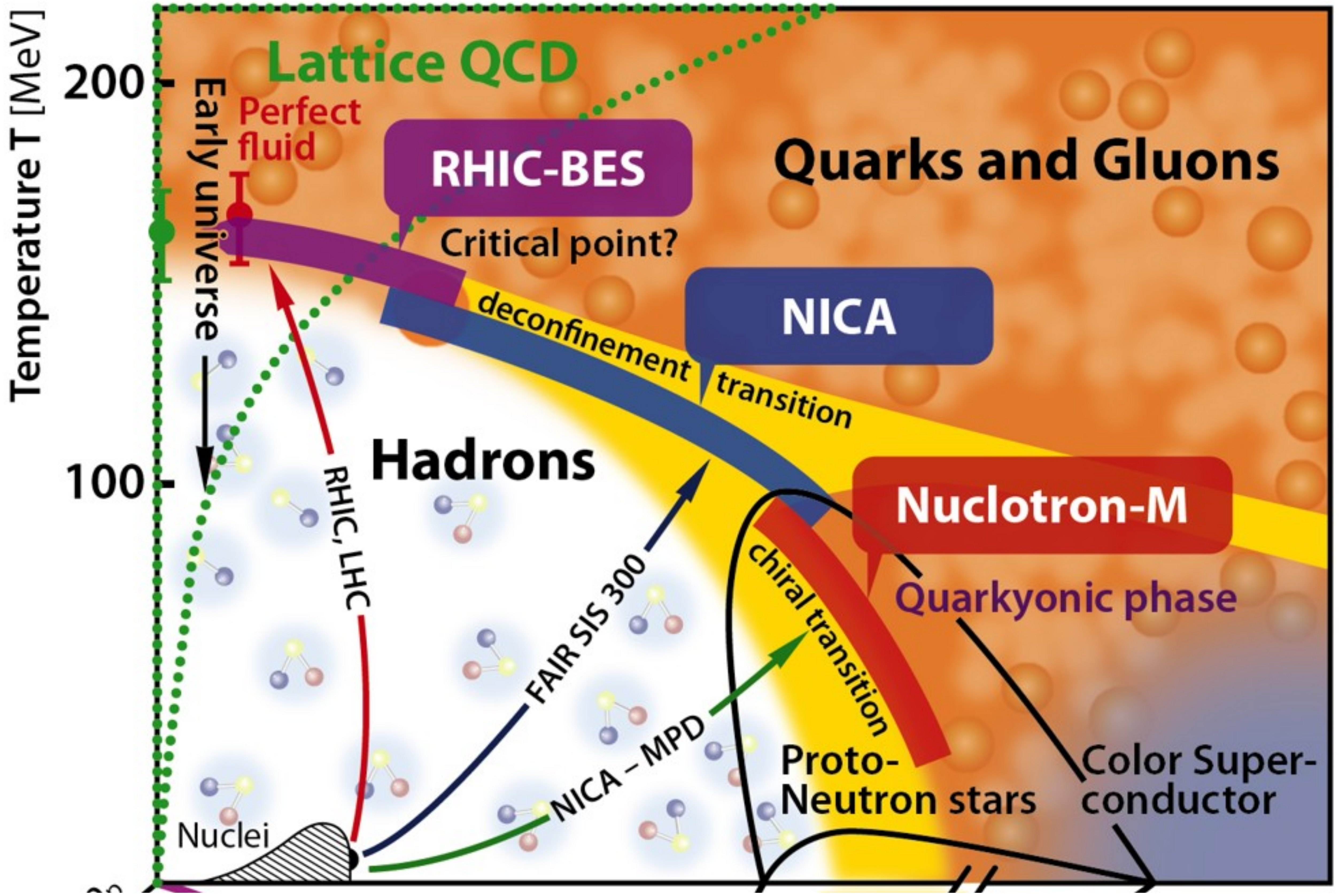


lead-lead



Introduction

Heavy-ion physics allows us to study QCD matter under extreme conditions of high temperature and energy density.



Feb 10, 2000:

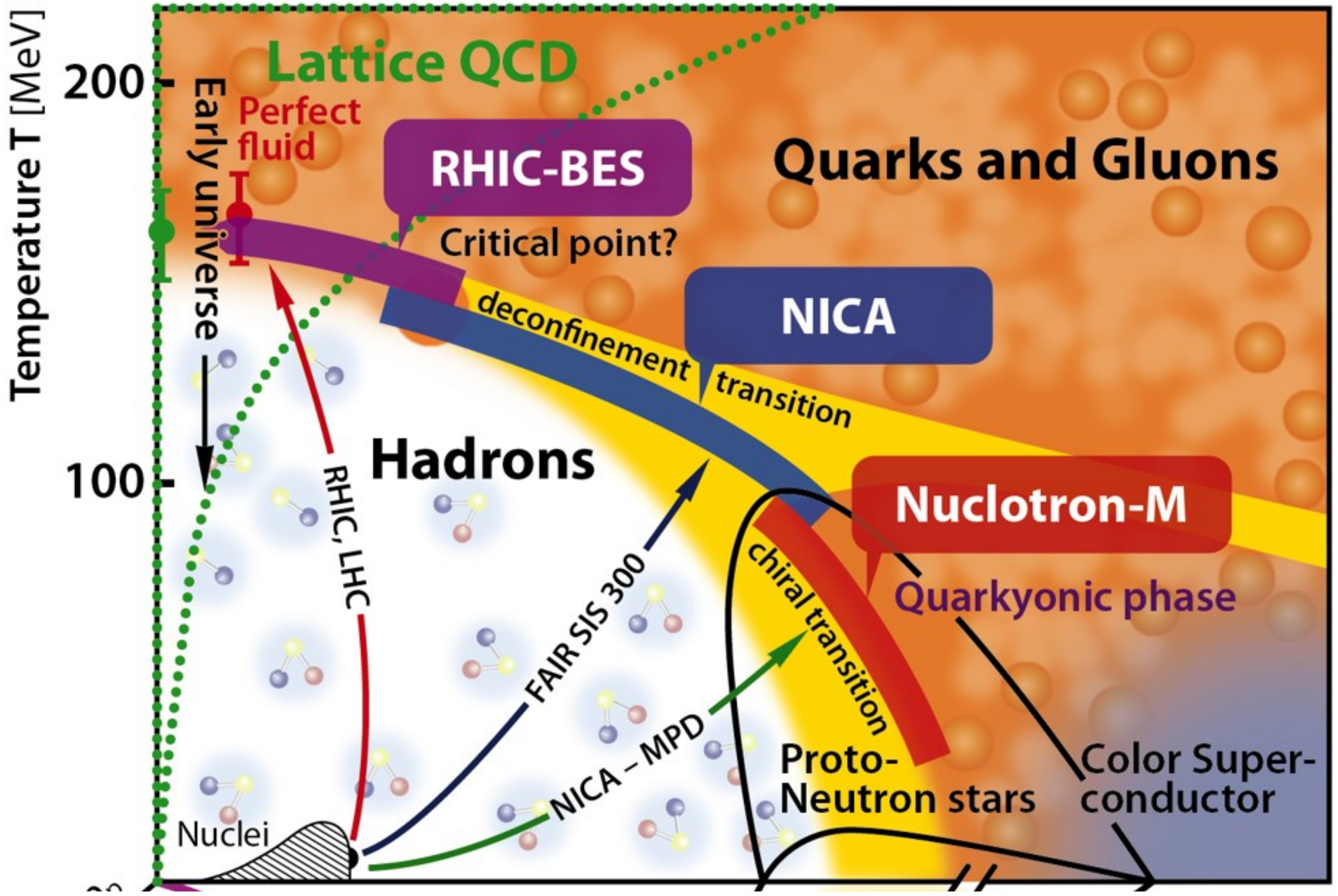
"...The data provide evidence for colour deconfinement in the early collision stage and for a
collective explosion of the collision fireball in its late stages. The new state of matter exhibits many of
the characteristic features of the theoretically predicted Quark-Gluon Plasma."

.....

" The higher energies of RHIC and LHC are needed to complete the picture and provide a full
characterization of the Quark-Gluon Plasma."

Introduction

Heavy-ion physics allows us to study QCD matter under extreme conditions of high temperature and energy density.



RHIC's results:

- **observation of strong "elliptic" flow** (Phys.Rev.Lett 86:402-407,2001)
- **observation of jet quenching** (suppression of hadrons with large pT, Phys.Rev.Lett.88:022301,2002)

LHC's results

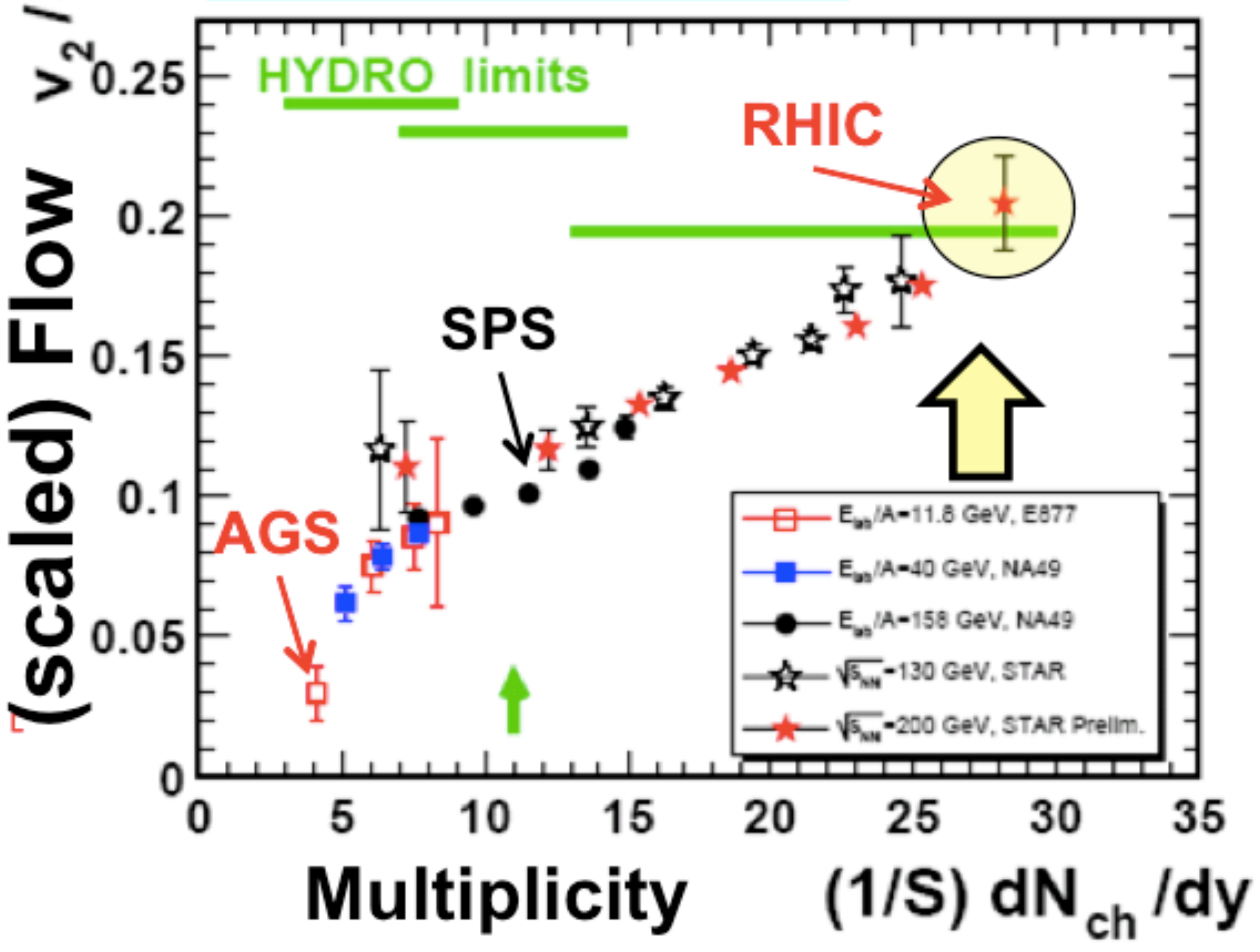
- **observation of long-range, near-side angular correlations in PbPb and pPb collisions** (Phys. Lett. B (718) 795-814)
- **hot and dense matter created in HIC behaves like a fluid with almost zero friction** (constrain on n/s, PRL 105, 252302 (2010))
- **enhanced production of multi-strange hadrons in high-multiplicity p-p collisions** (proton collisions present similar patterns to those observed in HIC, doi:10.1038/nphys4111)
- **angular correlations in photo-nuclear ultra peripheral Pb+Pb collisions** (26/01/2021, https://arxiv.org/pdf/2101.10771.pdf)

BUAP

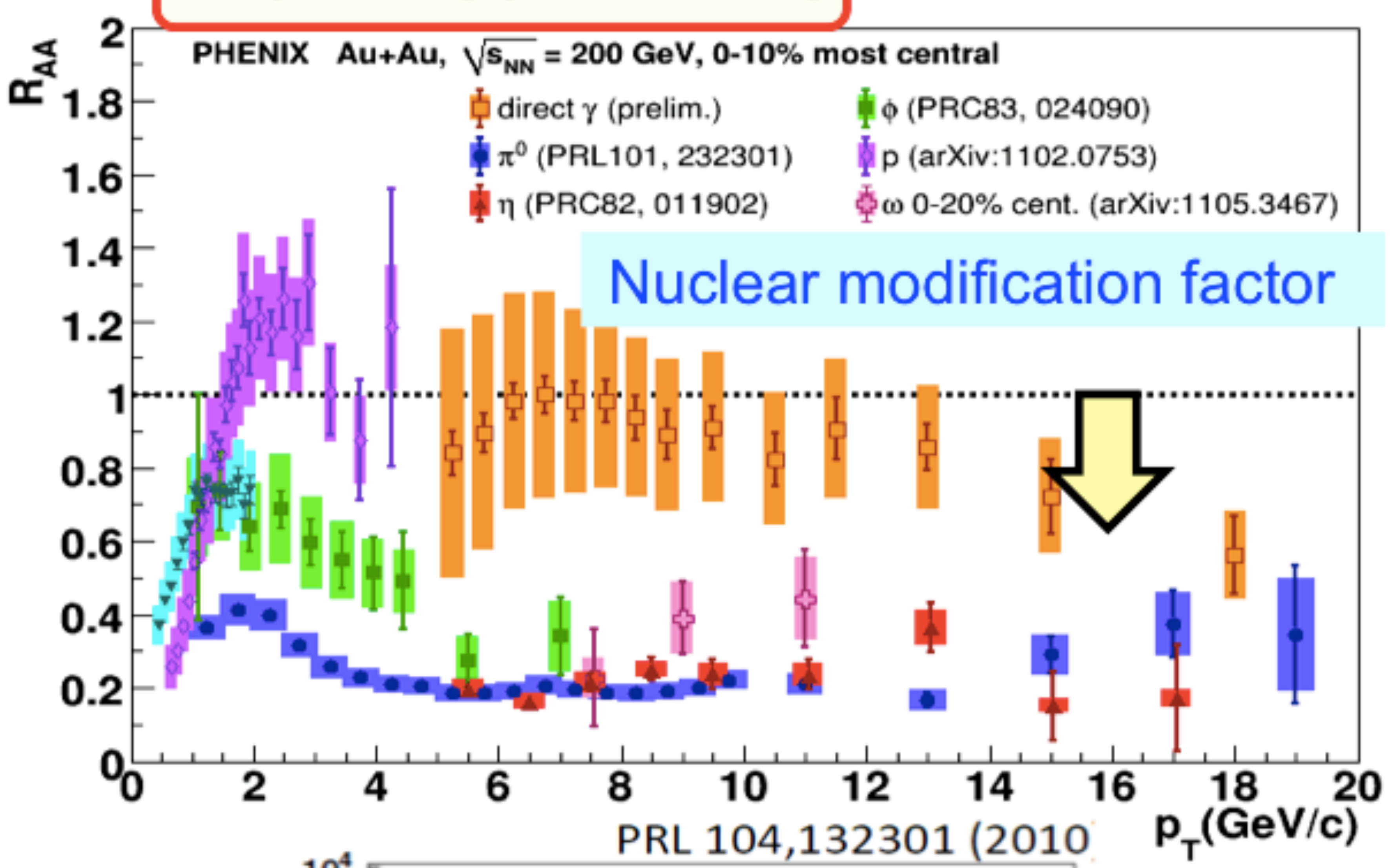
Main Results from RHIC

- strong elliptic flow
  - ⇨ ~ maximum possible i.e 'ideal liquid' ($\eta/s \approx 0$)
  - ⇨ mostly produced in the early phase (partonic?)

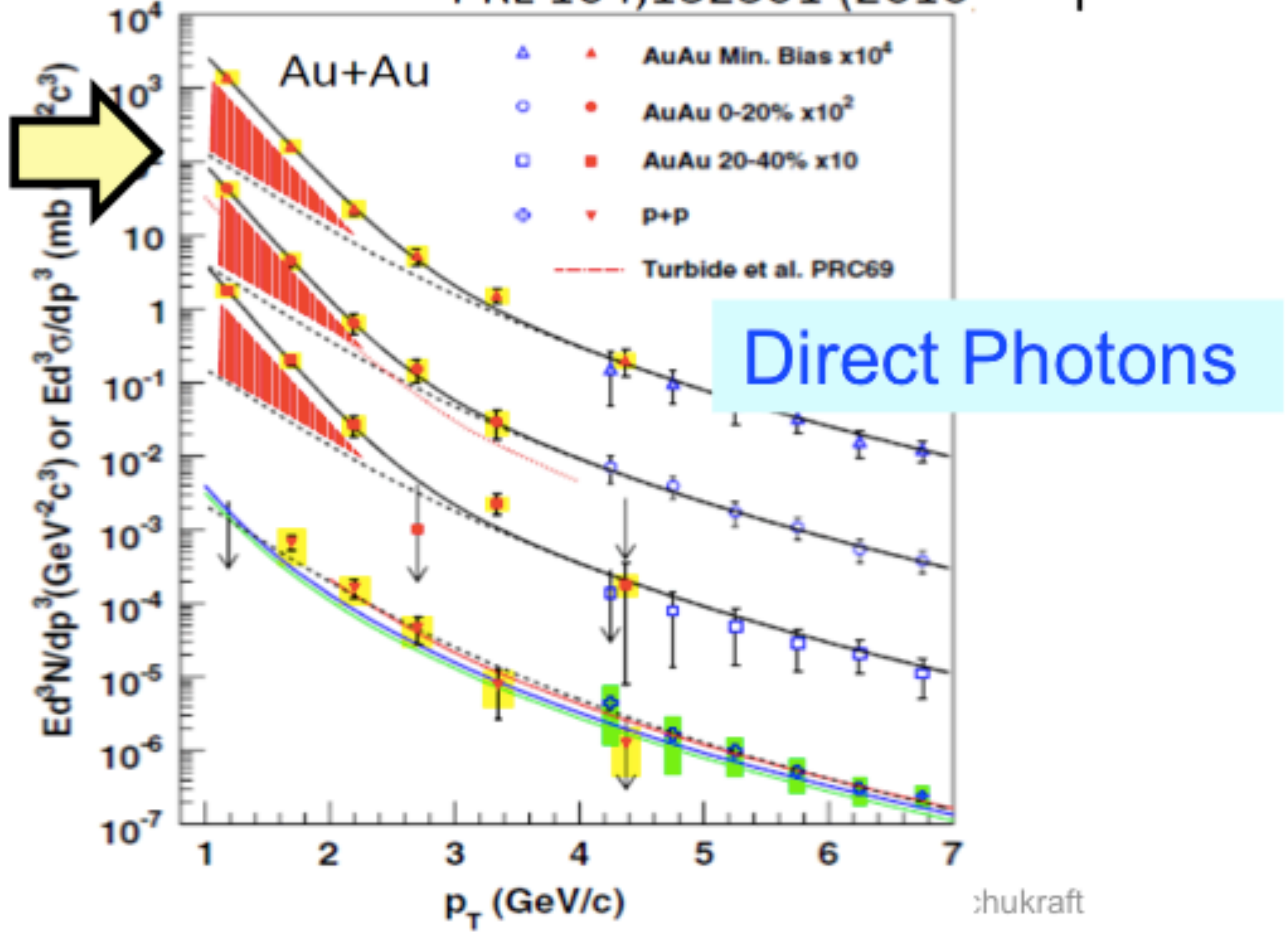
Elliptic flow strength



- high p_T suppression 'jet-quenching'
  - ⇨ very strongly interacting (large energy loss)



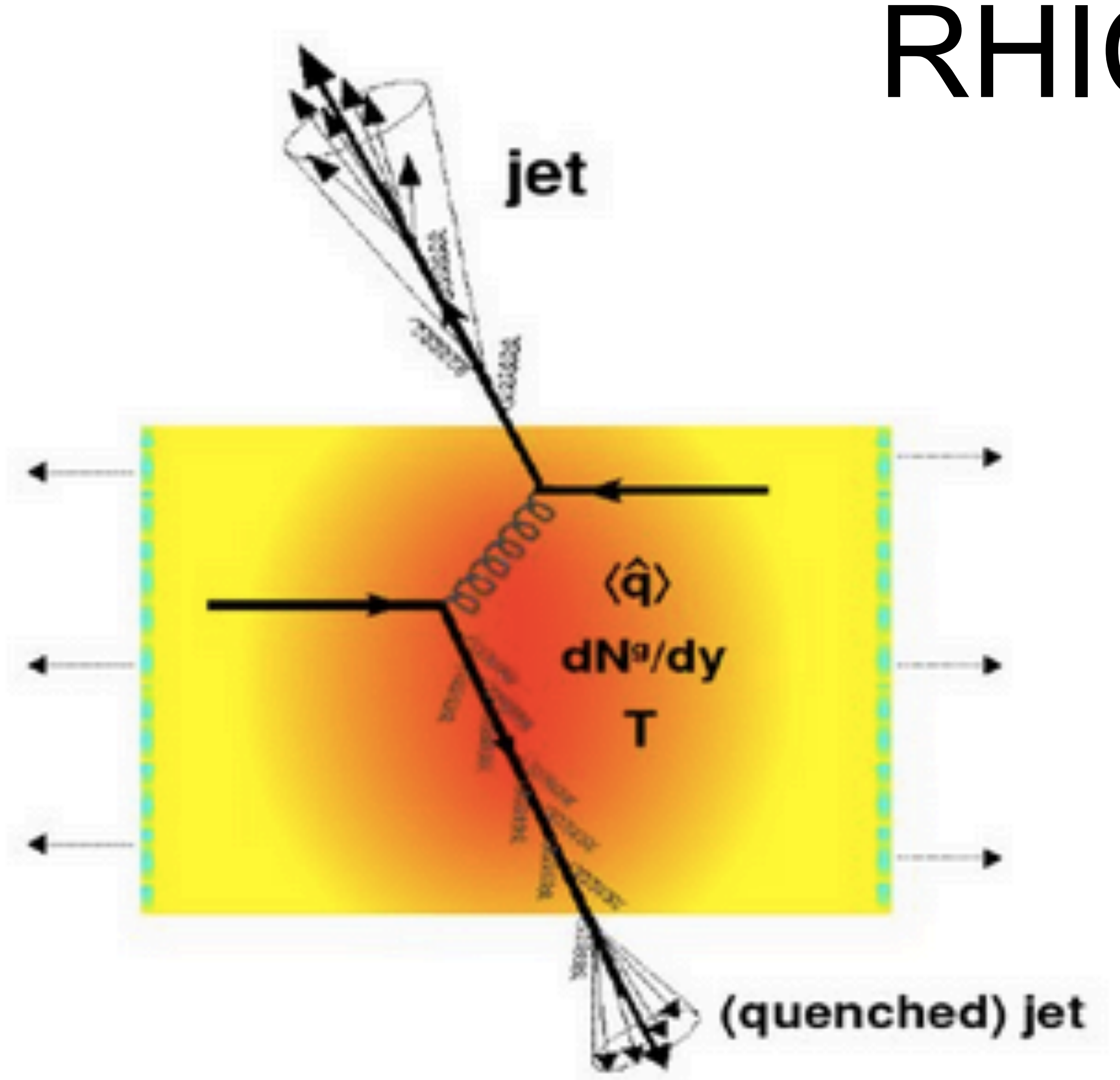
PRL 104,132301 (2010)



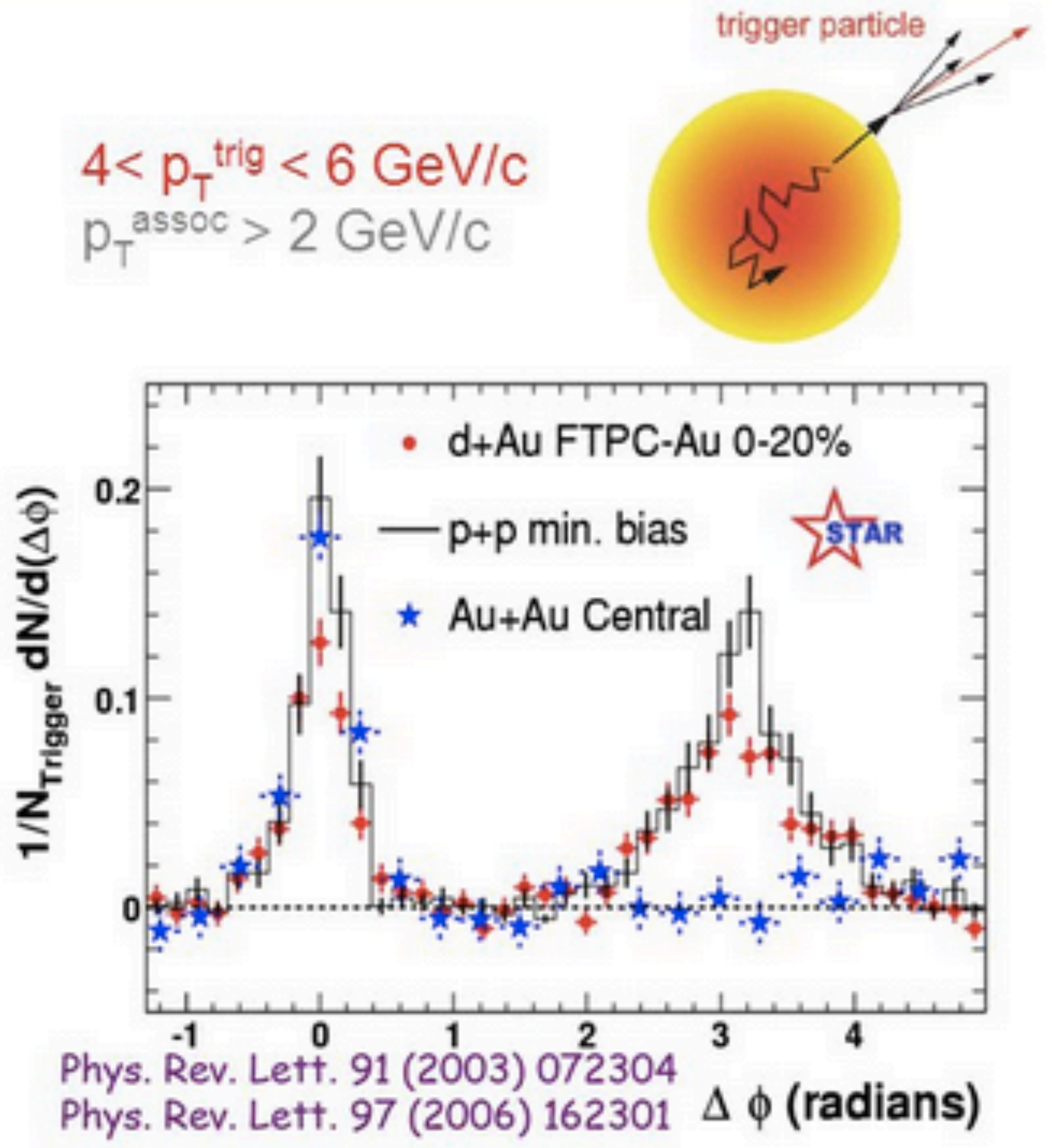
- direct 'thermal' photons => 'hot matter'
  - ⇨ data: inverse slope T ~ 220 ± 20 MeV
    model dependent T_0: 300 - 600 MeV

Introduction

RHIC

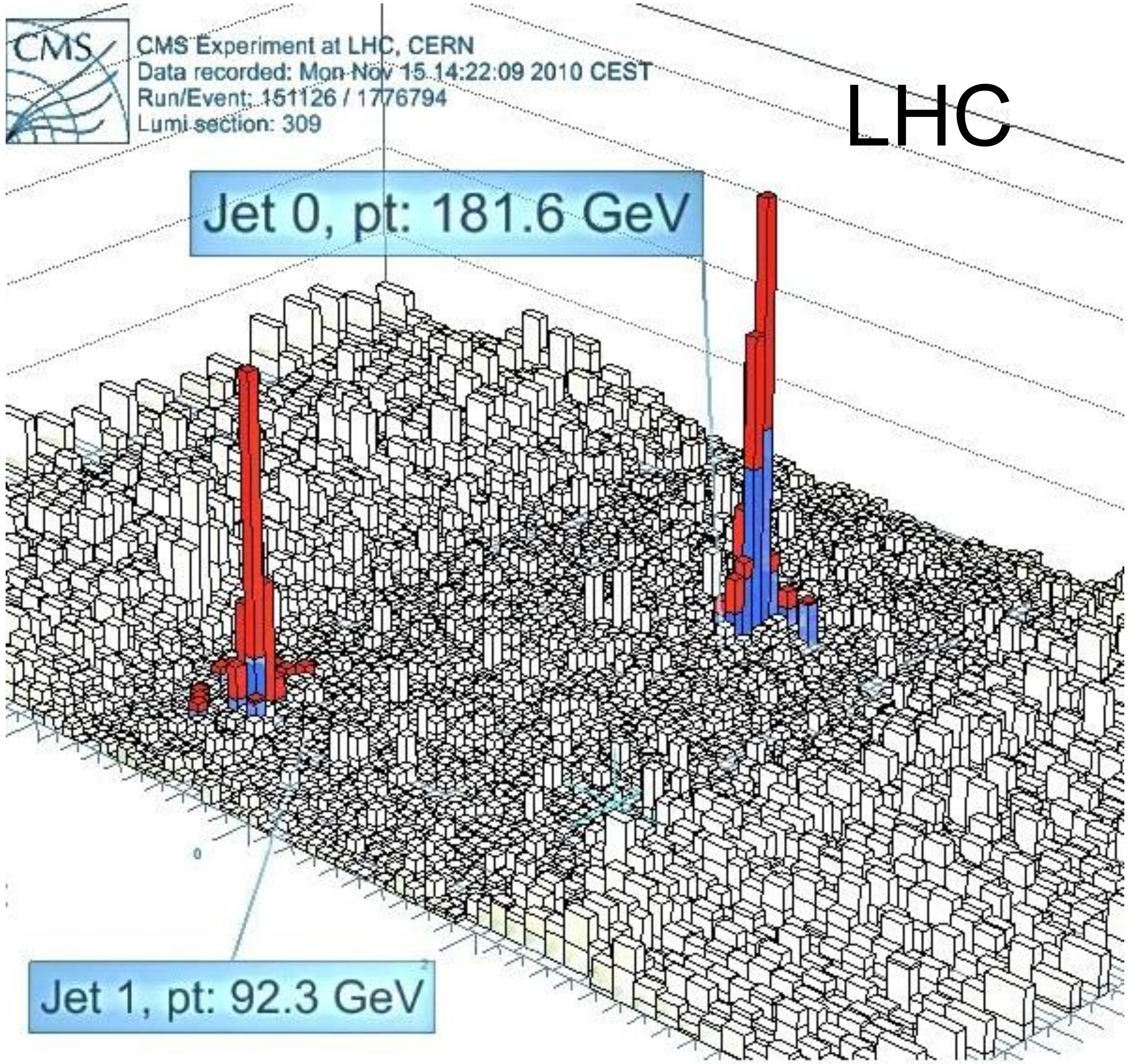


Jet-quenching (Bjorken, 1982)



Indication of jet quenching:
Suppression of high p_T particles

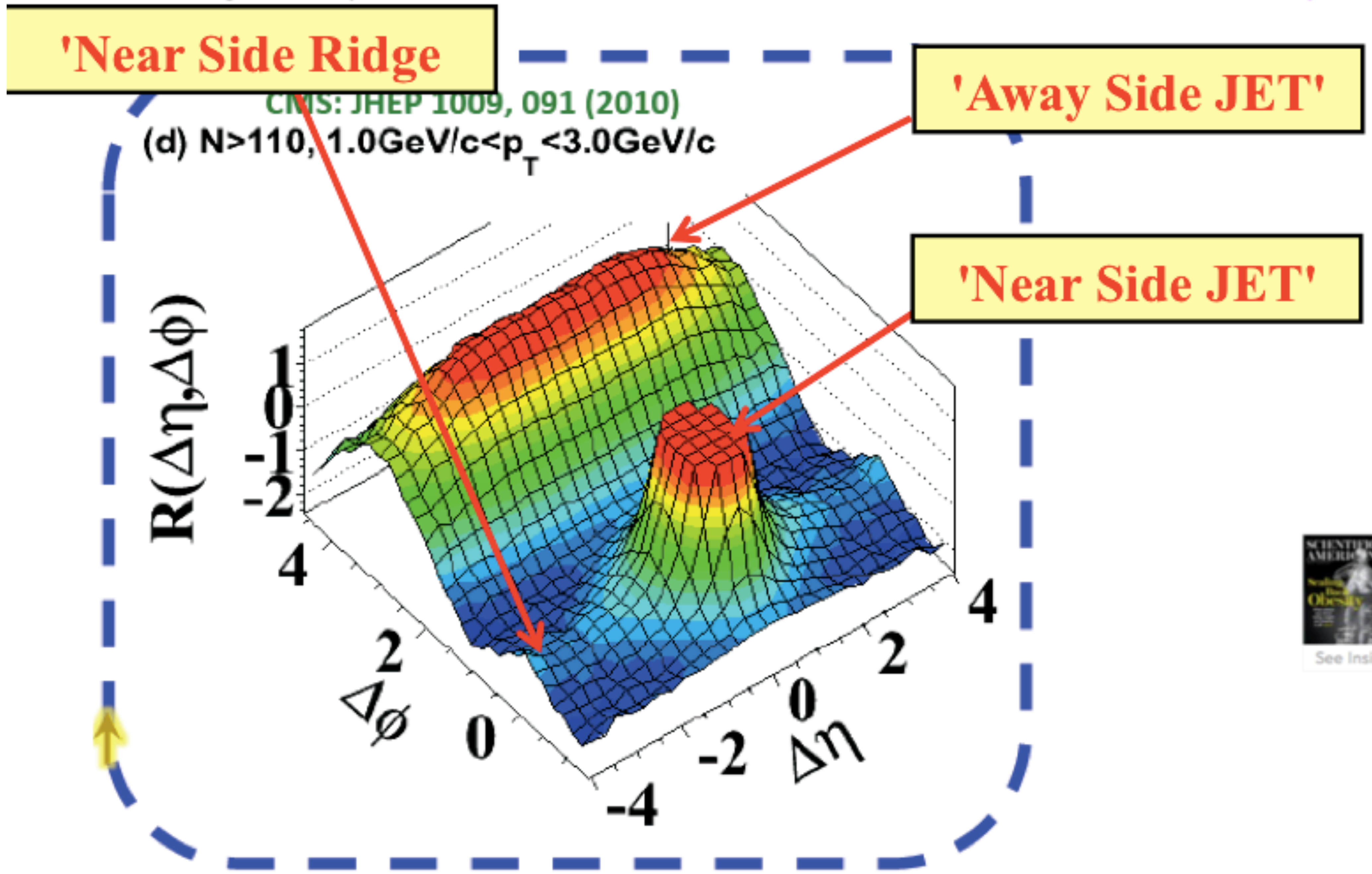
LHC



Introduction

Discovery

- The first LHC Discovery (pp, Sept 2010)
  - ⇨ long range rapidity 'ridge' in 2-particle correlations
    - visible in the highest multiplicity pp collisions
    - arguably still the most unexpected LHC discovery



Particles That Flock: Strange Synchronization Behavior at the Large Hadron Collider Scientific American, February (2011)

Scientists at the Large Hadron Collider are trying to solve a puzzle of their own making: why particles sometimes fly in sync

If we are here today it is because we didn't succeed to kill it.

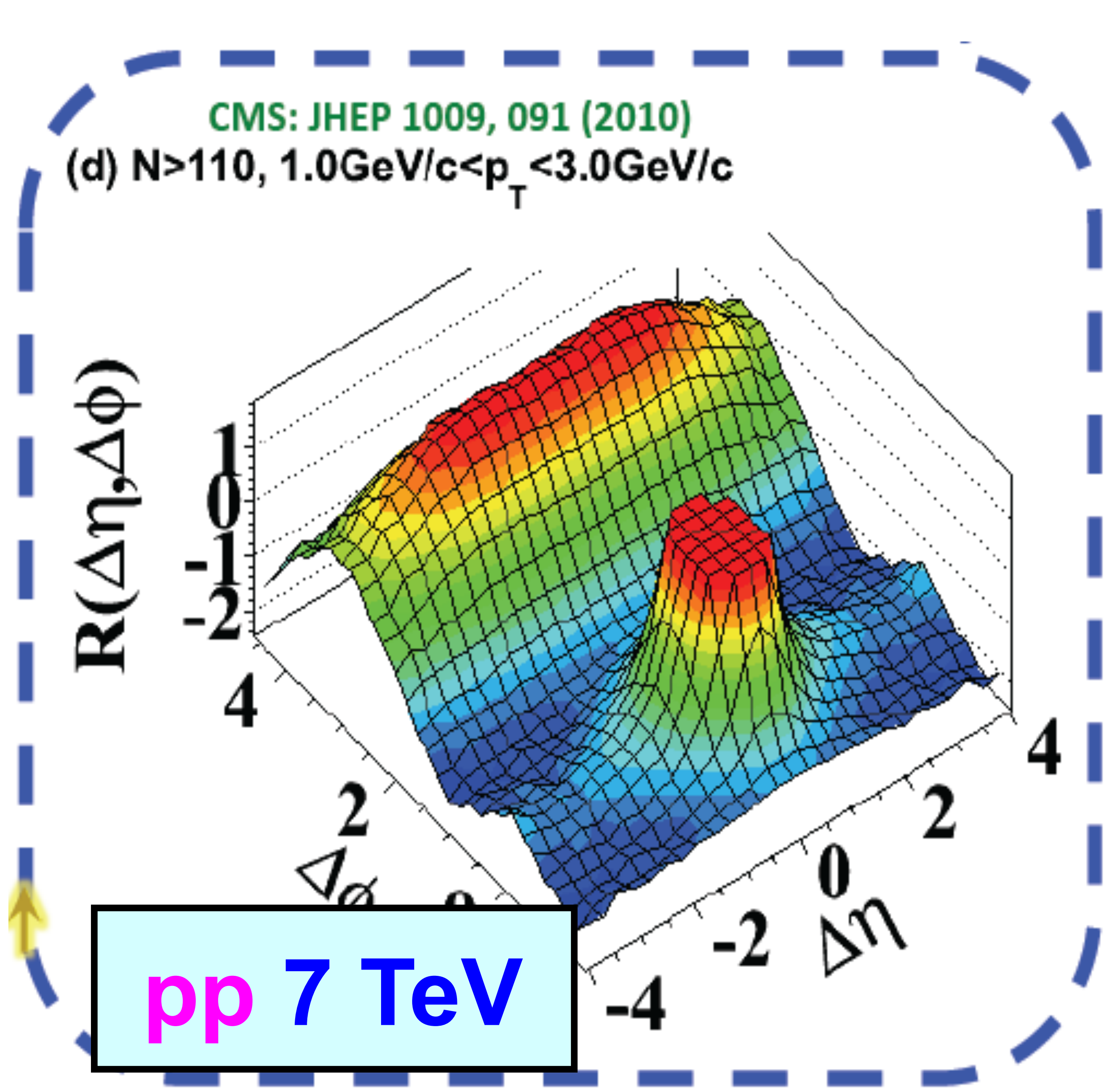
We have therefore submitted the paper to expose our findings to the scrutiny of the scientific community at large.

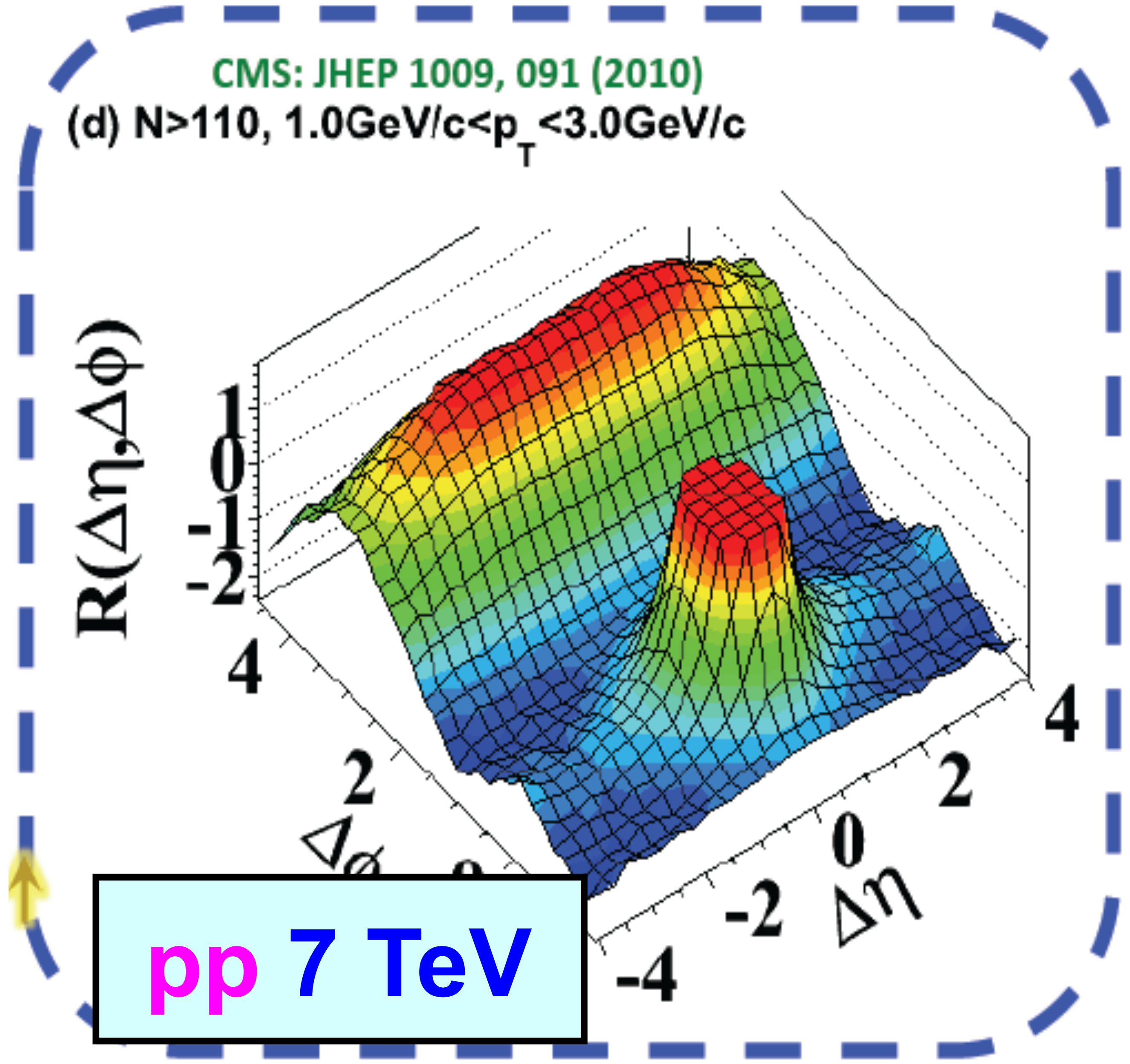
G. Tonelli, CERN/INFN/UNIPI CERN LPCC/EP/PP SEMINAR September, 21 2010

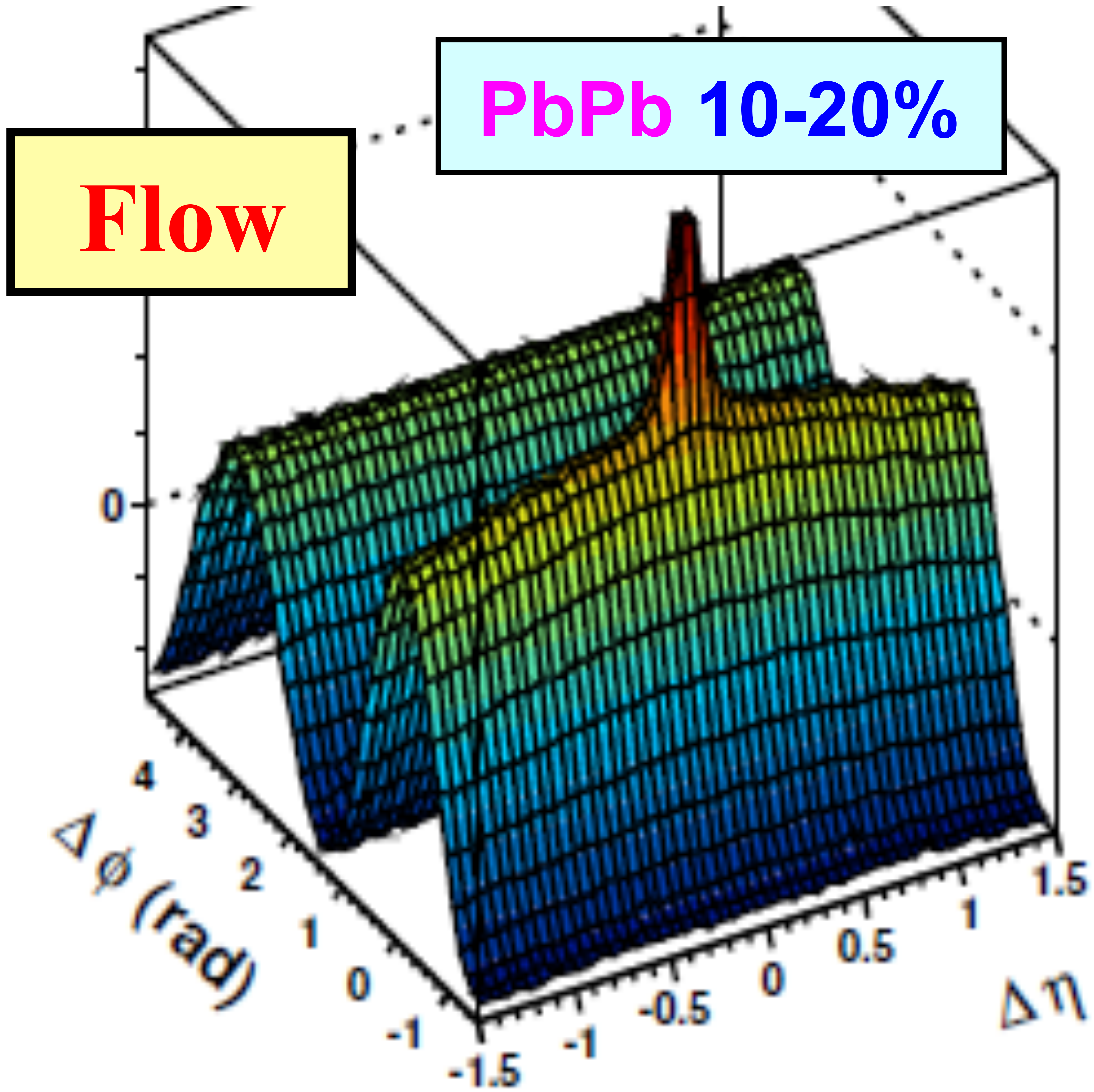
29

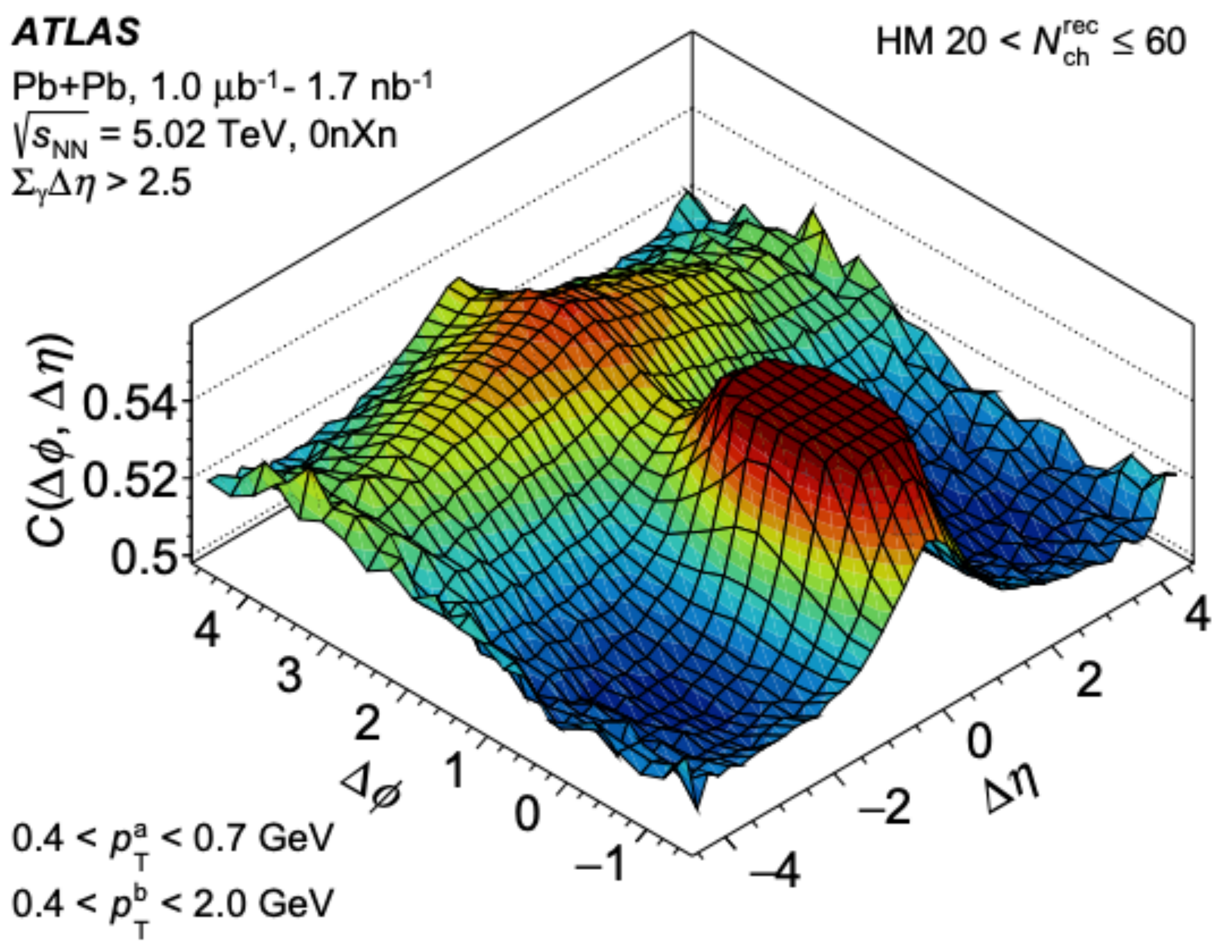
Dec. 2013 Kyoto J. Schukraft

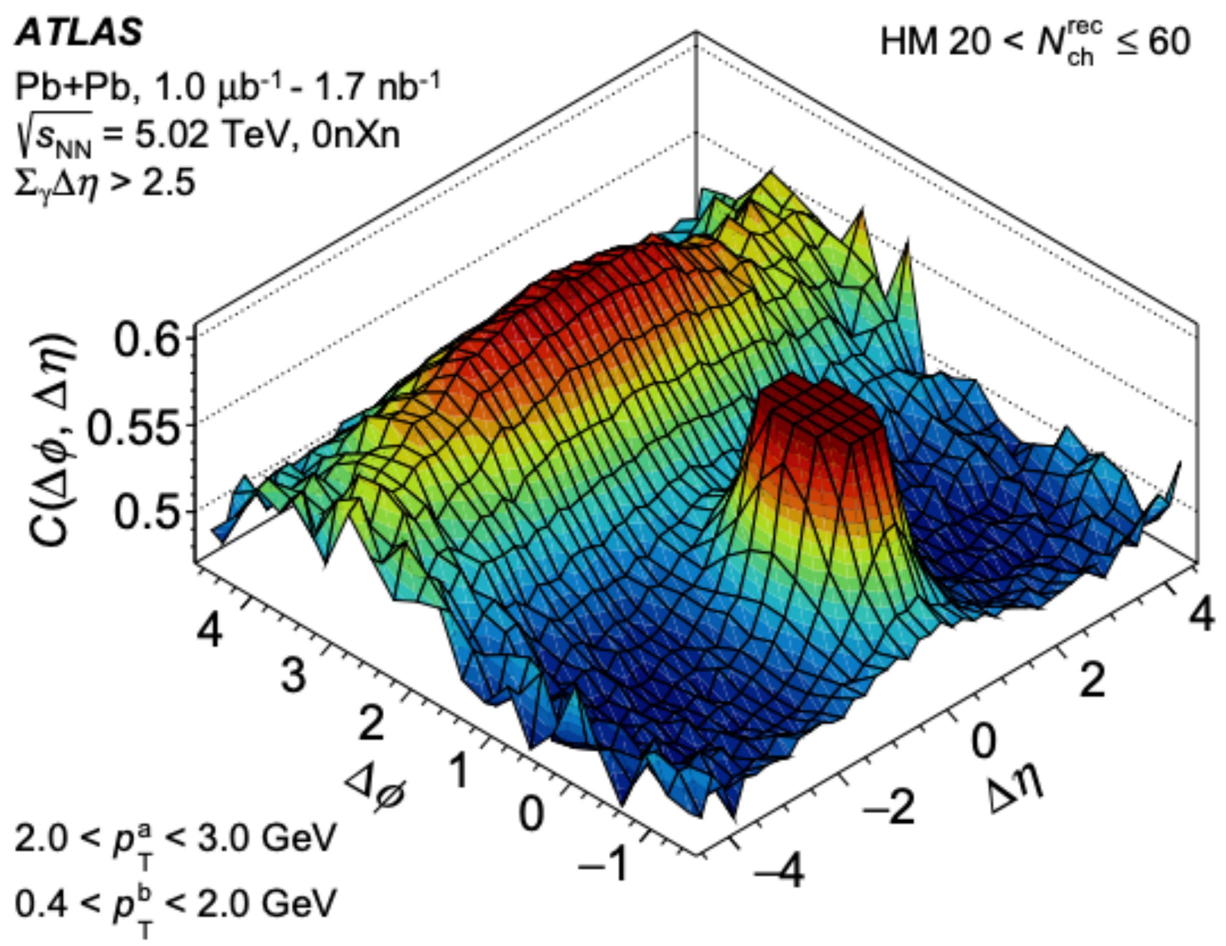
Introduction











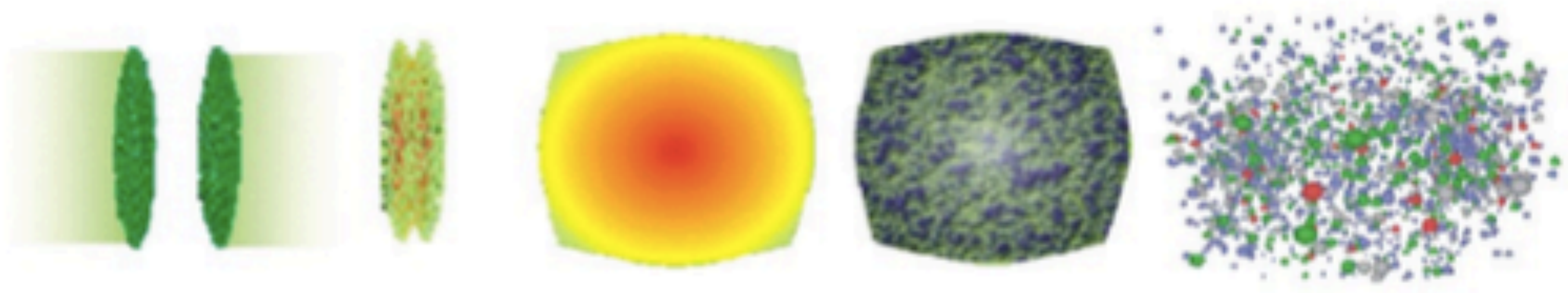
Pb+Pb 5.02 TeV (2021)

Introduction

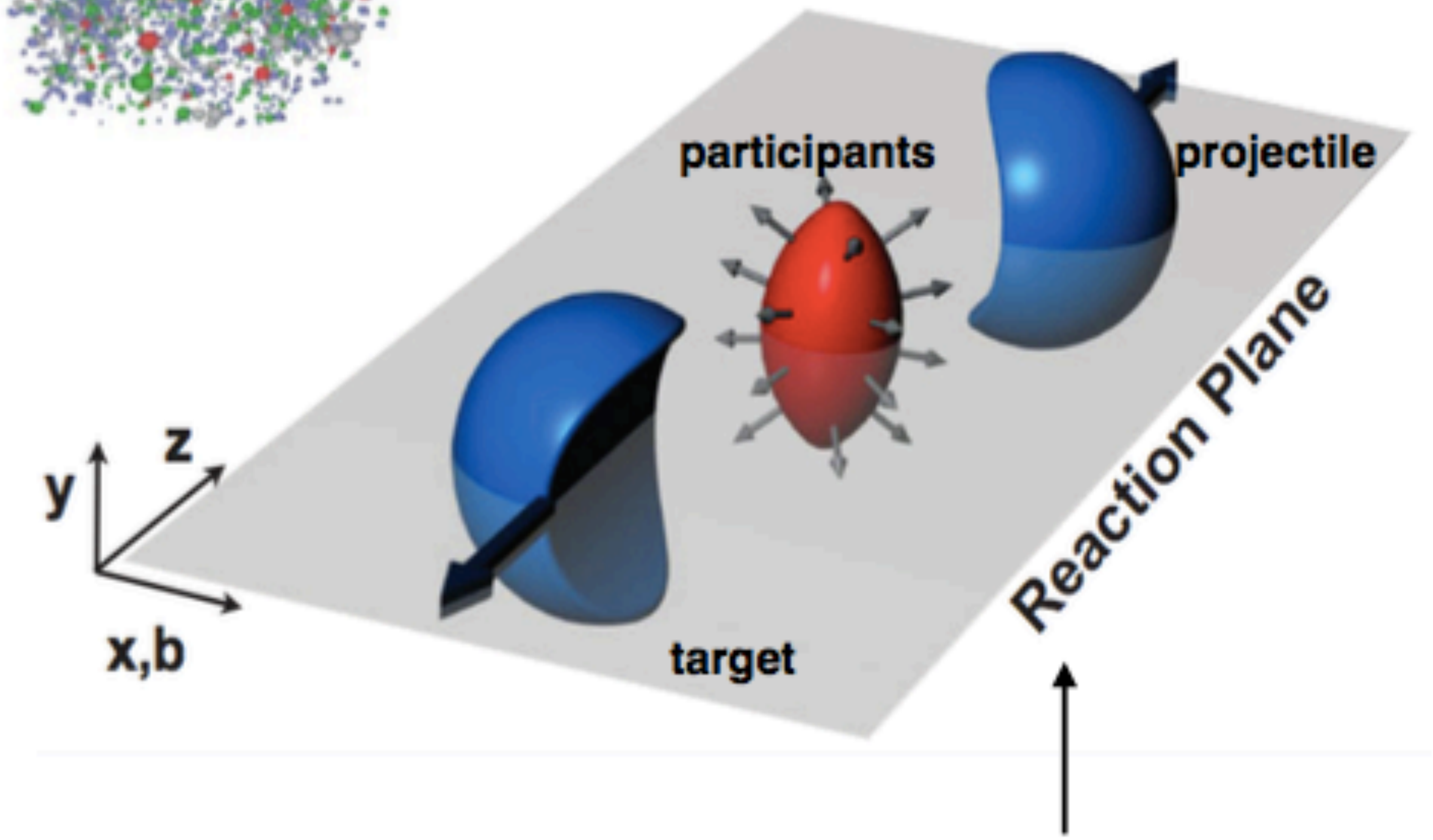
The azimuthal dependence for the particle yield can be written in the form of a Fourier series:

$$E\frac{d^3N}{d^3p}=\frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}\left(1+\sum_{n=1}^{\infty}2v_n\cos[n(\phi-\Psi_R)]\right)$$

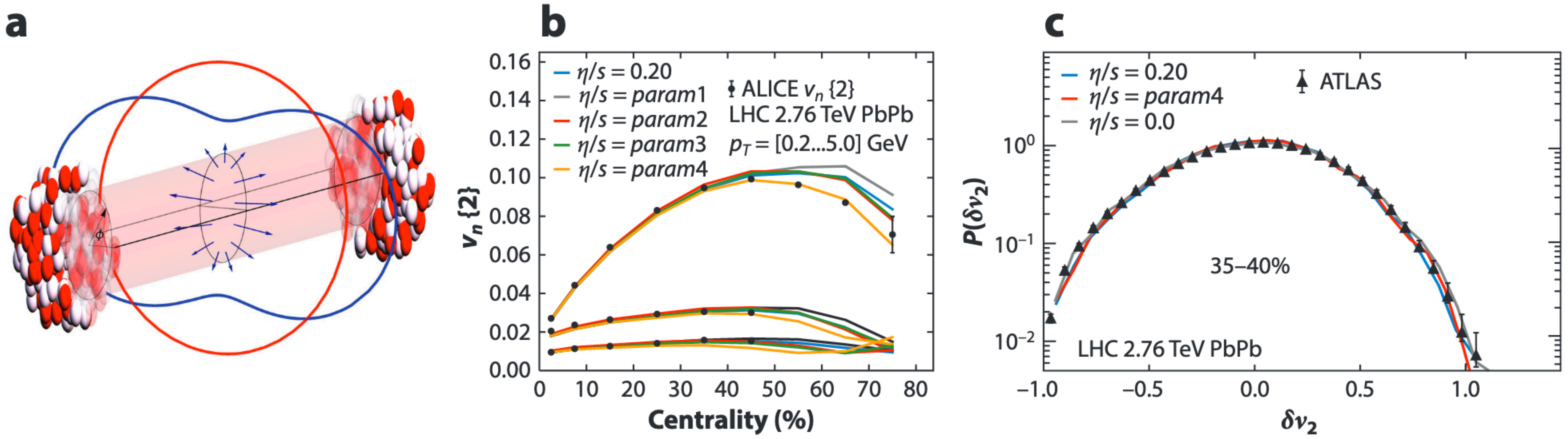
E: energy of the particle
p: momentum
p_t: transverse momentum
ϕ: azimuthal angle
ψ_R: reaction plane angle
v_n: differential flow (v_1, directed flow and v_2 elliptic flow)



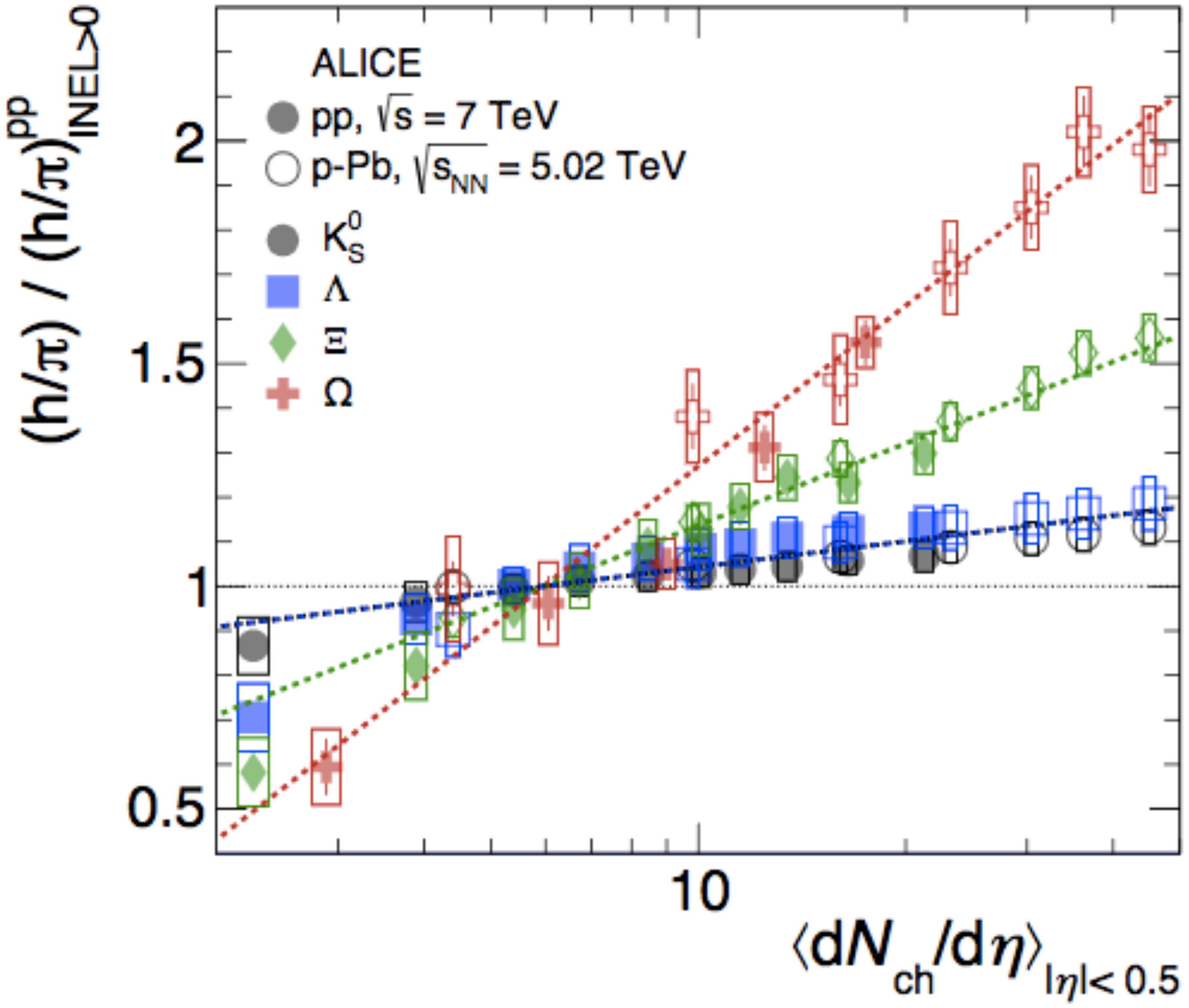
- Flow provides information on the equation state and the transport properties of matter created in a heavy-ion collision.
- Azimuthal anisotropy in particle production is the clearest experimental signature of collective flow.
- Elliptic flow depends on the ratio of shear viscosity to entropy ratio: η/s.
- Measurements of elliptic flow at RHIC revealed that hot and dense matter created in the collision there flows as a good fluid (almost no friction)



Introduction



Introduction

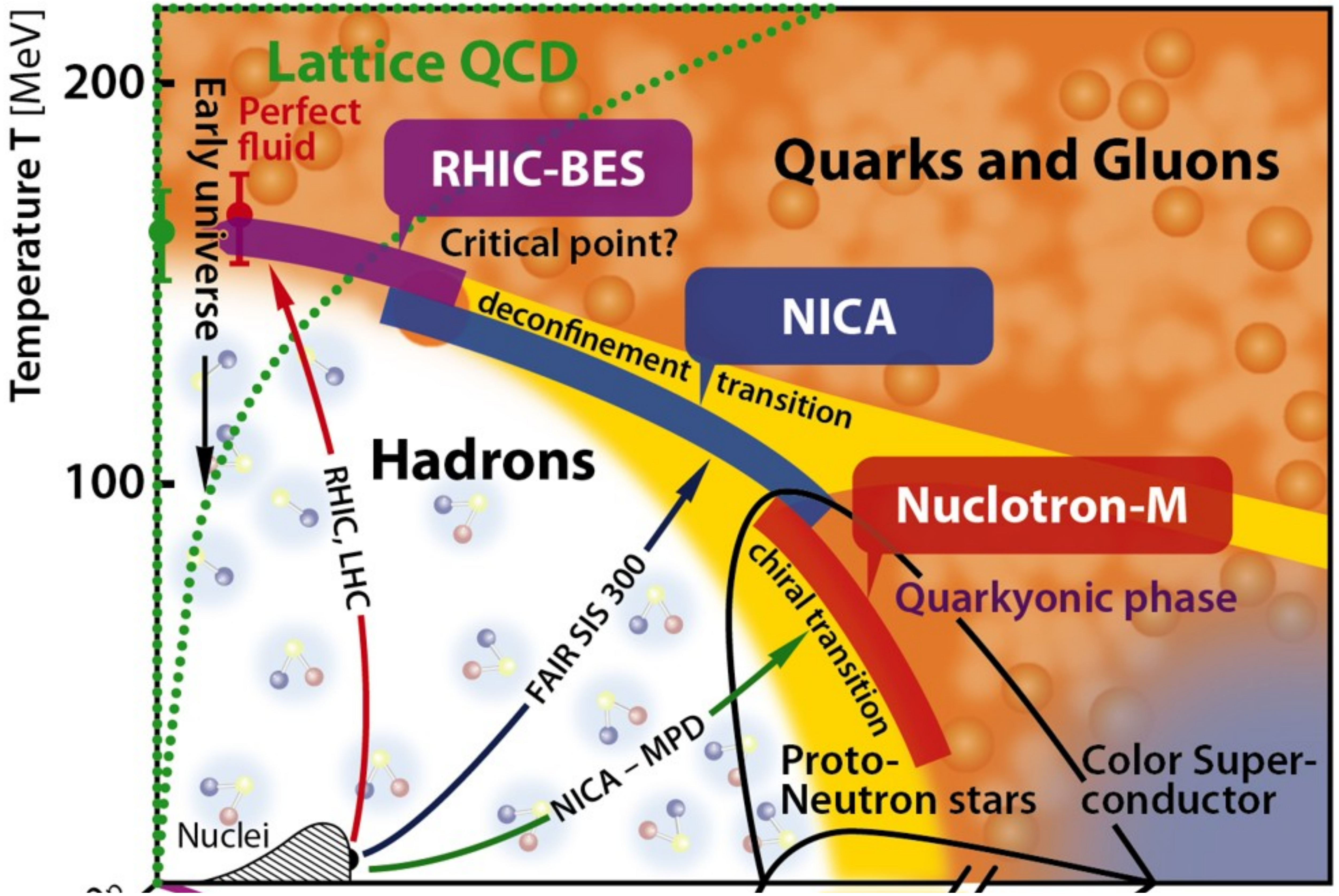


The pT spectra become harder as the multiplicity increases.
The mass and multiplicity dependences of the spectral shapes are reminiscent of the patterns seen in p–Pb and Pb-Pb collisions at the LHC, which can be understood assuming a collective expansion of the system in the final state.

The data show for the first time in pp collisions that the pT integrated yields of strange and multi-strange particles relative to pions increase significantly with multiplicity.
These particle ratios are similar to those found in p–Pb collisions at the same multiplicity densities.

Introduction

Heavy-ion physics allows us to study QCD matter under extreme conditions of high temperature and energy density.



Main NICA targets

- **study of hot and dense baryonic matter**
- **investigation of nucleon spin structure, polarization phenomena**

Energy range of NICA **—> unexplored region of the QCD phase diagram**

- **highest net baryon density**
- **onset of deconfinement phase transition**

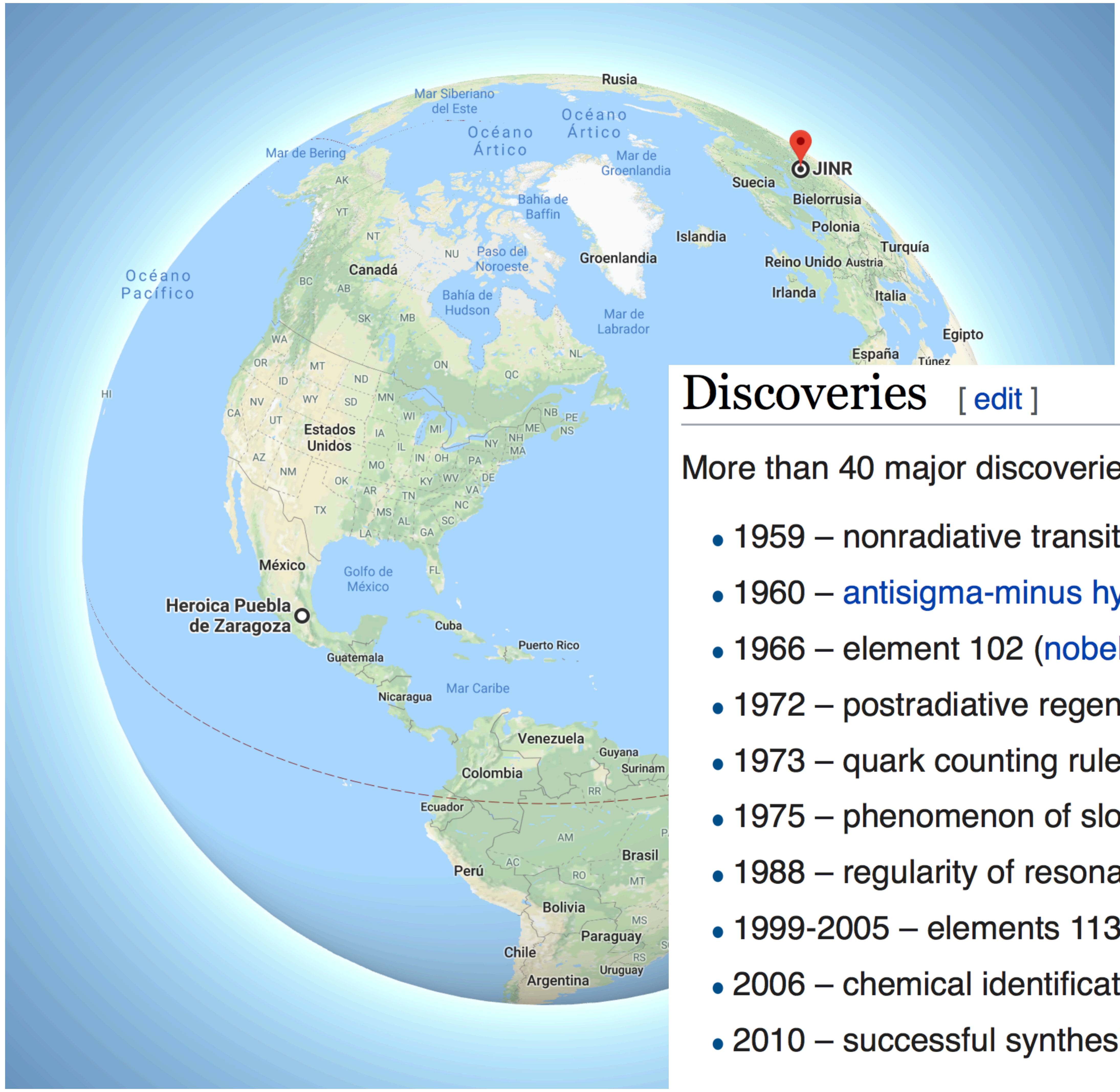
discovery potential

- **Critical End Point (CEP)**
- **Chiral symmetry restoration**
- **hypothetic quarkonic phase**

complementary to

- **RHIC/BES, NA61/CERN, CBM/FAIR and Nuclotron-M experimental programs**

MPD-NICA experiment at JINR



Founded in 1956 (2 years after CERN foundation)

Discoveries [edit]

More than 40 major discoveries have been made.

- 1959 – nonradiative transitions in mesoatoms
- 1960 – antisigma-minus hyperon
- 1966 – element 102 (nobelium)
- 1972 – postradiative regeneration of cells
- 1973 – quark counting rule
- 1975 – phenomenon of slow neutron confinement
- 1988 – regularity of resonant formation of muonic molecules in deuterium
- 1999-2005 – elements 113 (nihonium), 114 (flerovium), 115 (moscovium), 116 (livermorium), and 118 (oganesson)
- 2006 – chemical identification of element 112 (copernicium)
- 2010 – successful synthesis of element 117 (tennessine)[5]

MPD-NICA experiment at JINR

MPD-NICA experiment at JINR

NICA (Nuclotron based Ion Colider fAcility)

Main targets:

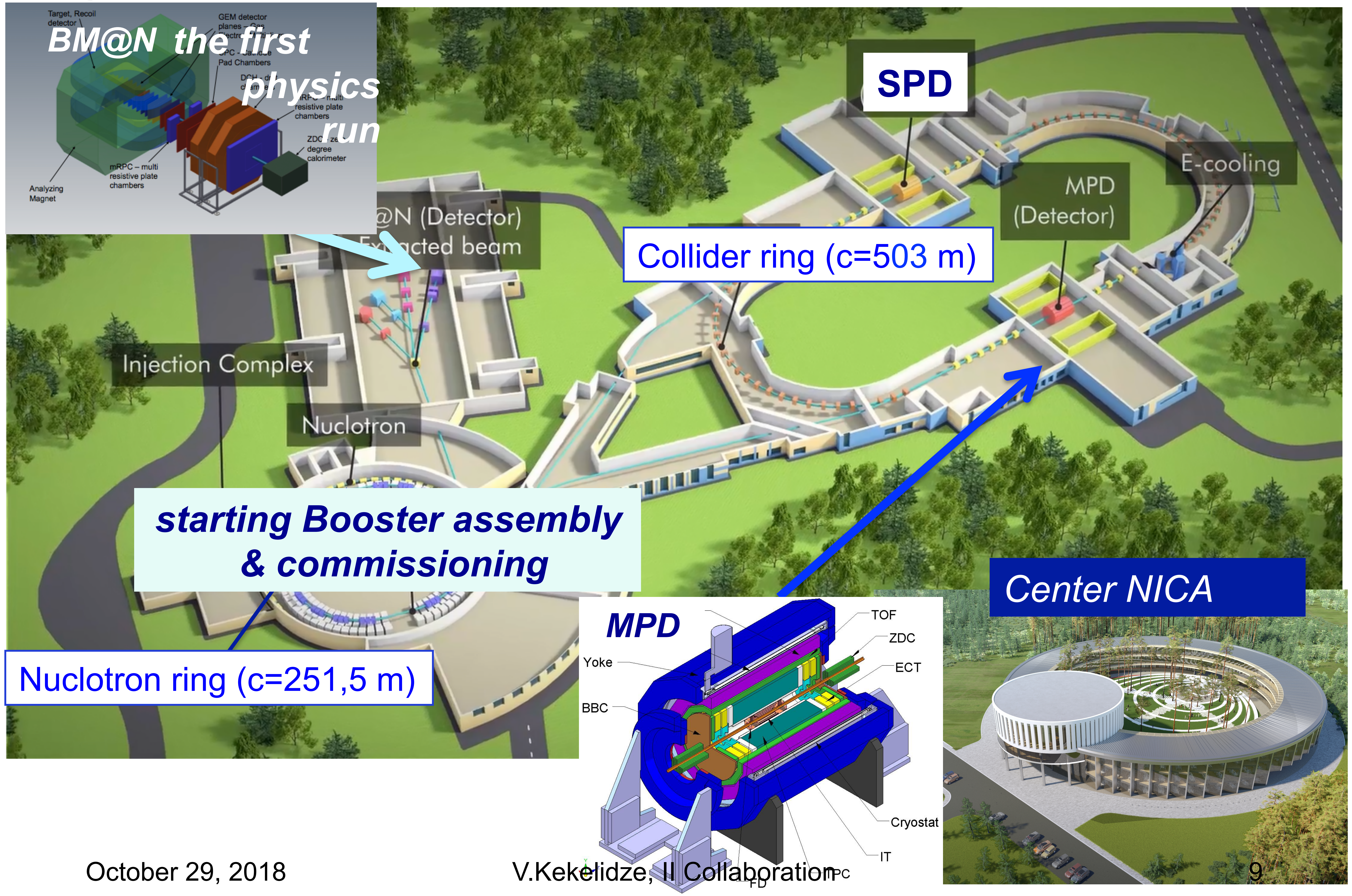
- *study of hot and dense baryonic matter at the energy range of max net baryonic density*
- *investigation of nucleon spin structure, polarization phenomena*

- *modernization of existing accelerator facility*
- *construction of **Collider** to collide*
  - *relativistic ions from **p** to **Au** at energy range $\sqrt{S_{NN}}$= **4** - **11** GeV*
  - *polarized **p** and **d** at energy up to $\sqrt{S}$ =**27** GeV (p)*

MPD-NICA experiment at JINR

NICA **basic facility**

2 major milestones in 2018



October 29, 2018 V.Kekelidze, II Collaboration 9

MPD-NICA experiment at JINR

NICA

Nuclotron-based
Ion Collider fAcility

NICA (Nuclotron-based Ion Collider fAcility) is a new accelerator complex designed at the Joint Institute for Nuclear Research (Dubna, Russia) to study properties of dense baryonic matter.

After puting the NICA collider into operation JINR scientists will be able to create in the Laboratory a special state of matter in which our Universe stayed shortly after the Big Bang – the Quark-Gluon Plasma (QGP).

Start of the construction: 2013.
Commissioning: 2020.

MPD-NICA experiment at JINR

BUAP

NICA

Nuclotron-based
Ion Collider fAcility

NICA (Nuclotron-based Ion Collider fAcility) is a new accelerator complex designed at the Joint Institute for Nuclear Research (Dubna, Russia) to study properties of dense baryonic matter.

After puting the NICA collider into operation JINR scientists will be able to create in the Laboratory a special state of matter in which our Universe stayed shortly after the Big Bang – the Quark-Gluon Plasma (QGP).

Start of the construction: 2013.
NICA will provide beams of ions over a wide range of atomic masses (from p to Au) at average luminosity of 10^{27} $cm^{-2}s^{-1}$ for gold-gold collisions and 10^{32} $cm^{-2}s^{-1}$ for proton-proton collisions. The center-of-mass energy will be between 4 to 11 GeV for Au+Au and up to 27 GeV for p+p.

Experimental data on hadron production properties at SPS suggest that this transition occurs within the NICA energy range.

Theoretical calculations indicate that the deconfinement phase transition can be accomplished by partial restoration of the chiral symmetry in heavy-ion collisions leading to possible modifications of hadronic spectral functions in dense hadronic matter.

MPD-NICA experiment at JINR

NICA

Nuclotron-based
Ion Collider fAcility

After the collision of two heavy-ion nuclei,

- the matter behaves as a thermalized system
- the hot fireballs cools down —> particle production tracing a trajectory on phase diagram (maybe close to the critical point)
- key study —> event by event fluctuations of physical observables of particles in its final state.

MPD-NICA experiment at JINR

BUAP

NICA

Nuclotron-based
Ion Collider fAcility

- event-by-event fluctuation in hadron productions (multiplicity, Pt etc.);
- femtoscopic correlation;
- directed and elliptic flows for various hadrons;
- multi-strange hyperon production (including hypernuclei): yield and spectra (the probes of nuclear media phases);
- photon and electron probes
- charge asymmetry

Where would this happen ?

MPD-NICA experiment at JINR

BUAP

NICA

Nuclotron-based
Ion Collider fAcility

MPD-NICA experiment at JINR

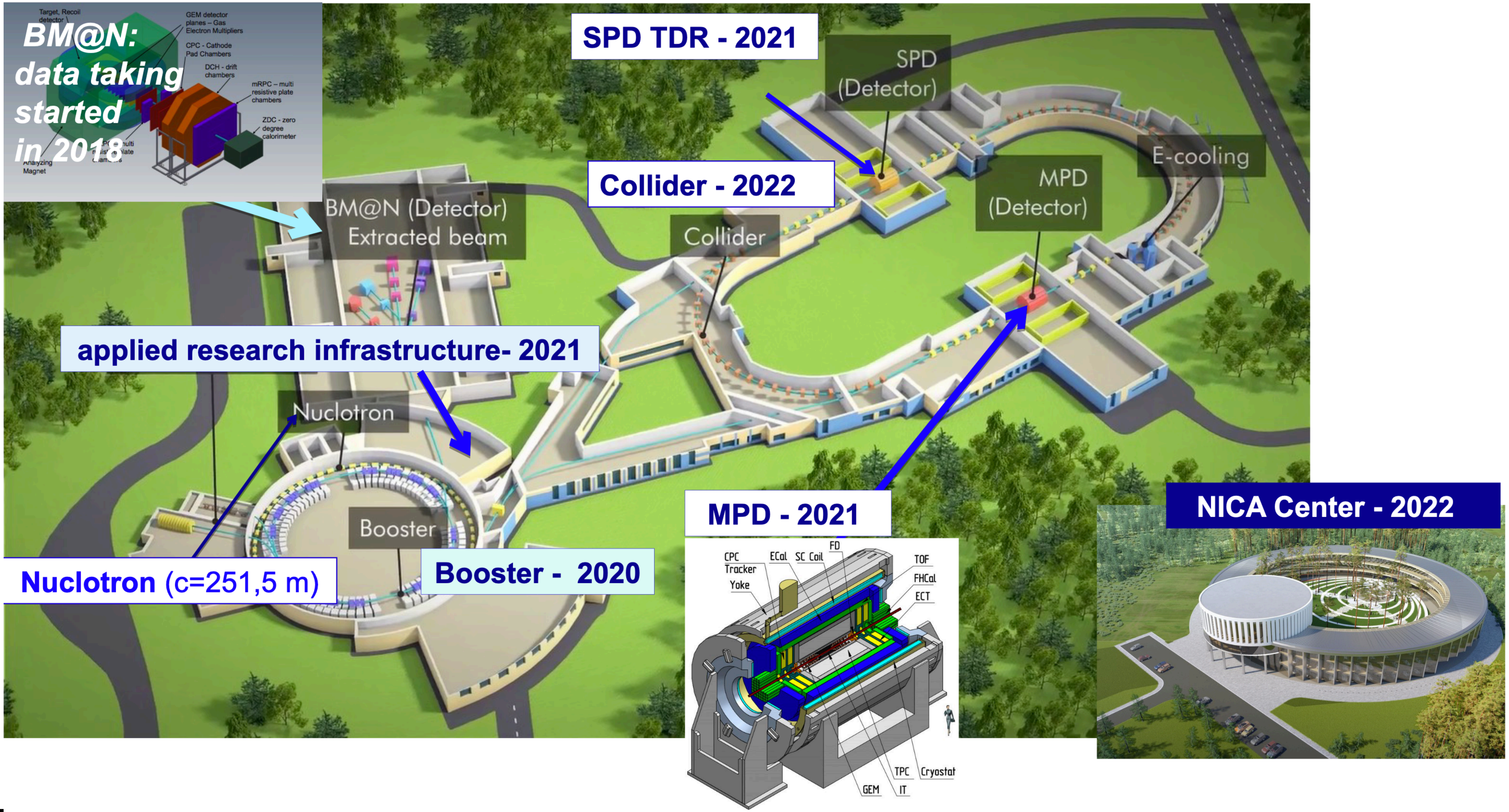
BUAP

NICA

Nuclotron-based
Ion Collider fAcility

MPD-NICA experiment at JINR

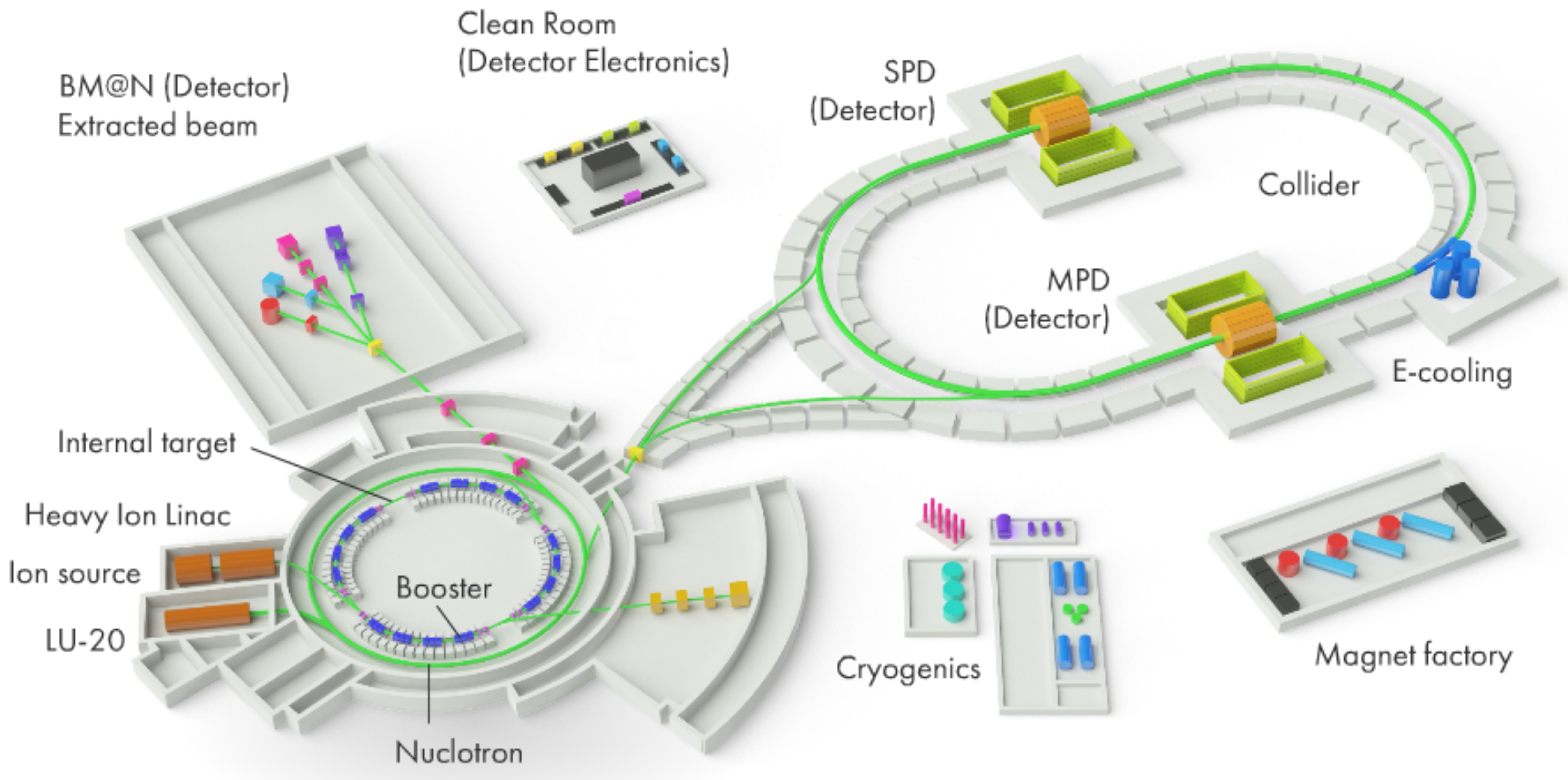
NICA Accelerator Complex in Dubna



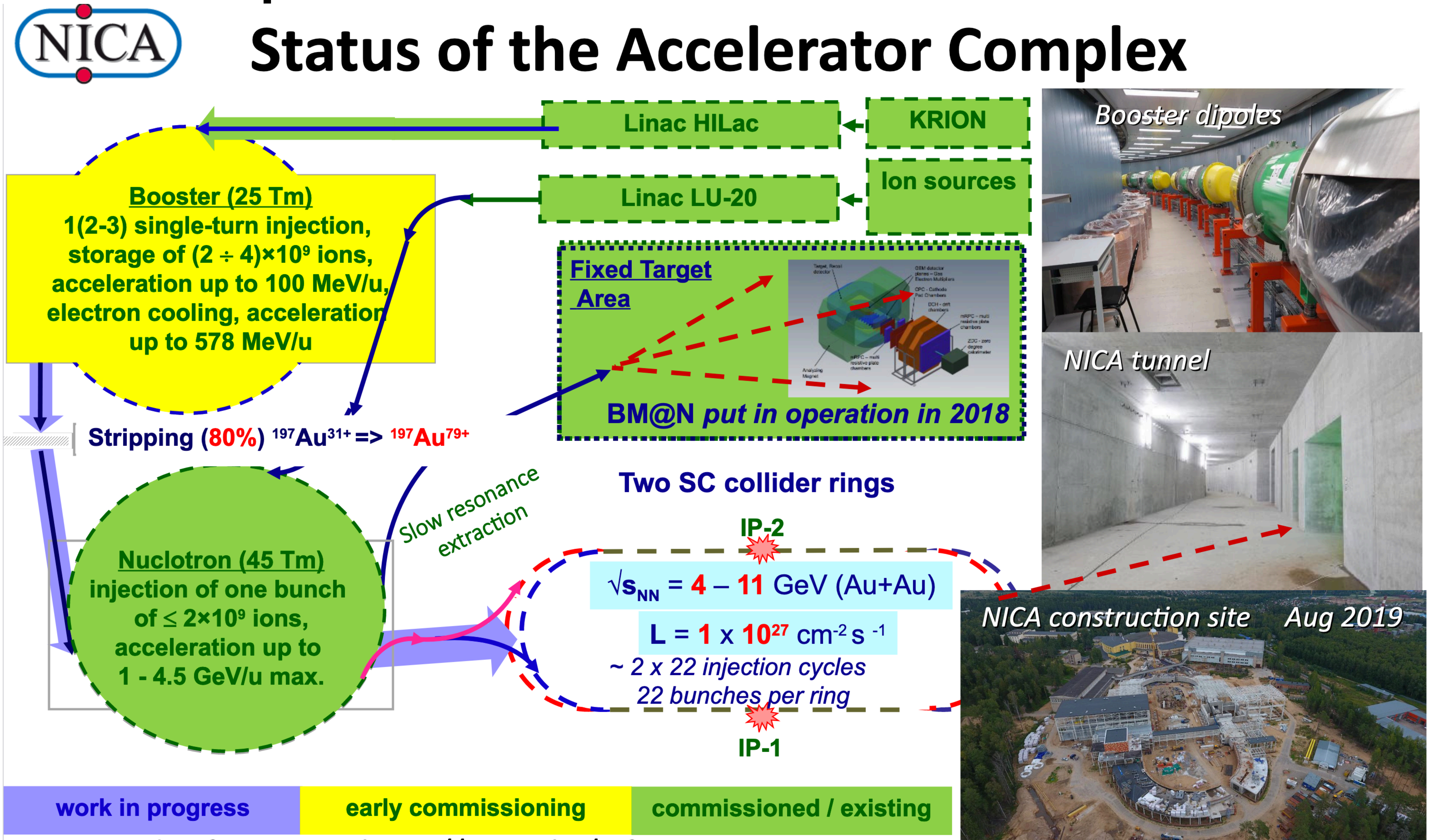
MPD-NICA experiment at JINR

NICA

Nuclotron-based
Ion Collider fAcility



MPD-NICA experiment at JINR



Recent video from NICA: https://youtu.be/mfOLT9XZOj0

MPD-NICA experiment at JINR

MPD Civil Construction status

- MPD Hall ready for limited scope of equipment installation, remaining works still ongoing

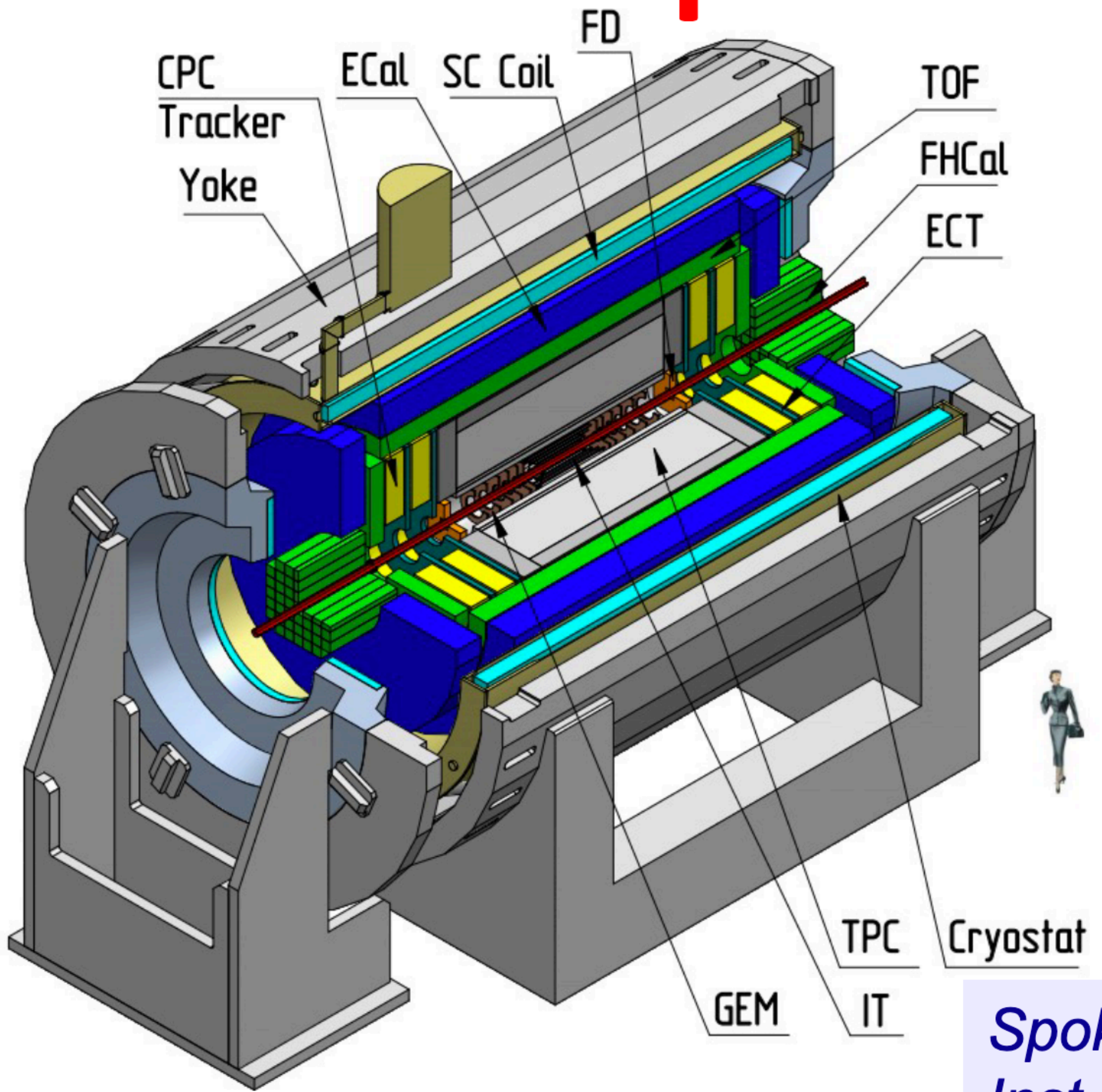
MPD Hall crane weight test

Exterior of the MPD Hall Building and high voltage connection housing

Epoxy floor finish ready in the MPD Hall

MPD-NICA experiment at JINR

Multi-Purpose Detector (MPD) Collaboration



***11** Countries, **>500** participants,*
39** Institutes and **JINR

NICA

*Spokesperson: **Adam Kisiel***
*Inst. Board Chair: **Fuqiang Wang***
*Project Manager: **Slava Golovatyuk***

Deputy Spokespersons:
Victor Riabov, Zebo Tang

*AANL, Yerevan, **Armenia;***
*Baku State University, NNRC, **Azerbaijan**;*
*University of Plovdiv, **Bulgaria;***
*University Tecnica Federico Santa Maria, Valparaiso, **Chile**;*
*Tsinghua University, Beijing, **China**;*
*USTC, Hefei, **China**;*
*Huzhou University, Huizhou, **China**;*
*Institute of Nuclear and Applied Physics, CAS, Shanghai, **China**;*
*Central China Normal University, **China**;*
*Shandong University, Shandong, **China**;*

*IHEP, Beijing, **China**;*
*University of South China, **China**;*
*Three Gorges University, **China**;*
*Institute of Modern Physics of CAS, Lanzhou, **China**;*
*Palacky University, Olomouc, **Czech Republic**;*
*NPI CAS, Rez, **Czech Republic**;*
*Tbilisi State University, Tbilisi, **Georgia**;*

MexNICA
***Joint Institute for Nuclear Research**;*
*FCFM-BUAP (Mario Rodriguez) Puebla, **Mexico**;*
*FC-UCOL (Maria Elena Tejeda), Colima, **Mexico**;*
*FCFM-UAS (Isabel Dominguez), Culiacán, **Mexico**;*
*ICN-UNAM (Alejandro Ayala), Mexico City, **Mexico**;*
*CINVESTAV (Luis Manuel Montaño), Mexico City, **Mexico**;*

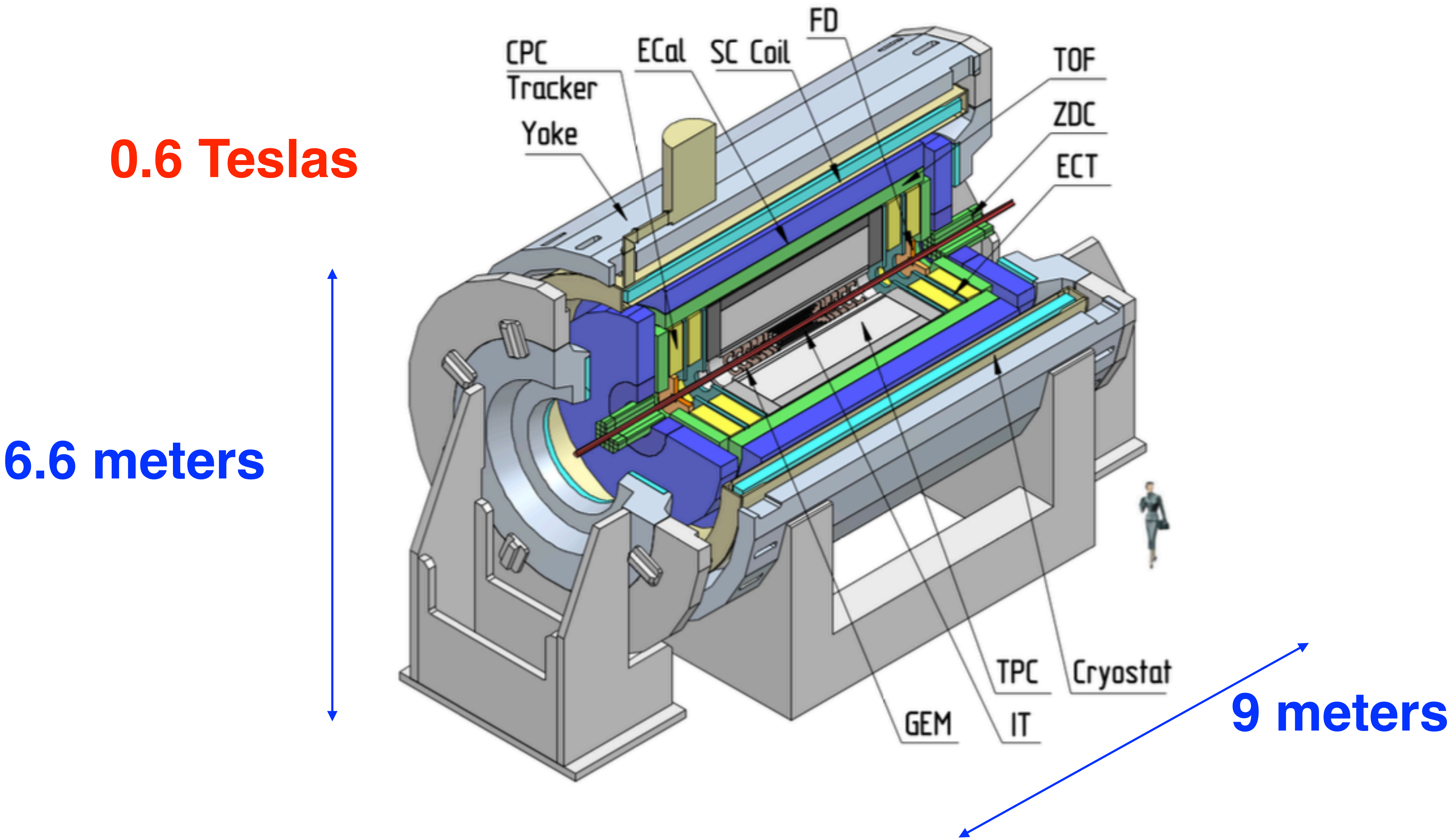
*Institute of Applied Physics, Chisinev, **Moldova**;*

NICA-PL
*WUT, Warsaw, **Poland**;*
*NCNR, Otwock – Świerk, **Poland**;*
*University of Wrocław, **Poland**;*
*University of Silesia, **Poland**;*
*University of Warsaw, **Poland**;*
*Jan Kochanowski University, Kielce, **Poland**;*

*Belgorod National Research University, **Russia**;*
*INR RAS, Moscow, **Russia**;*
*MEPhI, Moscow, **Russia**;*
*Moscow Institute of Science and Technology, **Russia**;*
*North Osetian State University, **Russia**;*
*NRC Kurchatov Institute, ITEP, **Russia**;*
*Kurchatov Institute, Moscow, **Russia**;*
*St. Petersburg State University, **Russia**;*
*SINP, Moscow, **Russia**;*
*PNPI, Gatchina, **Russia**;*

MPD-NICA experiment at JINR

MPD: **M**ulti-**P**urpose **D**etector (typically cylindrical particle detector)



MPD-NICA experiment at JINR

Stage 1 (Mid-rapidity region, TPC, TOF, ECAL, ZDC, FD)

- Particle yields and spectra (pions, Kaons, protons, etc)
- Event-by-event fluctuations
- Femtoscopy involving pions, Kaons and protons
- Collective flow for identified hadrons
- Electromagnetic probes (electrons, gammas)

MPD-NICA experiment at JINR

Stage 2 (Mid-rapidity region, TPC, TOF, ECAL, ZDC, FD + ITS)

- Total particles multiplicities
- Asymmetries study (better reaction plane determination)
- Di-lepton precise study
- Charm
- Exotic (soft photons, hypernuclei)

MexNICA proposal

MEXnICA

Mexican group joining to the MPD-NICA efforts at JINR.

List of participants institutions

- BUAP (Facultad de Ciencias Físico Matemáticas)
- CINVESTAV (Departamento de Física)
- UAS
- UNISON
- UCol
- UNAM (Instituto de Ciencias Nucleares)

MexNICA proposal

Main goal:

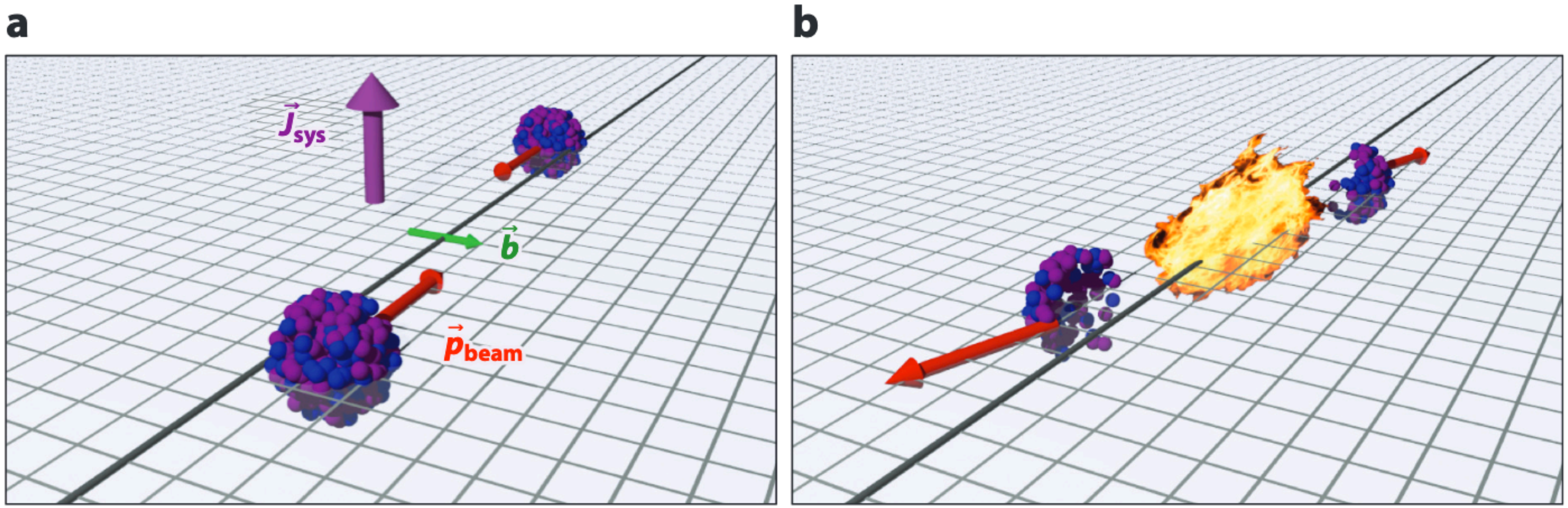
To contribute in the study of the QGP phase diagram (CEP)

How?

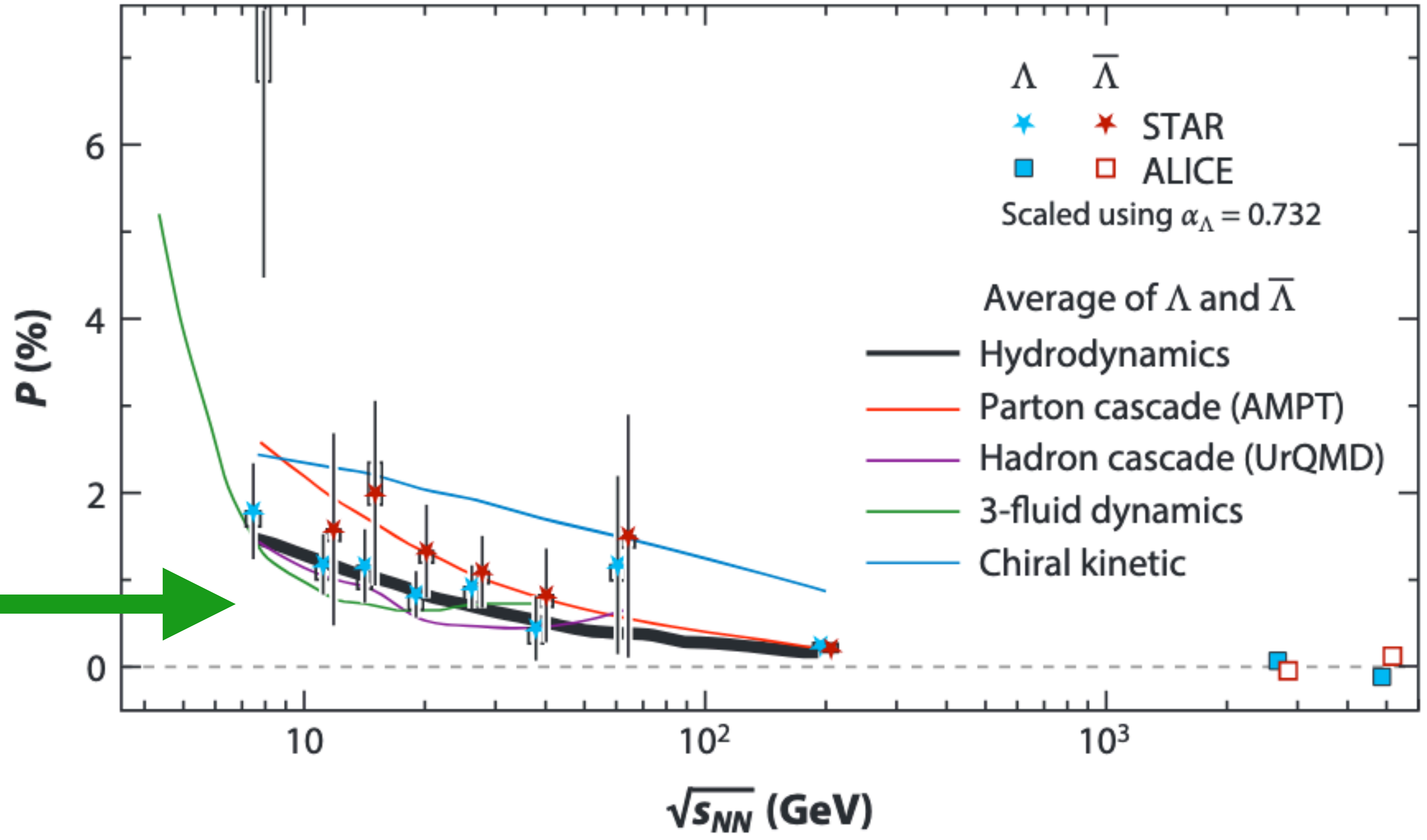
To study, from theoretical point of view, the mechanism responsible for the restoration of chiral symmetry.

To study, from theoretical point of view, the QCD phase diagram at finite values of temperature and density.

MexI

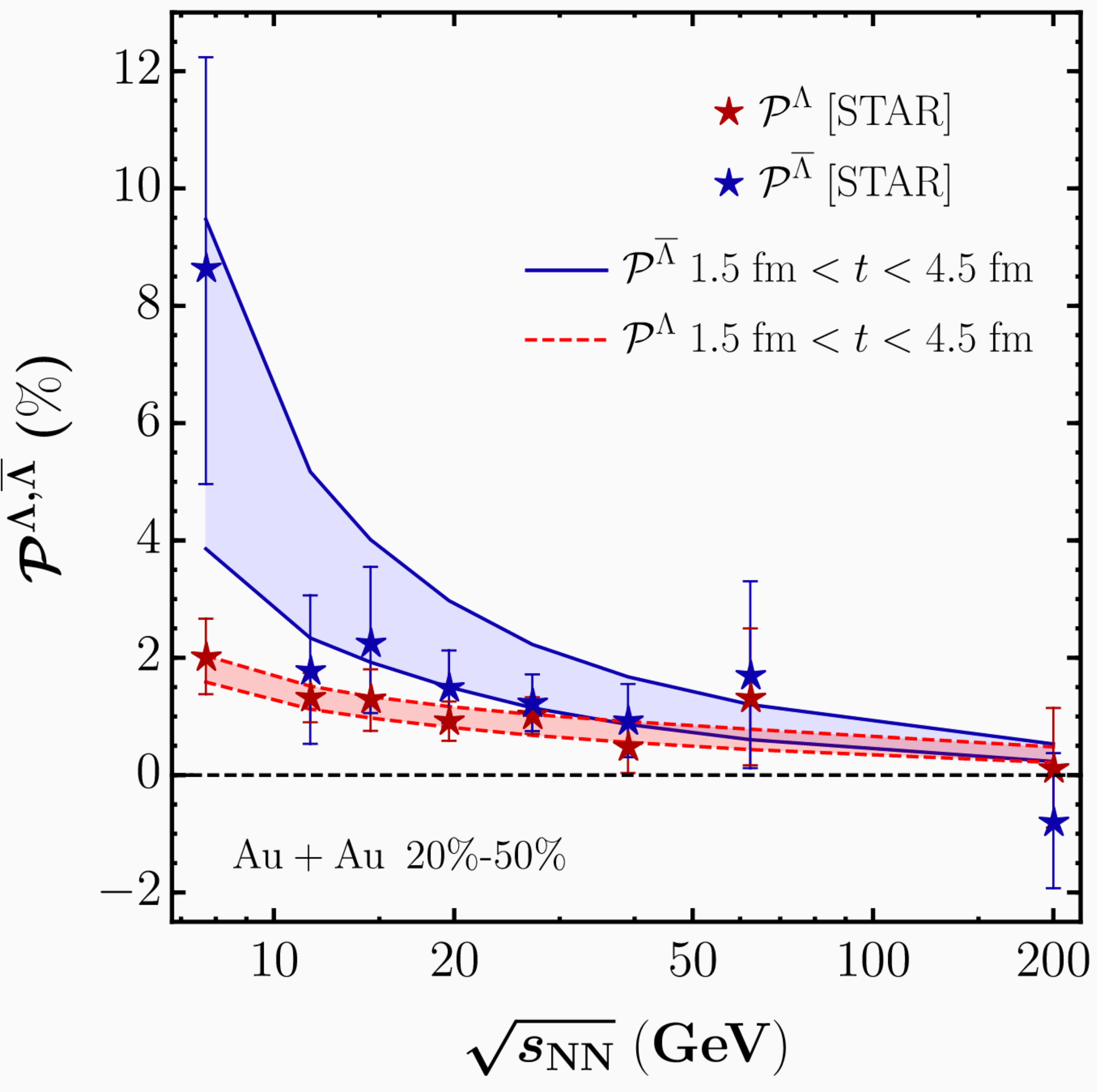


a
$\vec{J}_{sys}$
$\vec{b}$
$\vec{p}_{beam}$
b



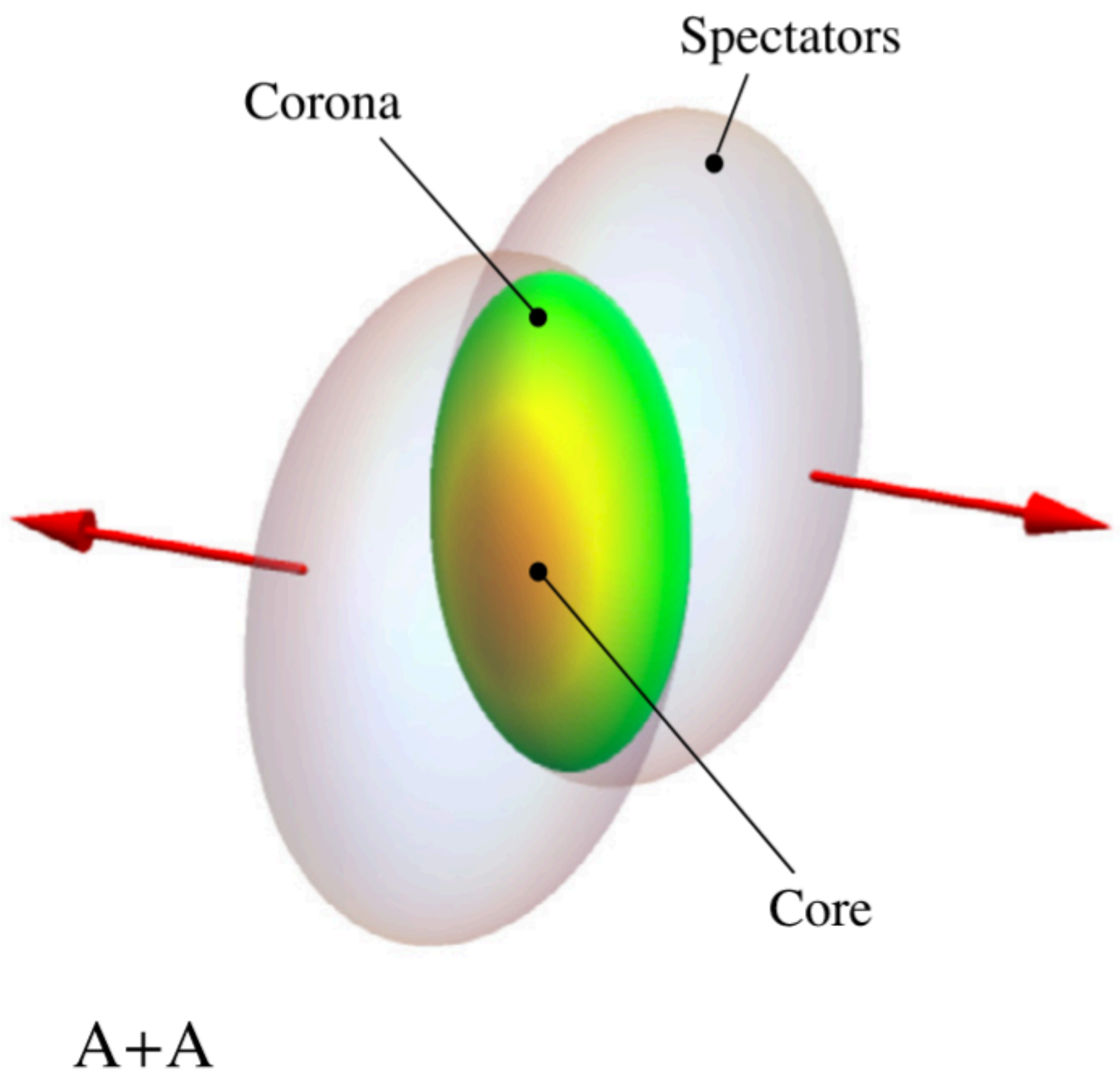
Λ Λ̄
STAR
ALICE
Scaled using $\alpha_\Lambda = 0.732$
Average of Λ and Λ̄
Hydrodynamics
Parton cascade (AMPT)
Hadron cascade (UrQMD)
3-fluid dynamics
Chiral kinetic
P (%)
$\sqrt{s_{NN}}$ (GeV)
NICA
LHC

MexNICA proposal

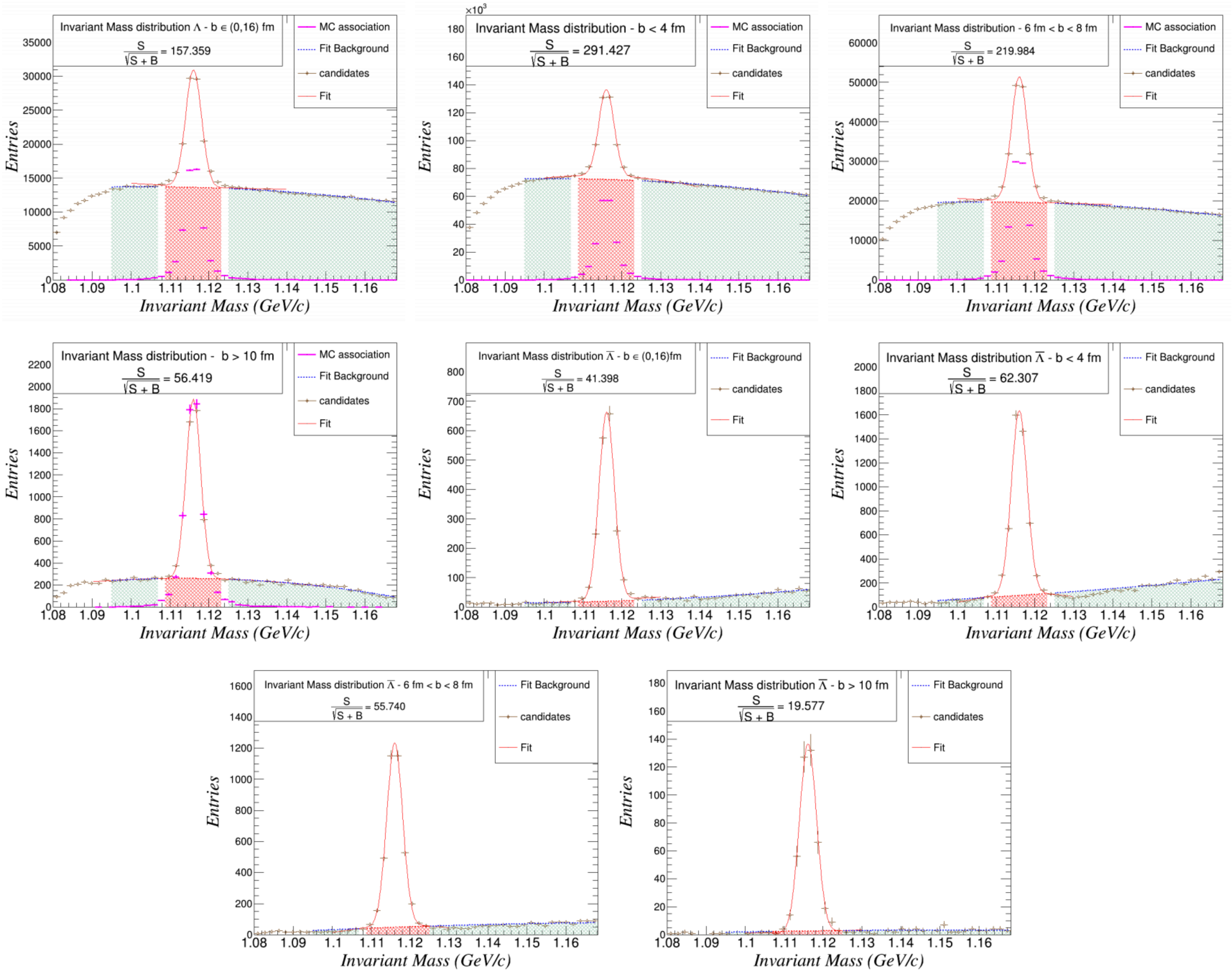


Au + Au 20-50% Λ and $\overline{\Lambda}$ polarization from core-corona model bands: Λ and $\overline{\Lambda}$ formation time in QGP range 1.5 fm $< t <$ 4.5 fm
vs
data STAR-BES Nature 548 (2017).

A.A. *et al.*, Phys. Lett. B **810**, 135818 (2020).



MexNICA proposal



MexNICA proposal

Main goal:

To contribute in the study of the QGP phase diagram (CEP)

How?

To study, from experimental point of view, signatures that allows to locate the CEP.

To study, from experimental point of view, the inclusion of a detector that allows to MPD increase its pseudorapidity acceptance.Bonus, optimization of event plane resolution, and trigger system

MexNICA proposal

BUAP

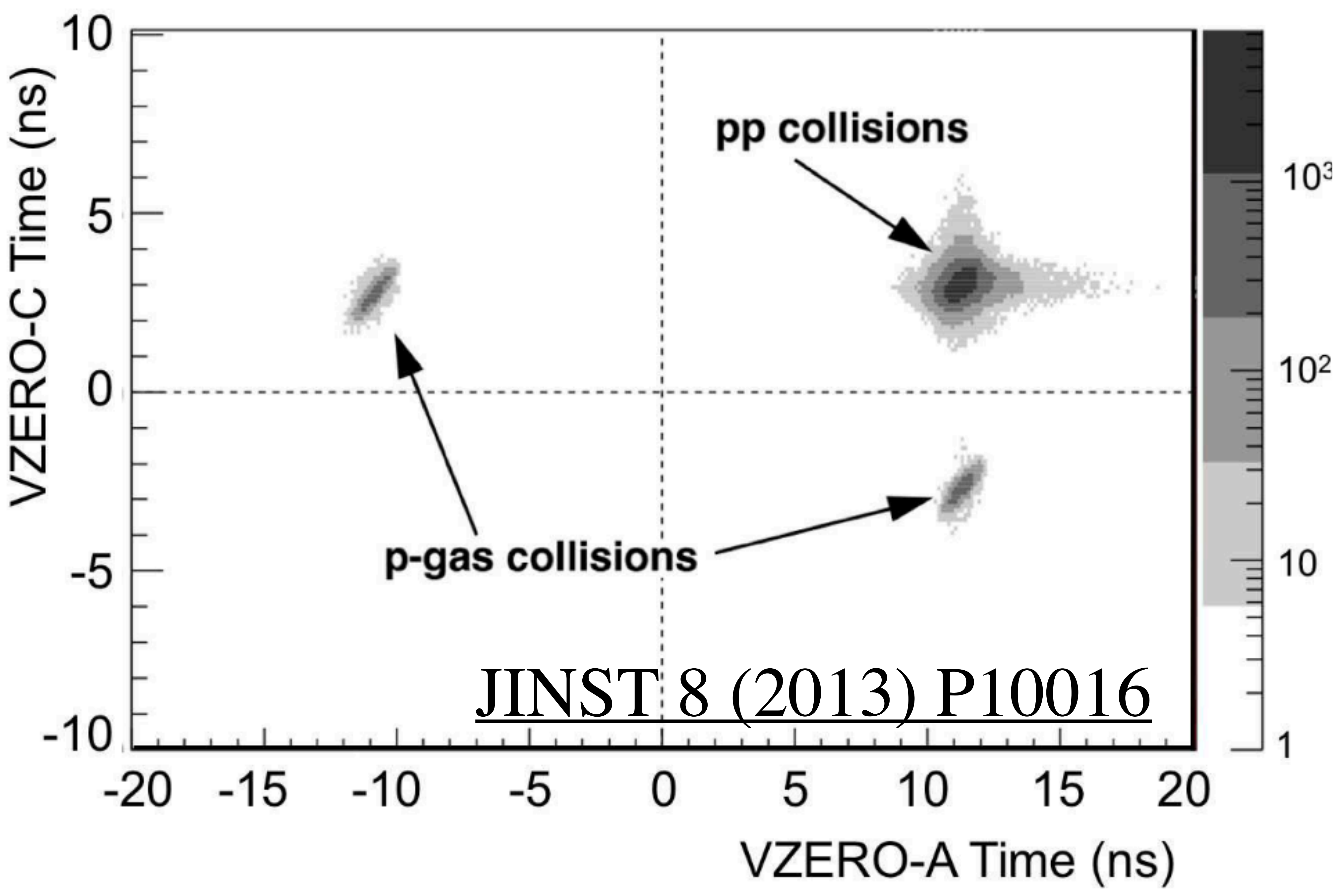
In collider experiments, a beam–beam counter detector is highly desirable.

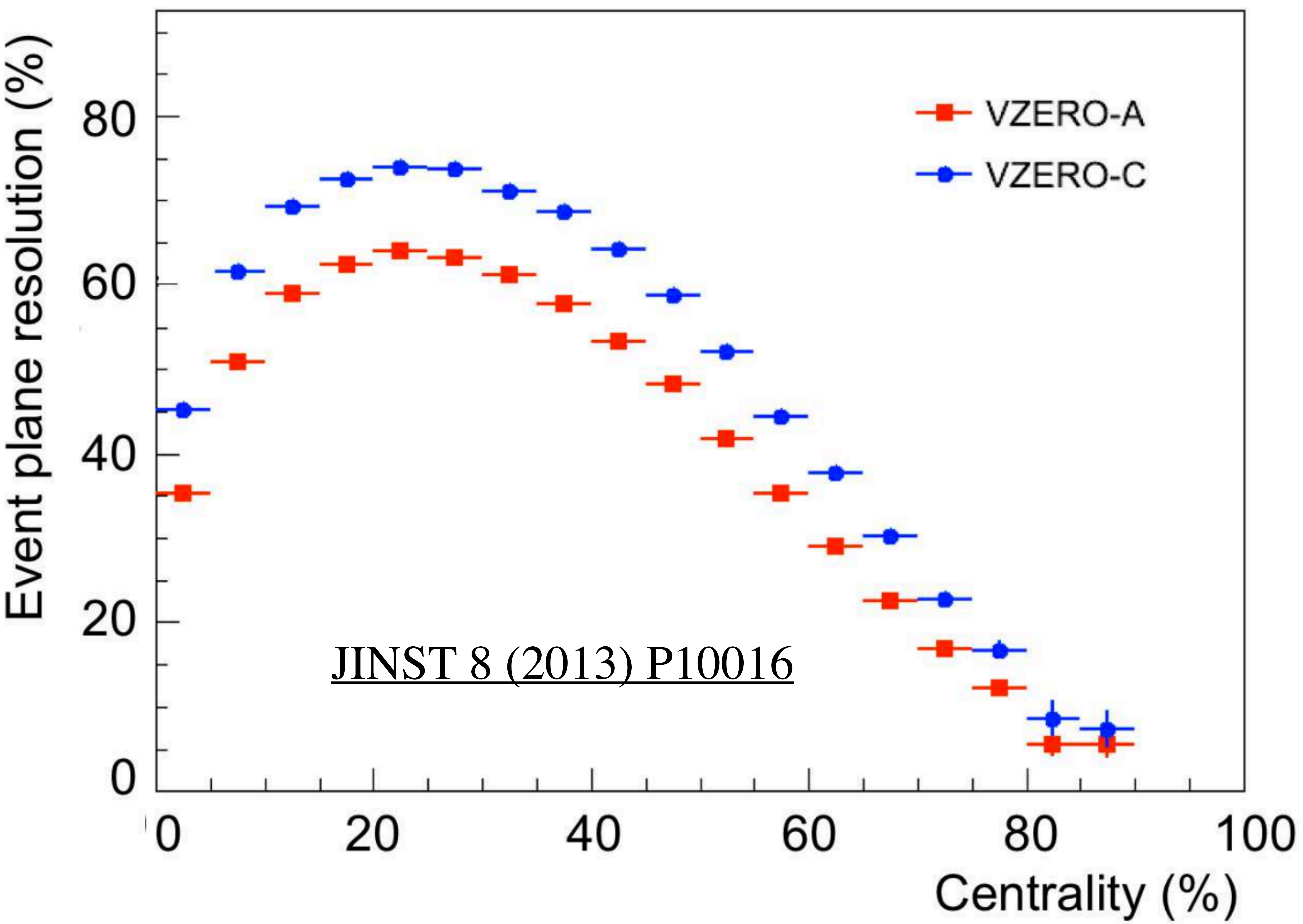
- **trigger system**: to identify and to discriminate beam–beam minimum bias or centrality events from background and beam–beam interactions.

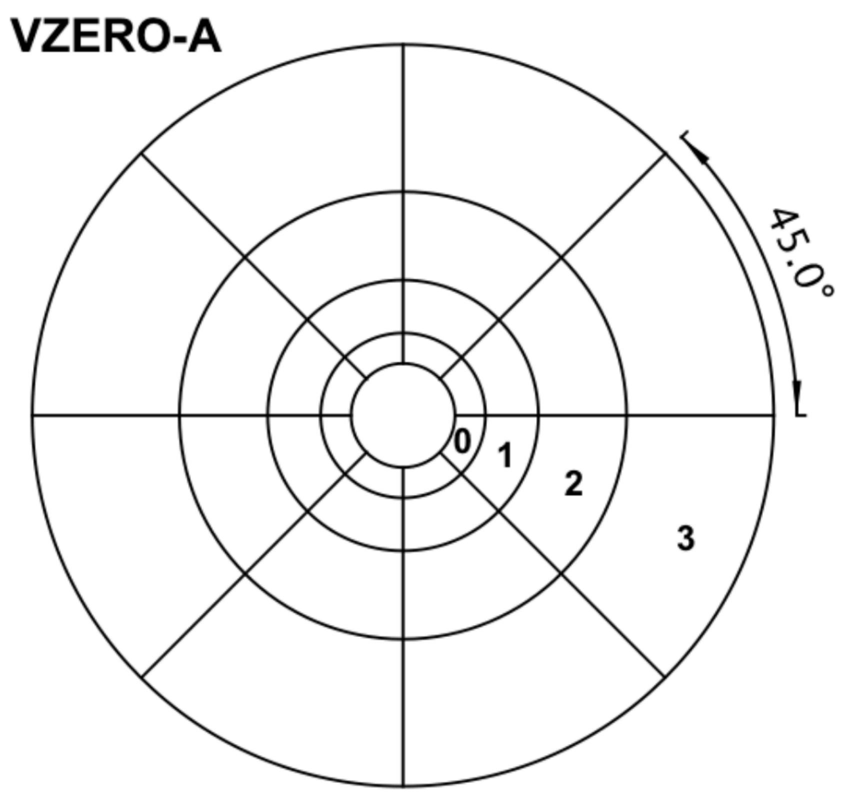
- **bonus, physics studies**:

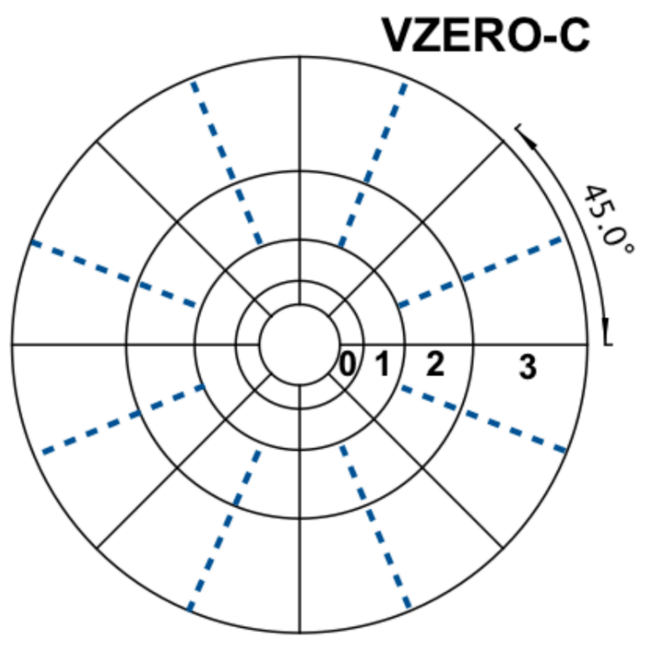
  - luminosity measurements, for the determination of absolute cross sections of reaction processes
  - multiplicity of charged particles, key observable for the determination of the centrality of the collisions events and event plane resolution

MexNICA proposal



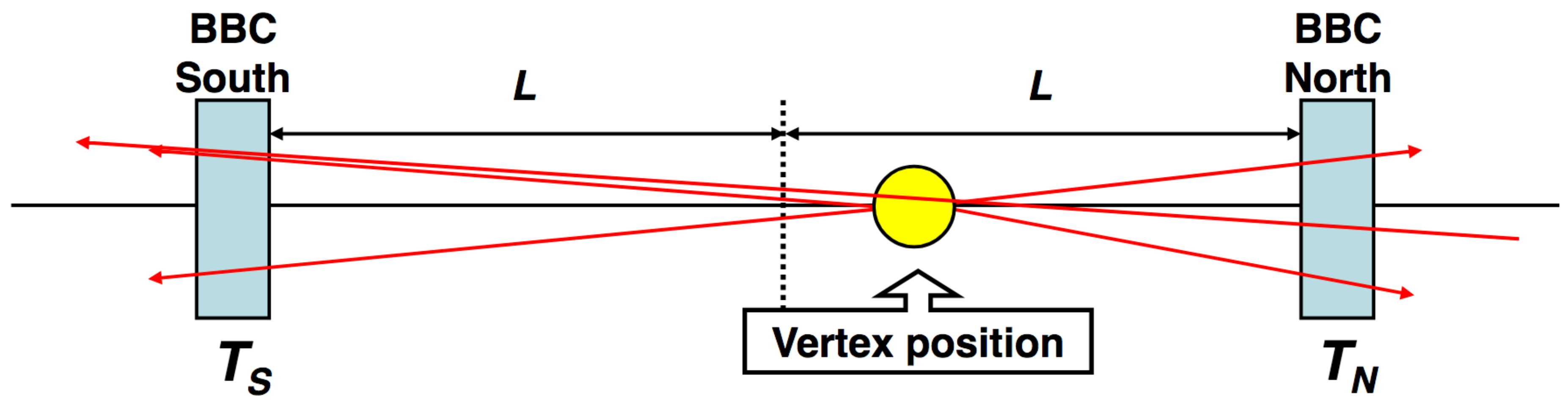




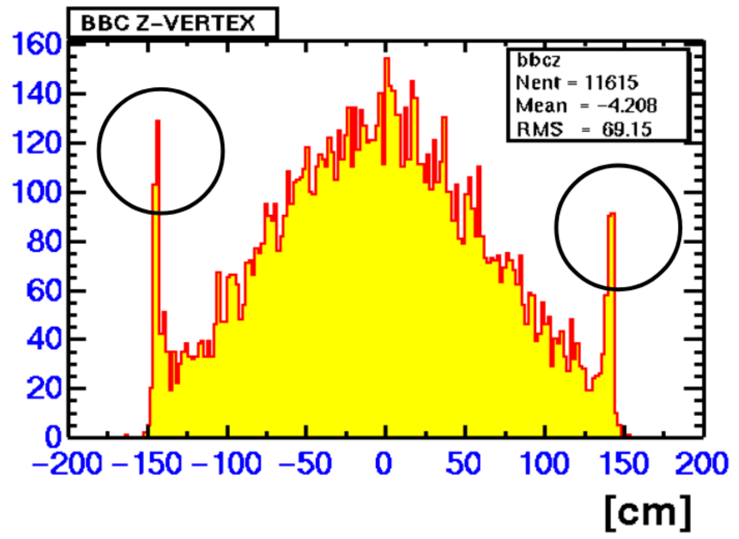


MexNICA proposal

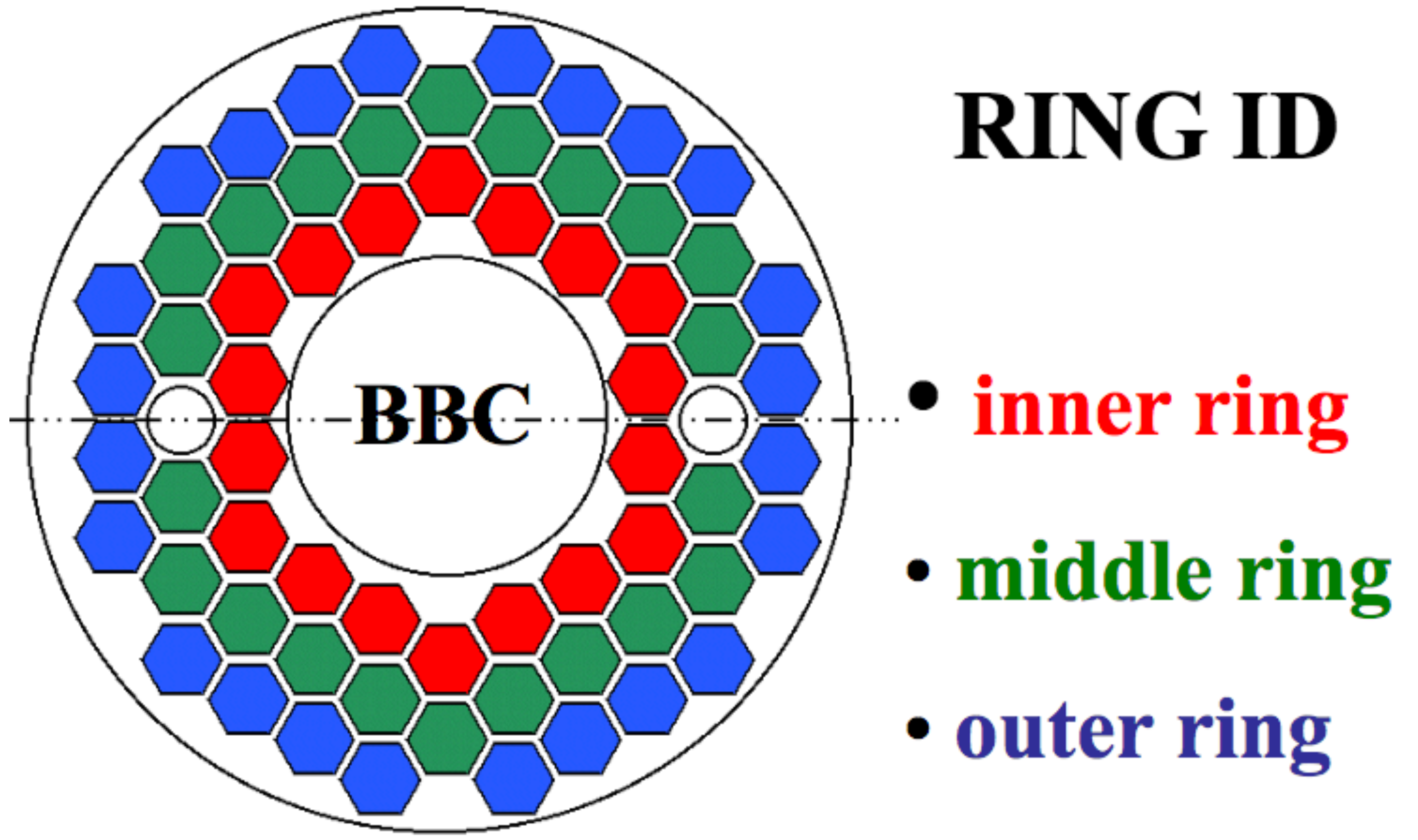
https://www.phenix.bnl.gov/WWW/intro/detectors/focus/focus_bbc.pdf

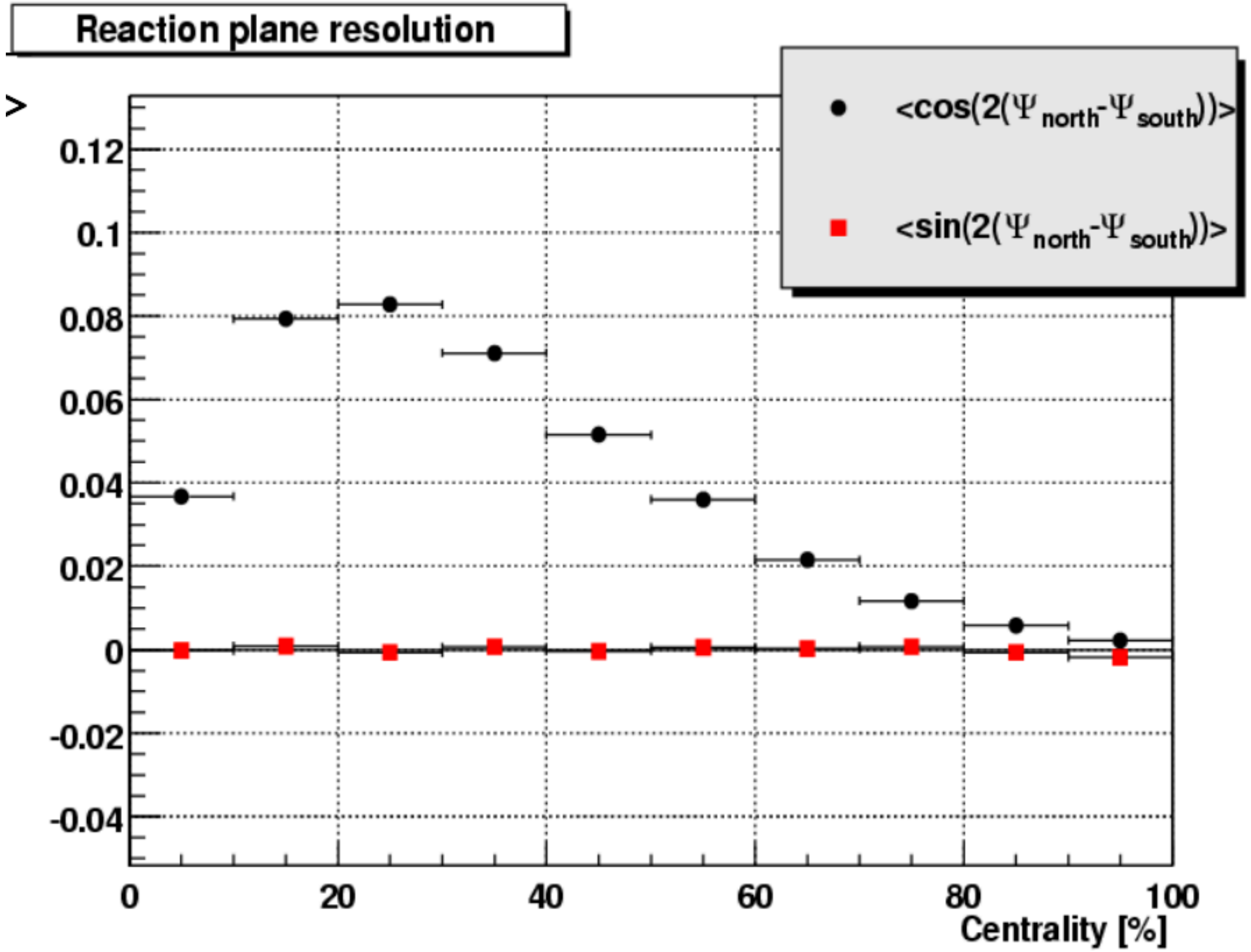


- *Z-Vertex* $= \dfrac{T_S - T_N}{2} \times c$
- Time zero $= \dfrac{T_S + T_N - 2L/c}{2}$



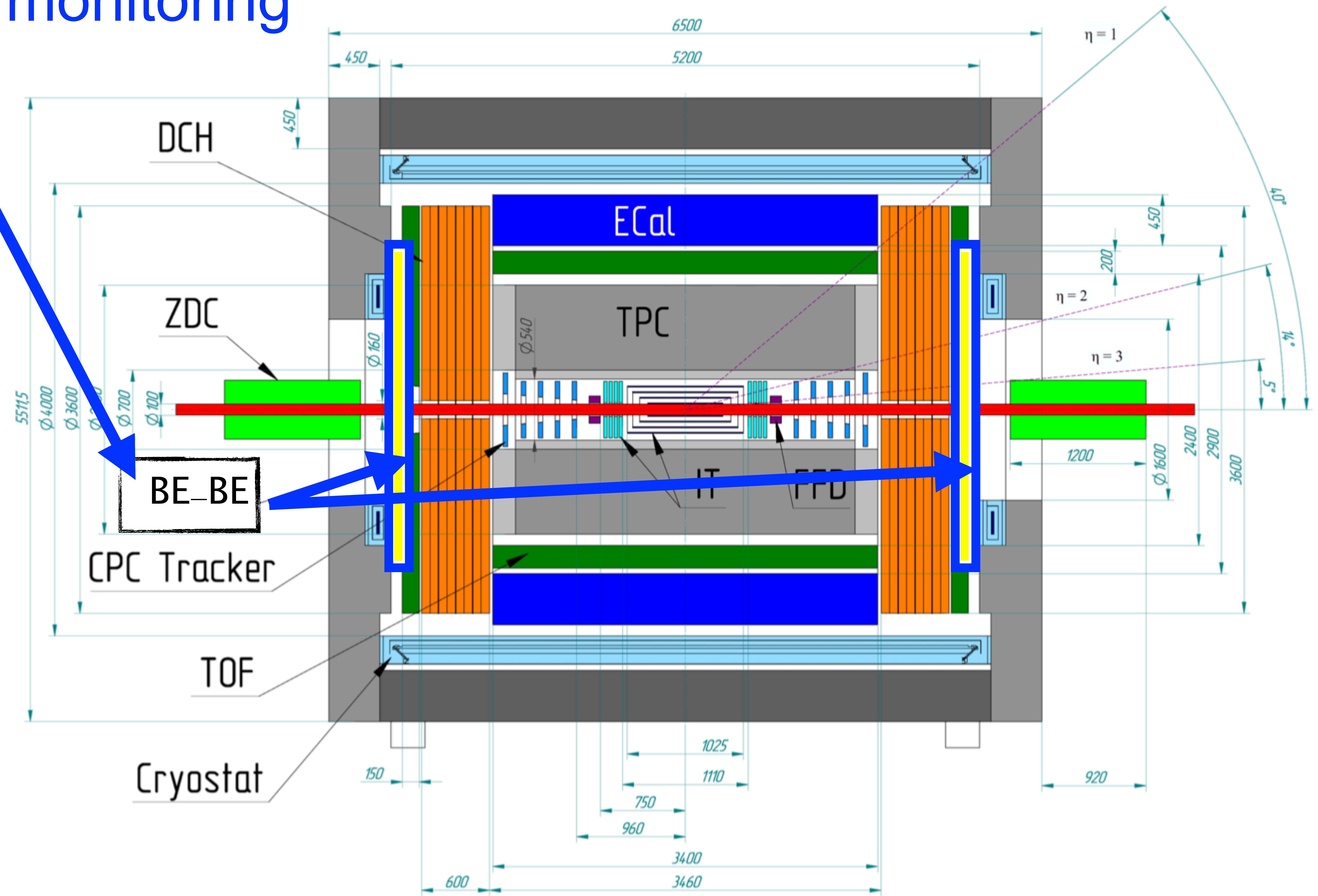
$T_{N/S}$: average hit time, c : light velocity, L : 144.35 cm



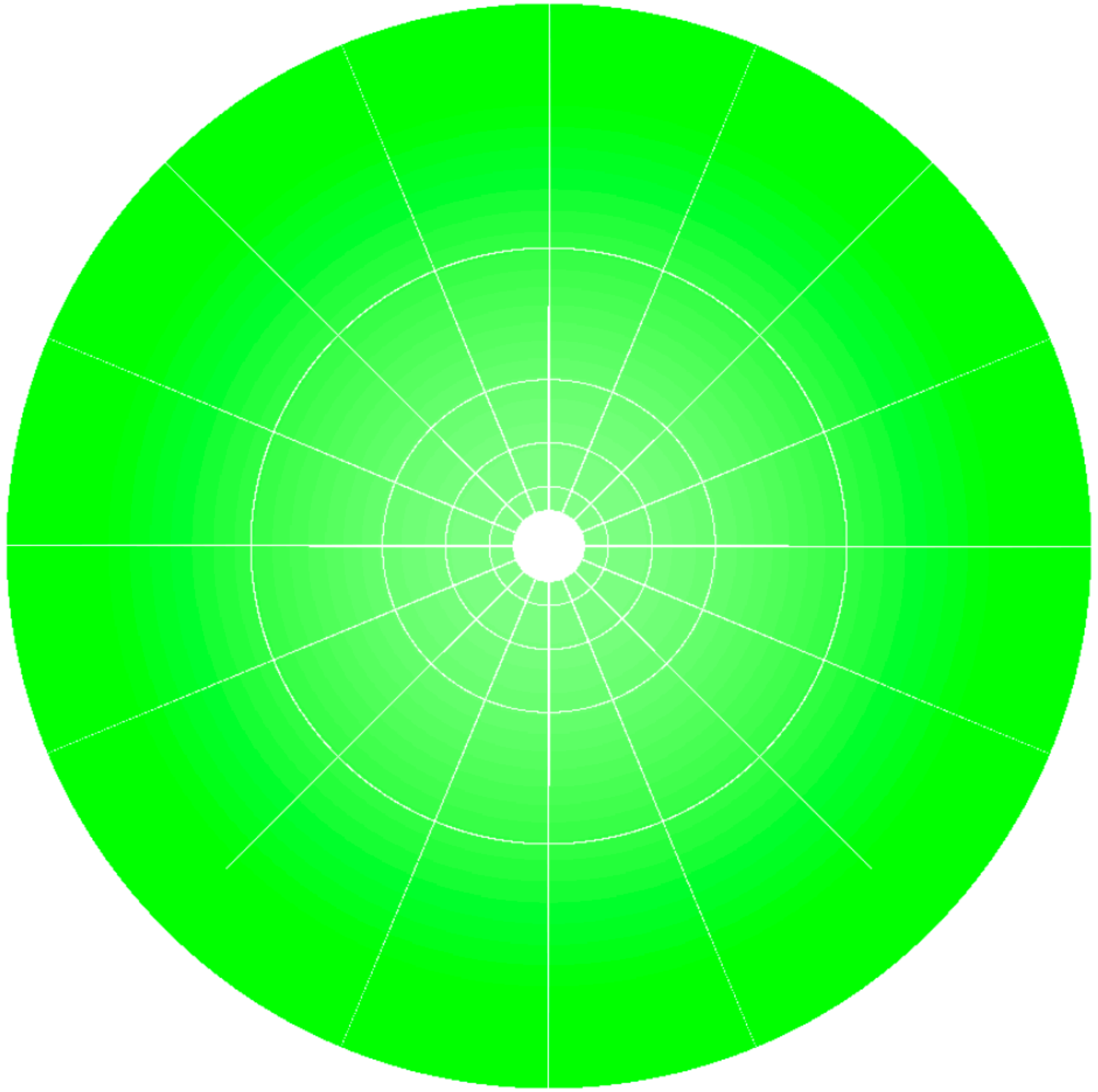


Detector concept

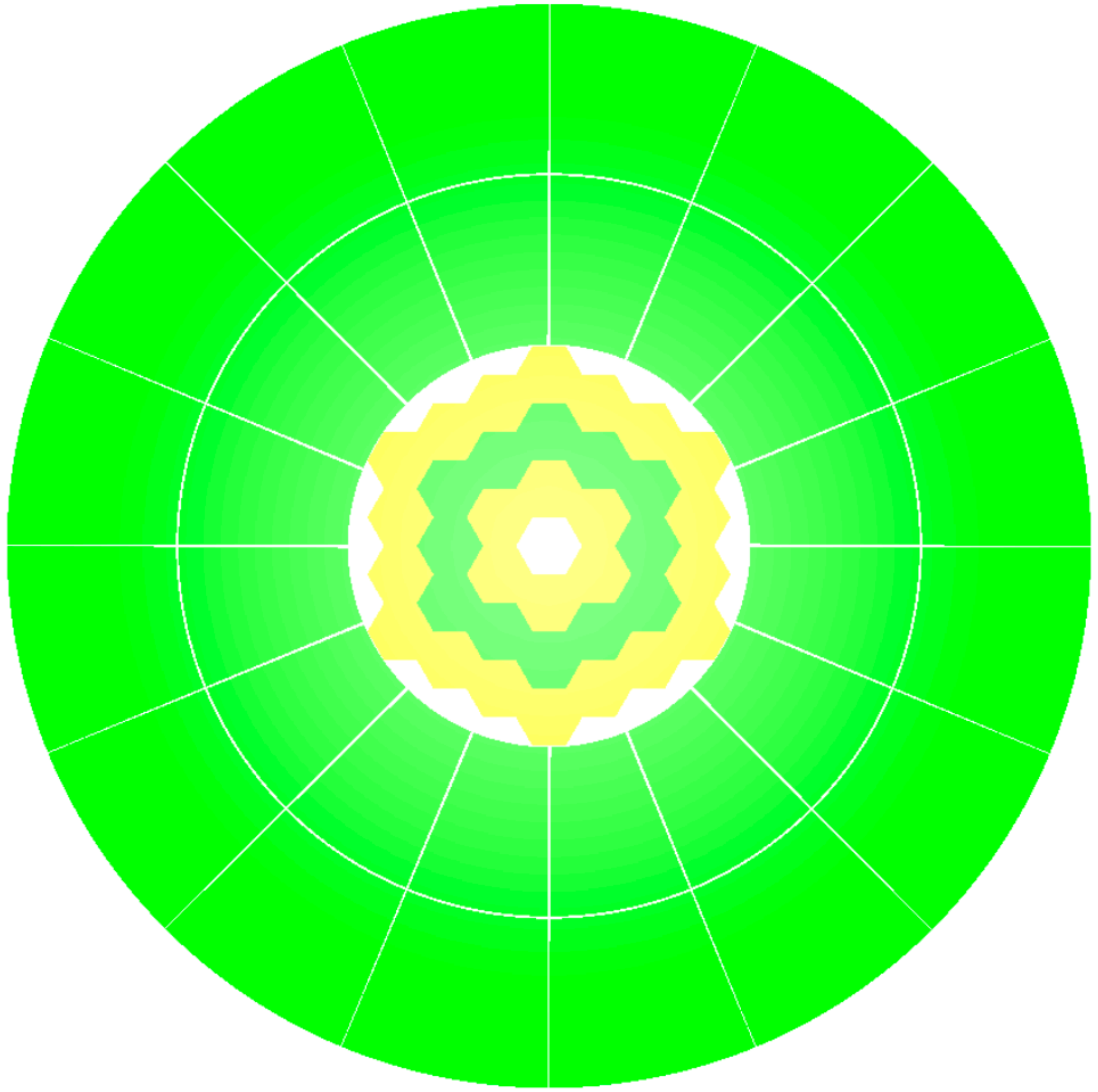
Beam-Beam monitoring



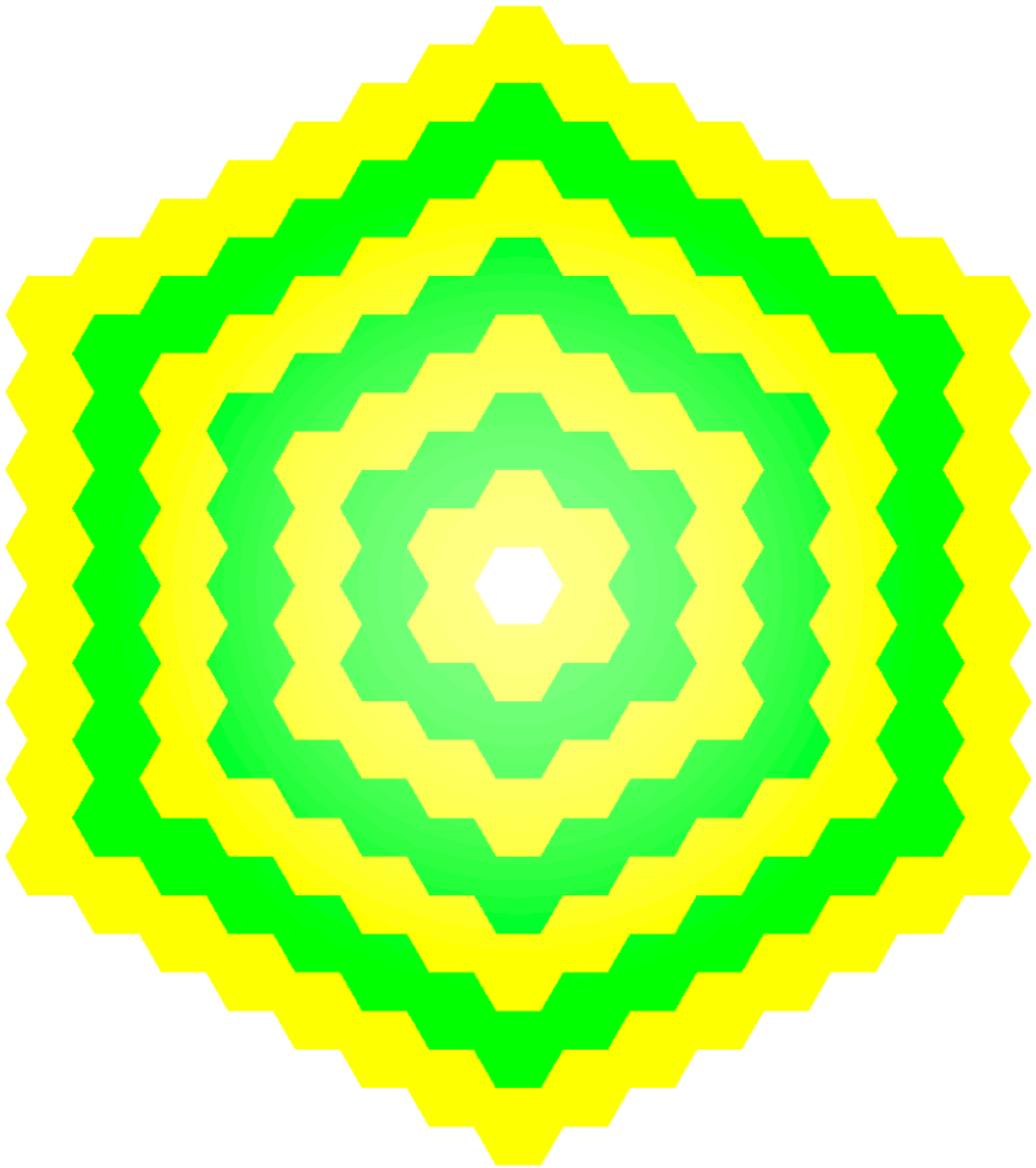
Evolution of BeBe geometry through the years (2016-Today)



2016,2020 (ALICE-LHC)

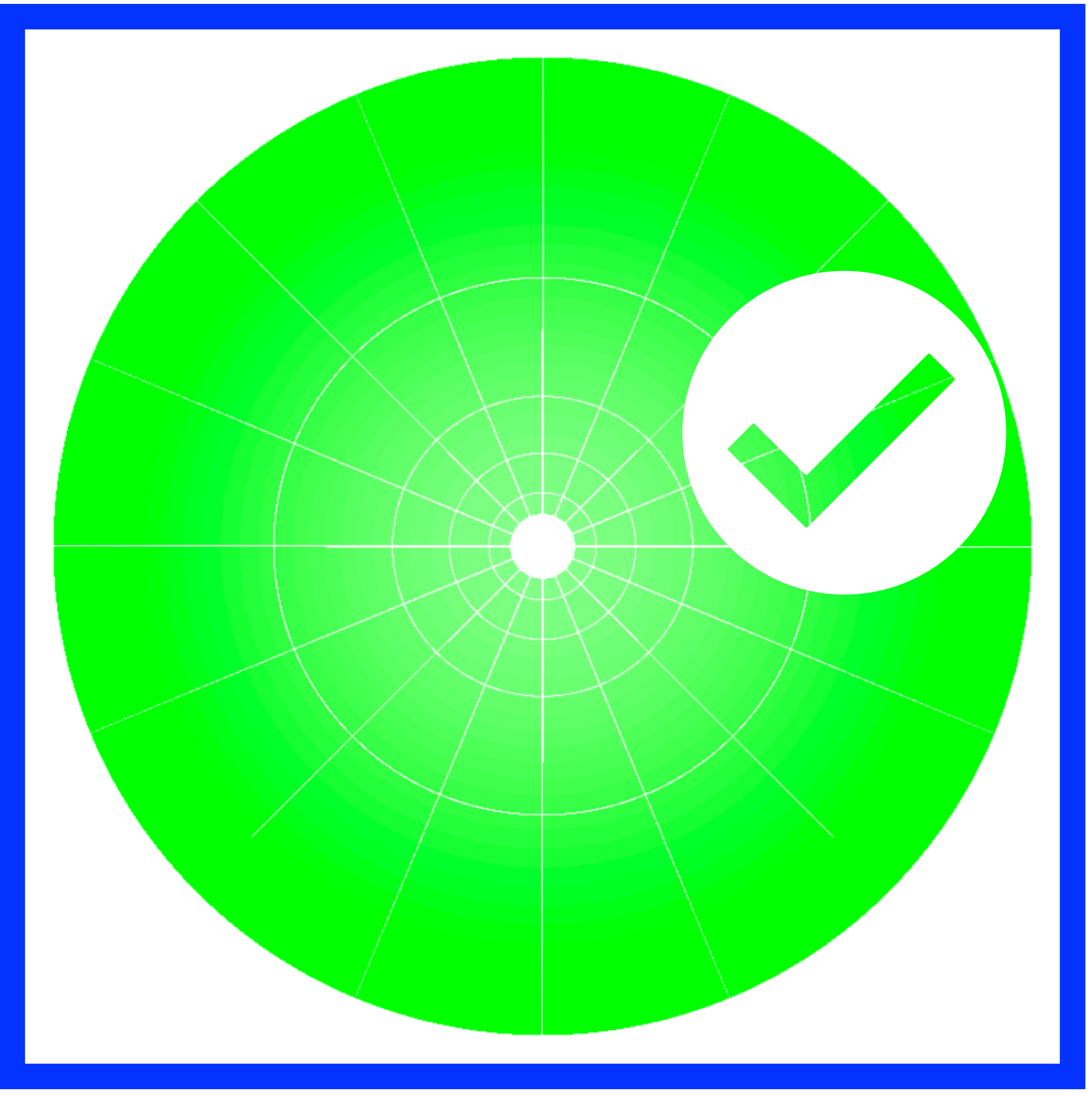


2017 (hybrid)



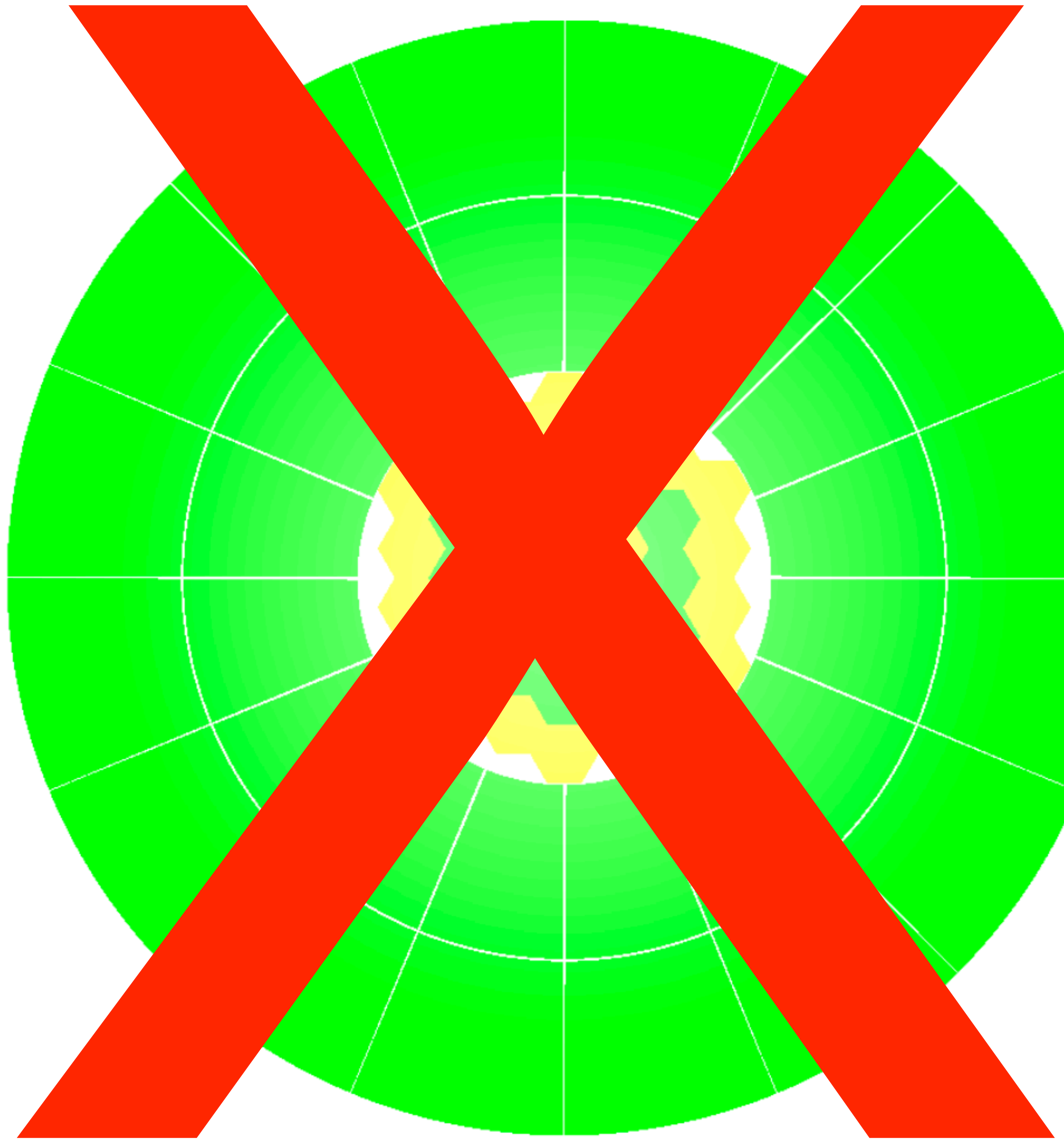
2018-2020 (RHIC)

Evolution of BeBe geometry through the years (2016-Today)

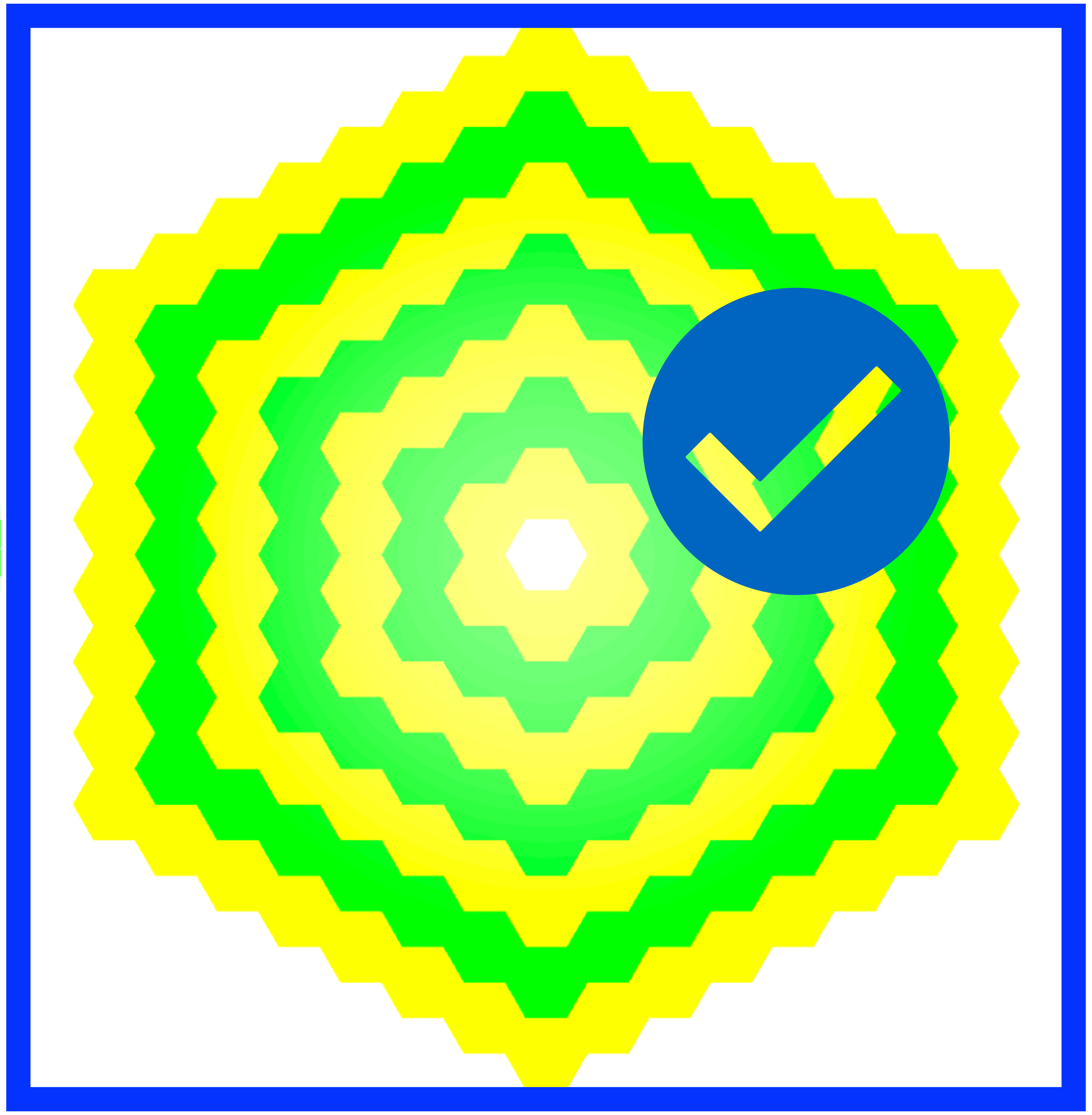


2016,2020 (ALICE-LHC)

OBSOLETE



2017 (hybrid)



2018-2020 (RHIC)

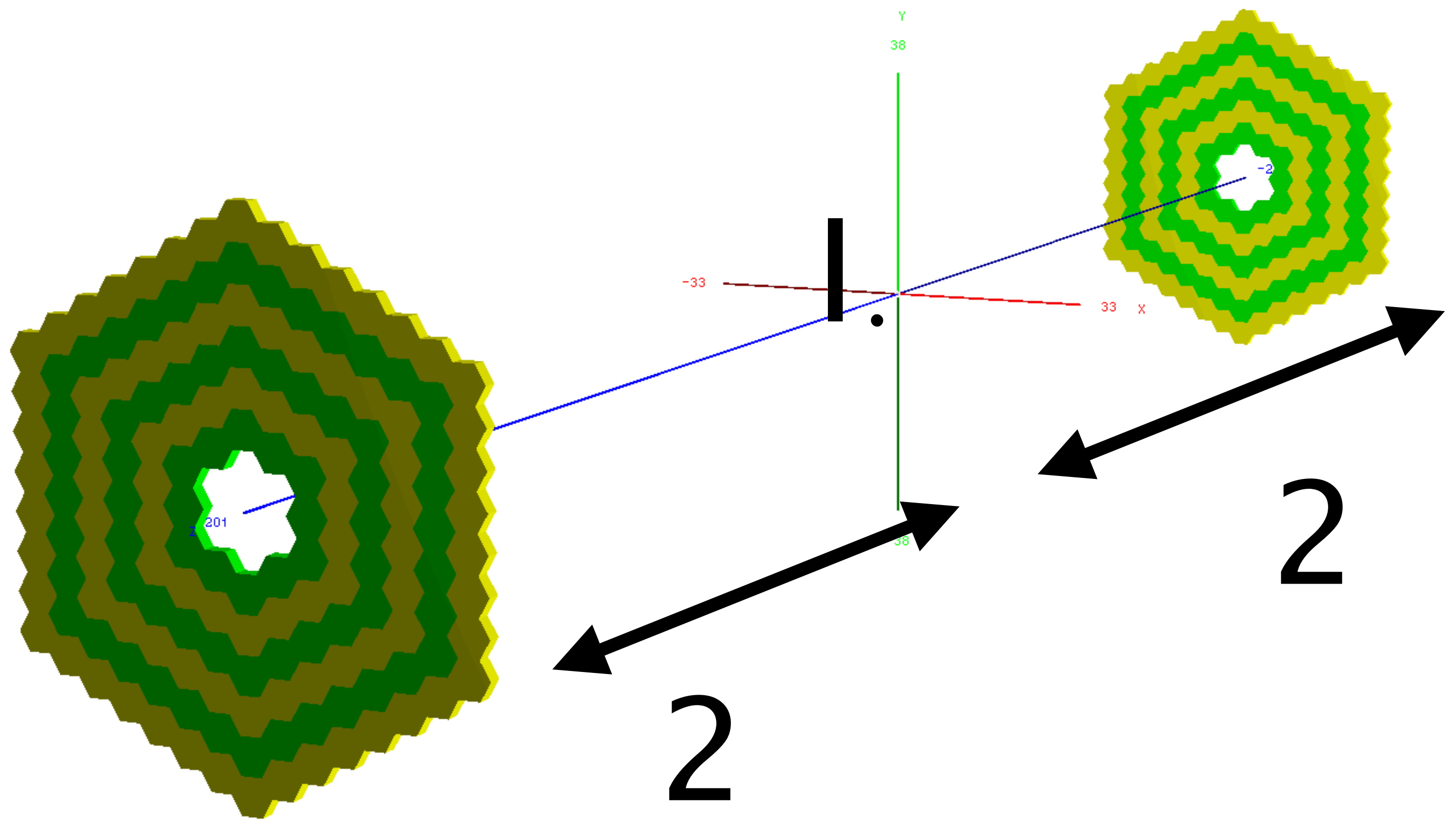
Detector concept

Geometry of BeBe detector

- two hodoscope detectors located, each located 2 m away from interaction point at opposite sides.

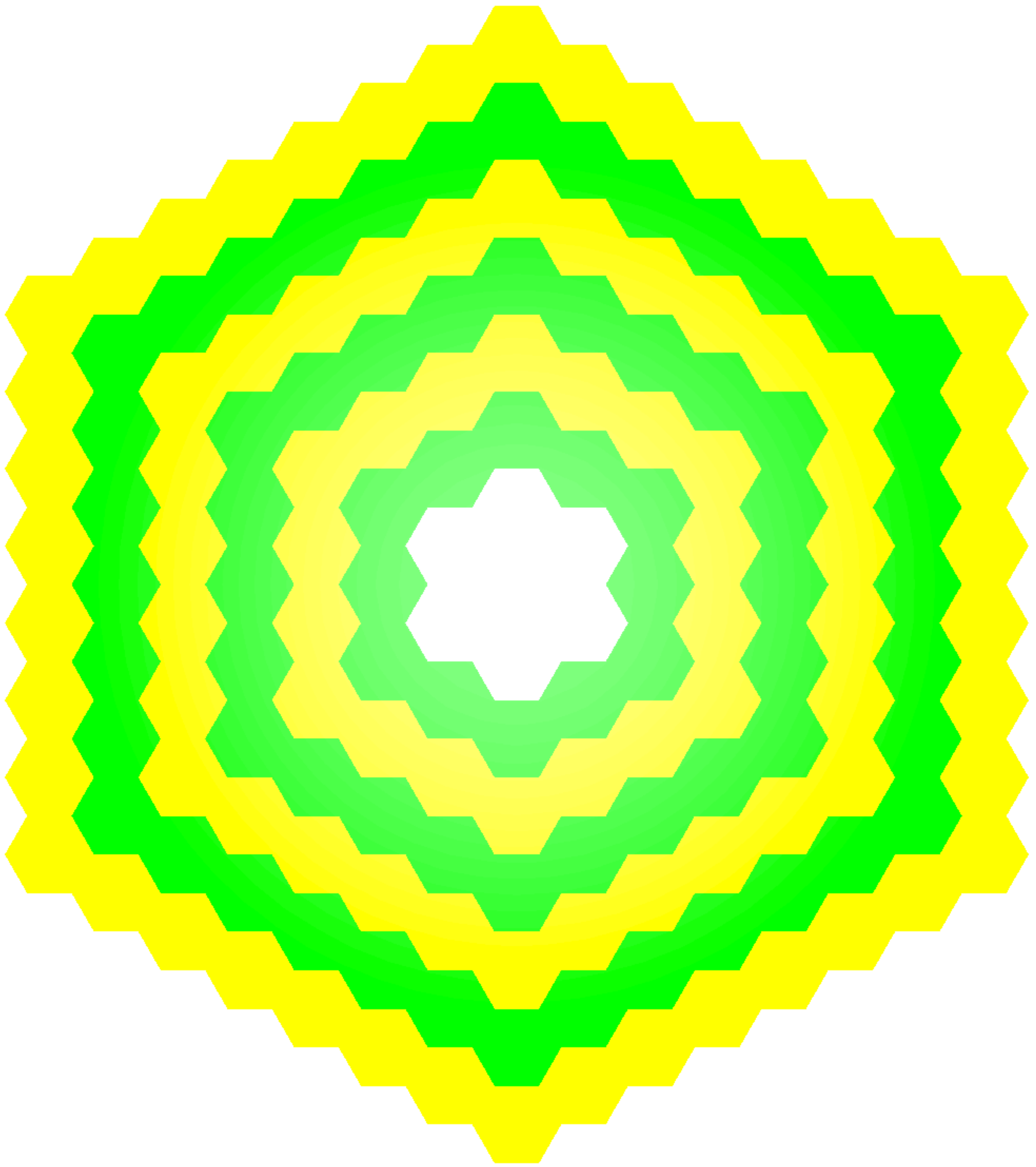
- two approaches: hexagonal cells (RHIC) OR disk cells (ALICE)

Detector concept: hexagonal cells



BeBe detector

- 162 hexagonal cells (5 cm height, 1 cm width)
- six concentric “rings”
- plastic scintillator BC404
- $1.9 < |\eta| < 3.97$
- photosensors: SiPM or PMT (do be decided)



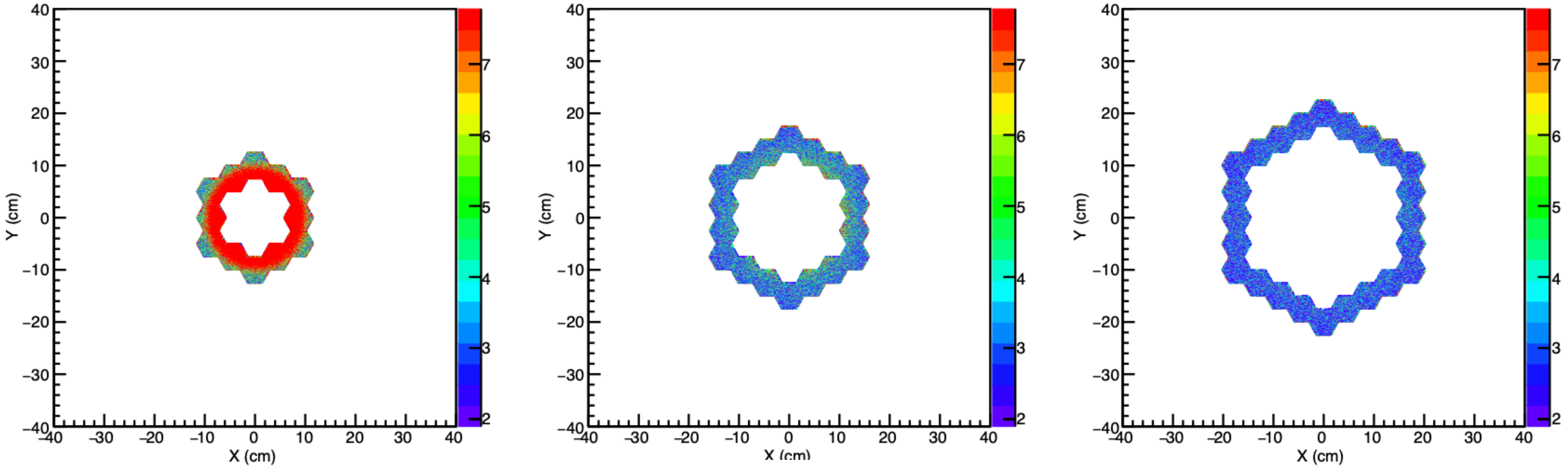
MexNICA proposal

Main role of MPD beam–beam counter detector (BE–BE): to produce a signal for the MPD Level–0 trigger.

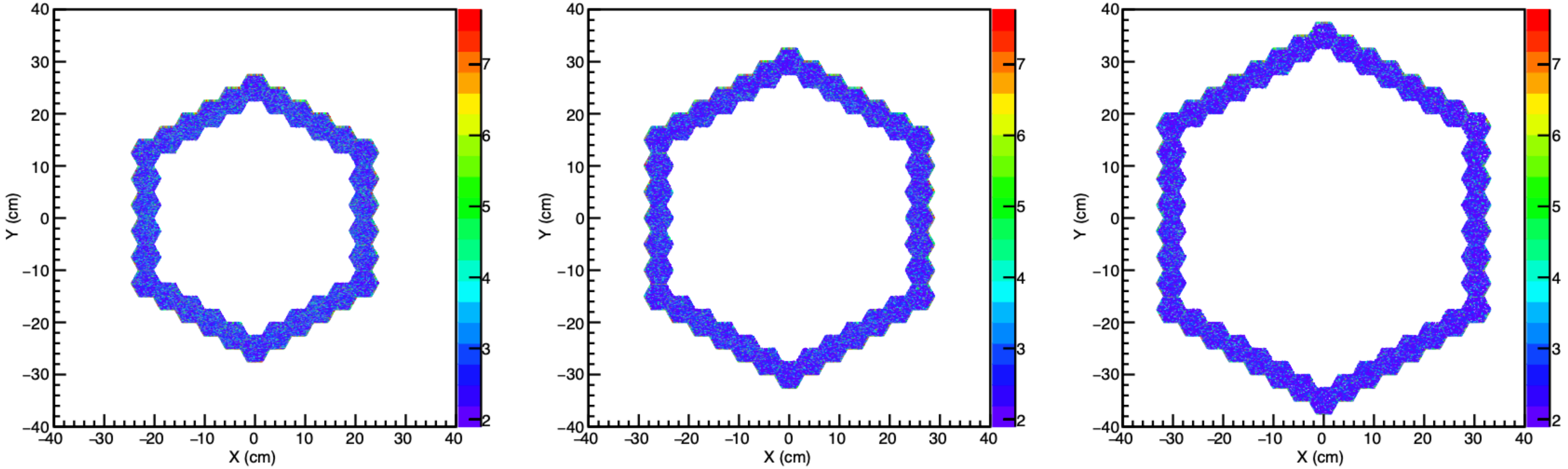
Requirements for BE–BE detector:

- radiation hard
- need to work in high magnetic field environment
- time resolution of 30 ps

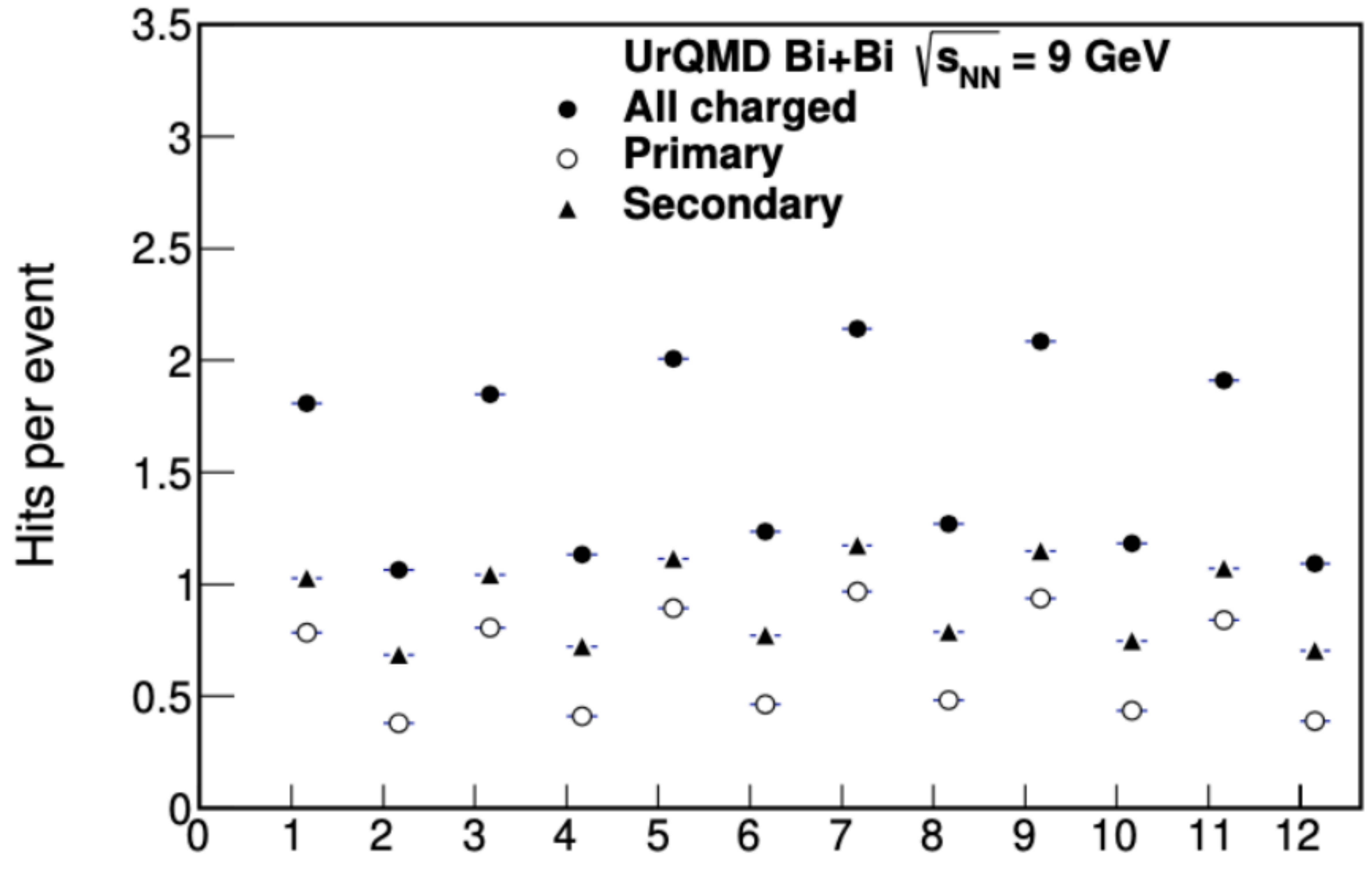
Simulation studies: hexagonal cells



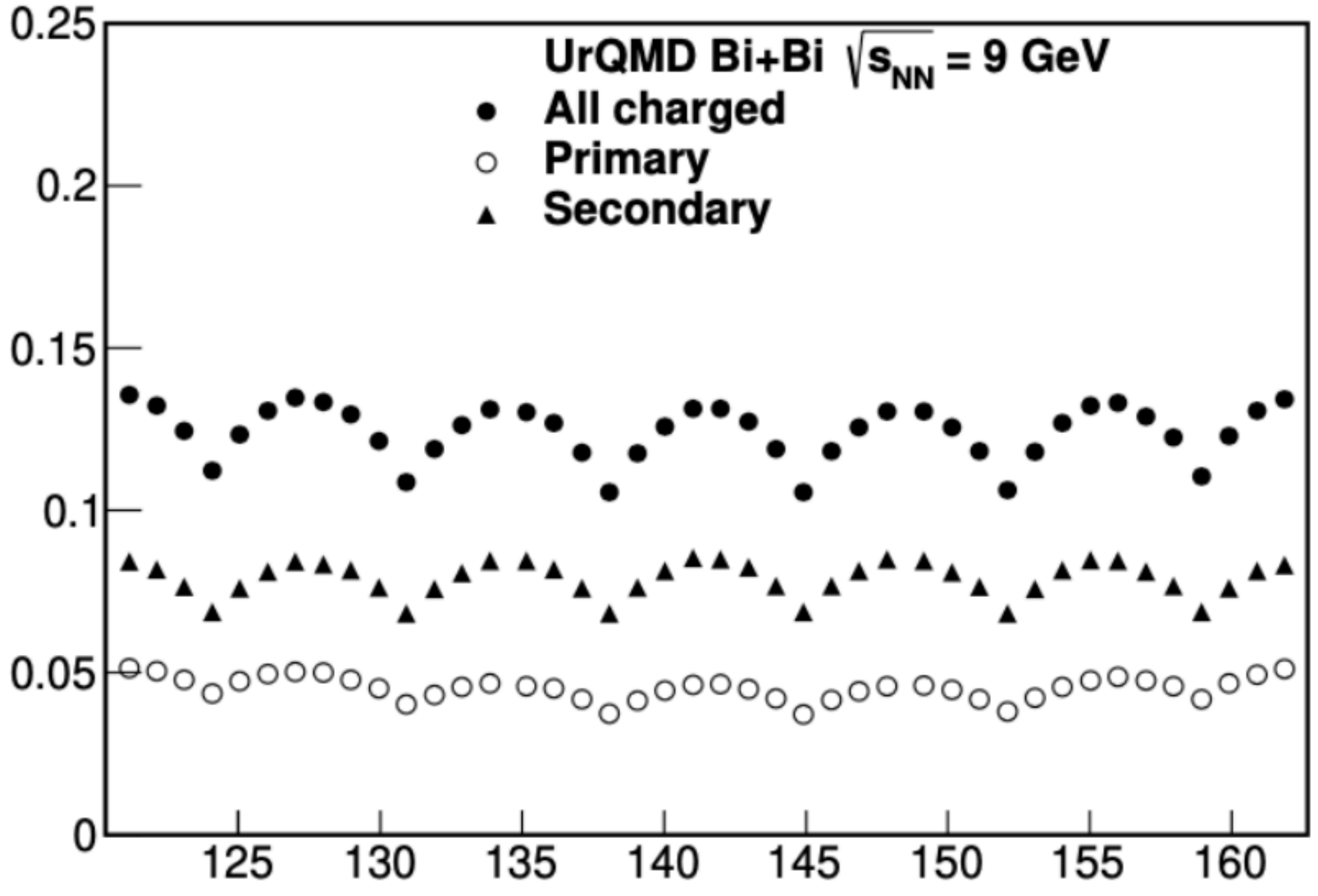
Internal Note 06-08-2020.v1 - MexNICA



Simulation studies: hexagonal cells



Cell ID

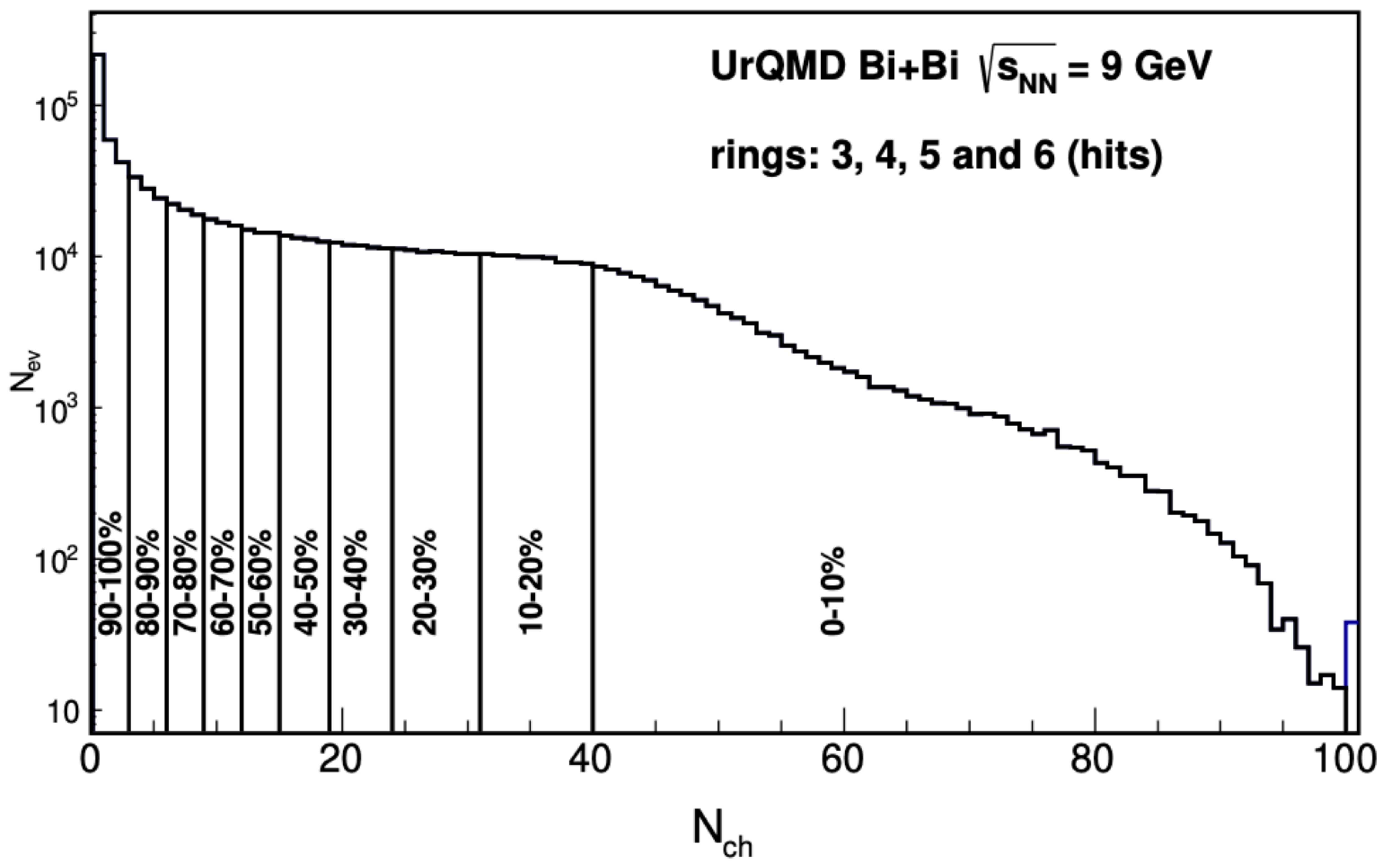


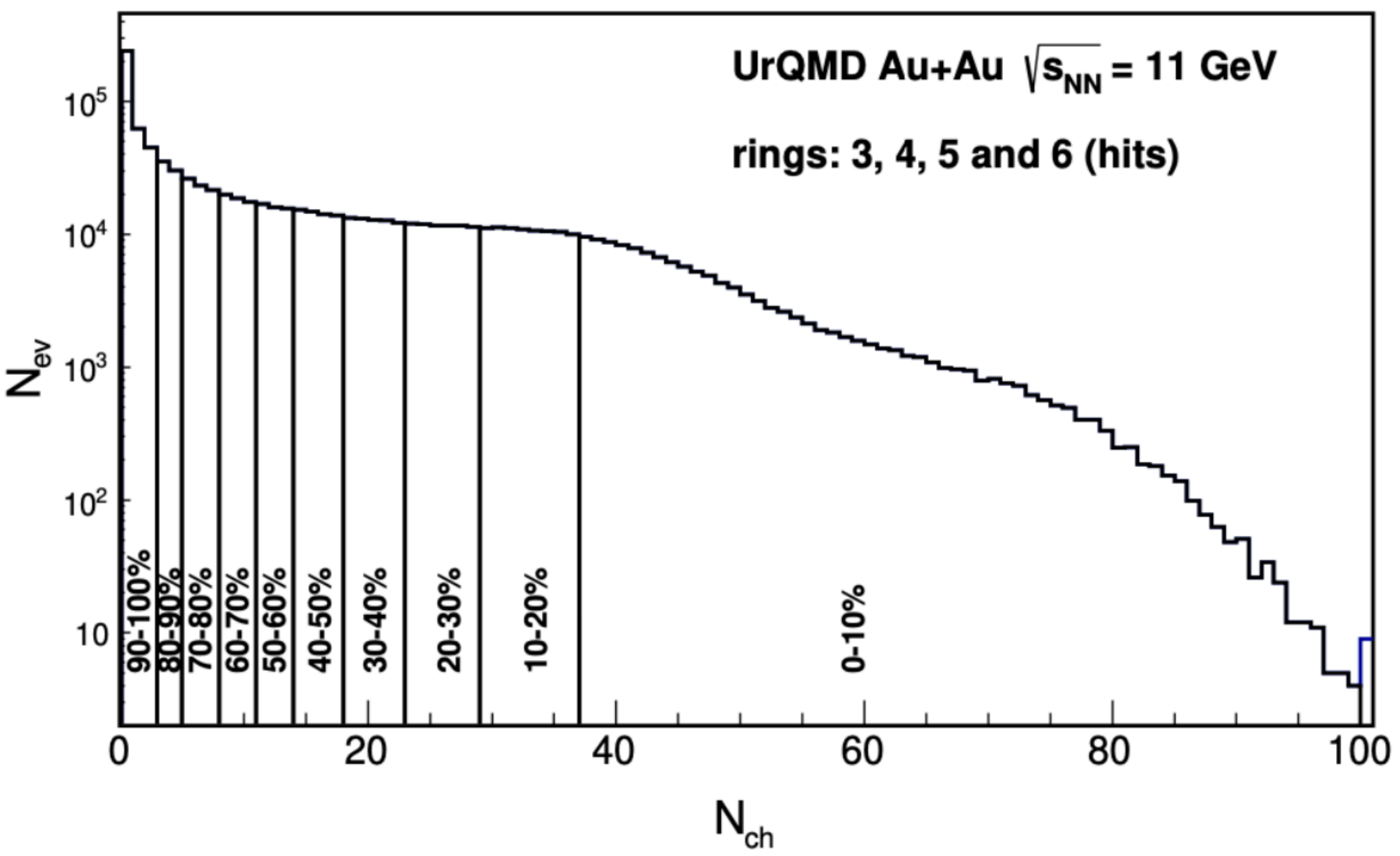
Cell ID

Internal Note 06-08-2020.v1 - MexNICA

Simulation studies: hexagonal cells

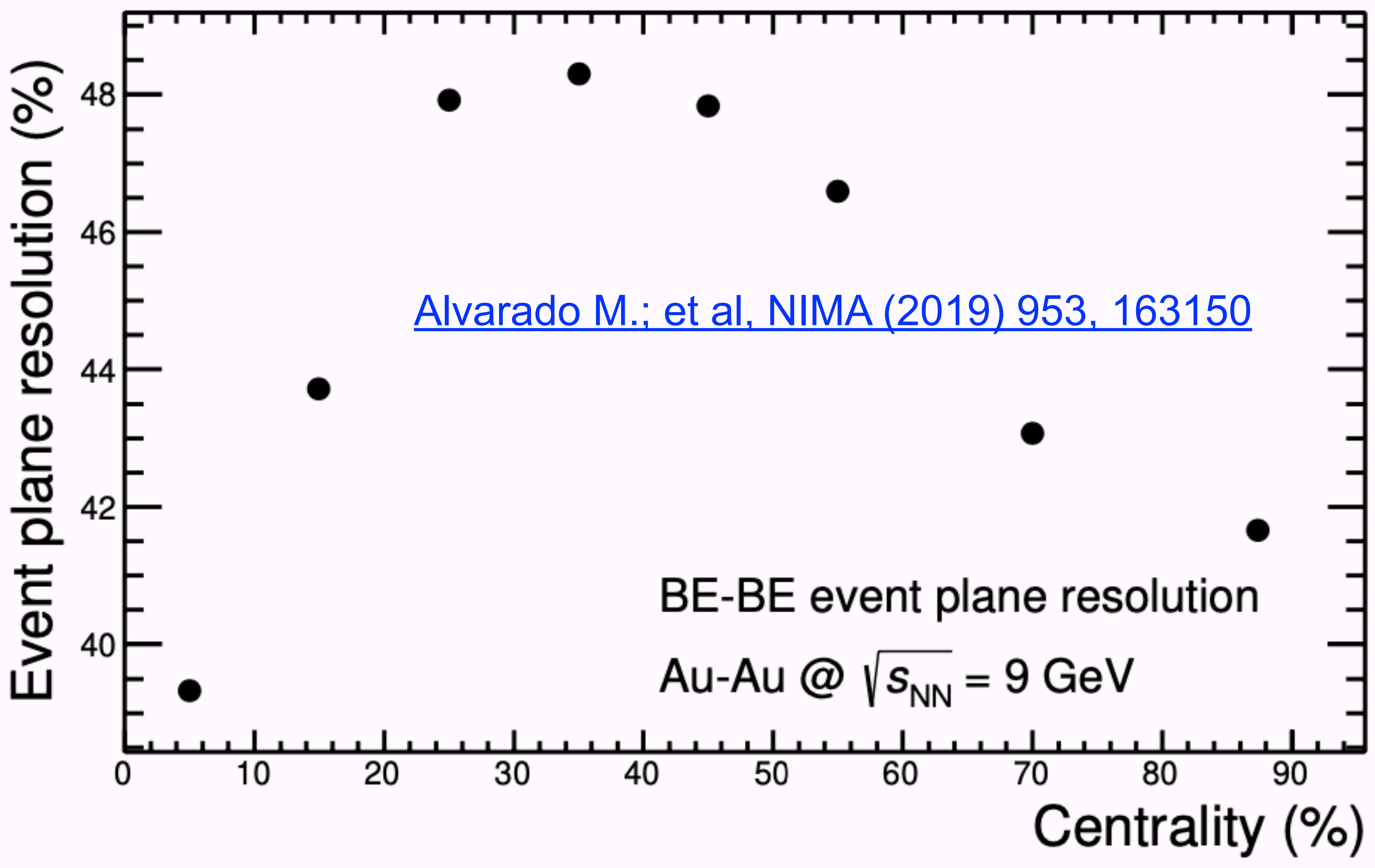
Internal Note 06-08-2020.v1 - MexNICA

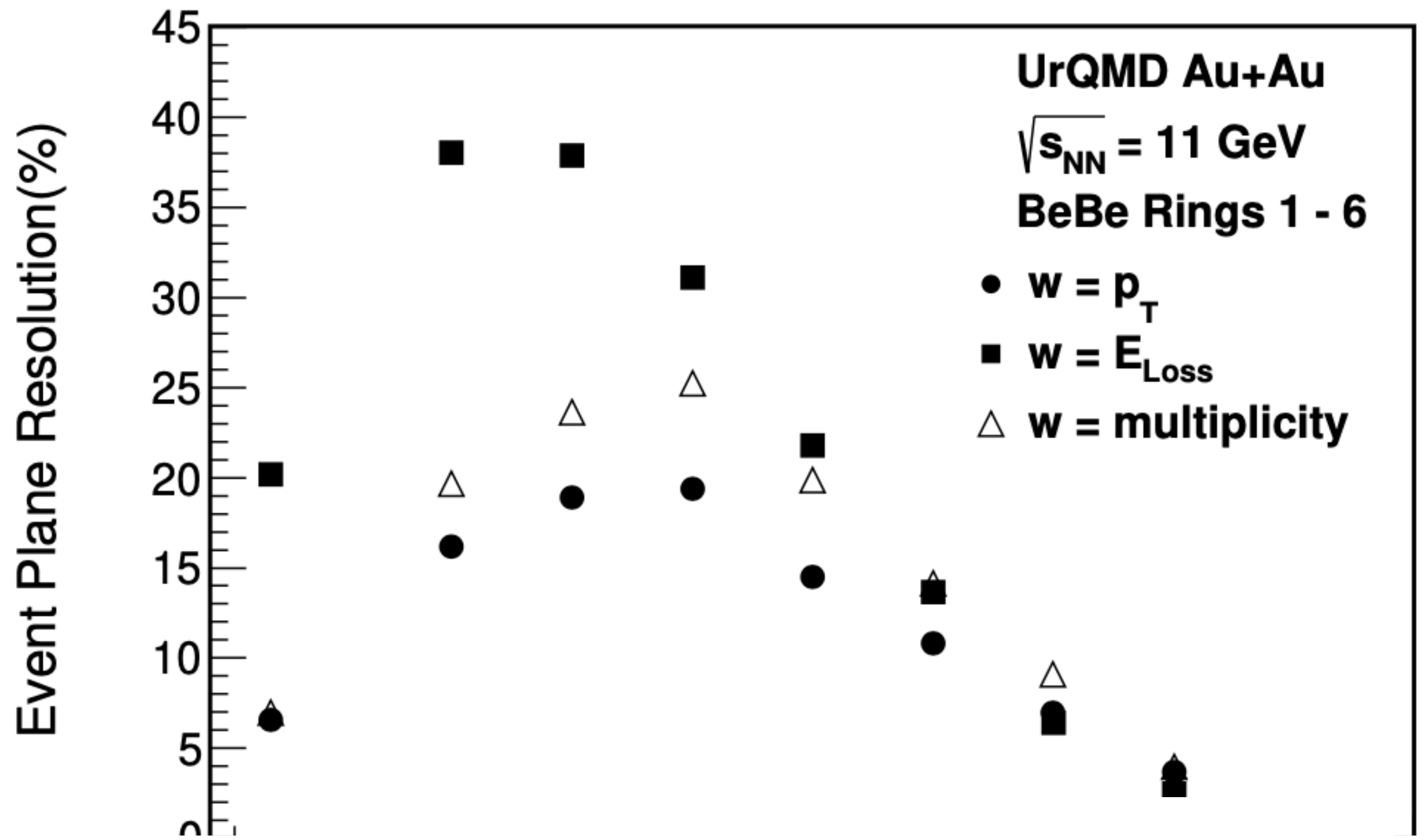




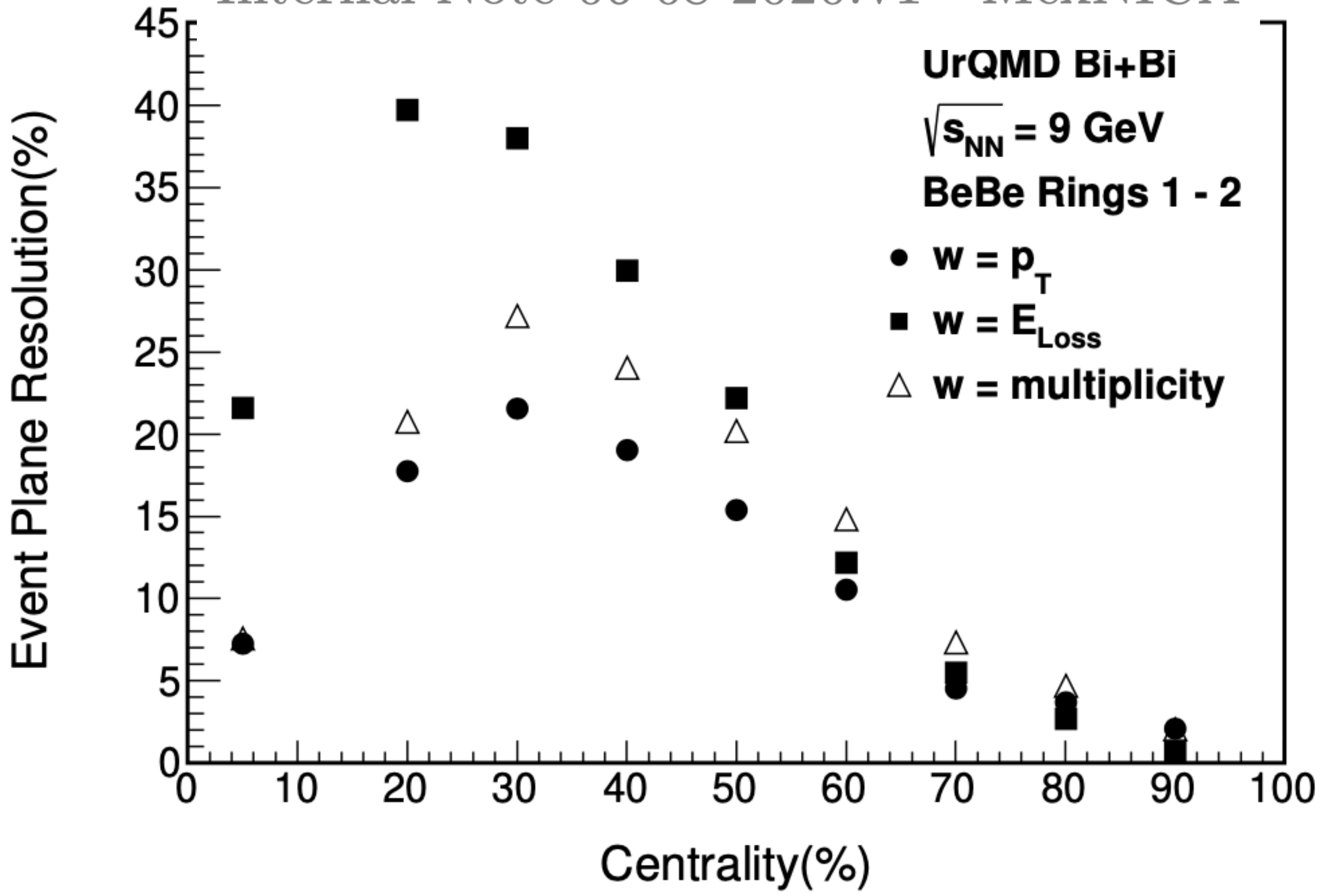
With the BeBe information would be possible to construct centrality classes using rings 3, 4, 5 and 6.

Simulation studies: hexagonal cells





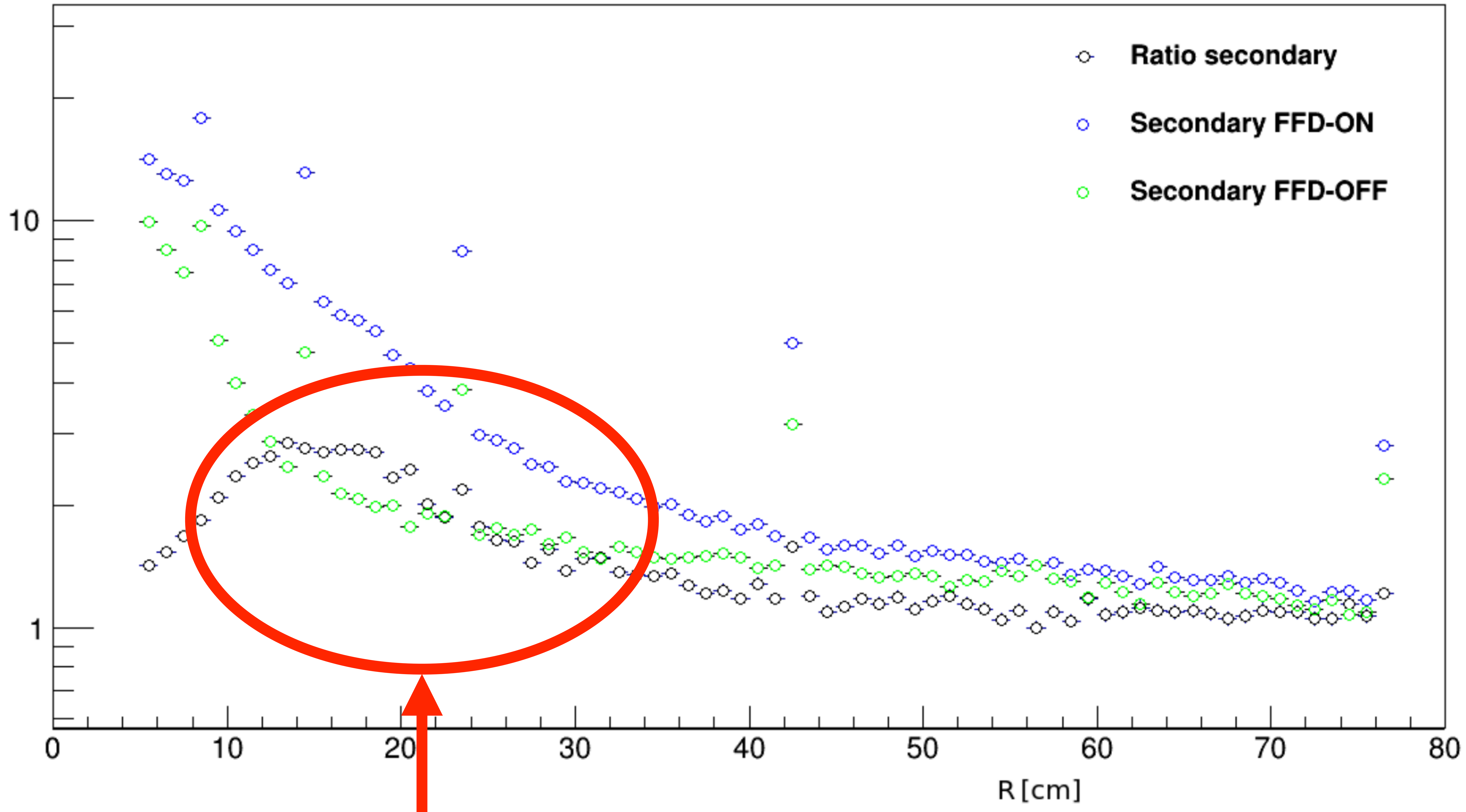
Internal Note 06-08-2020.v1 - MexNICA



$$\Psi_n^{BB} = \frac{1}{n} \tan^{-1}\left[\sum_{i=1}^{m} w_i \sin(n\varphi_i) \Big/ \sum_{i=1}^{m} w_i \cos(n\varphi_i)\right]$$

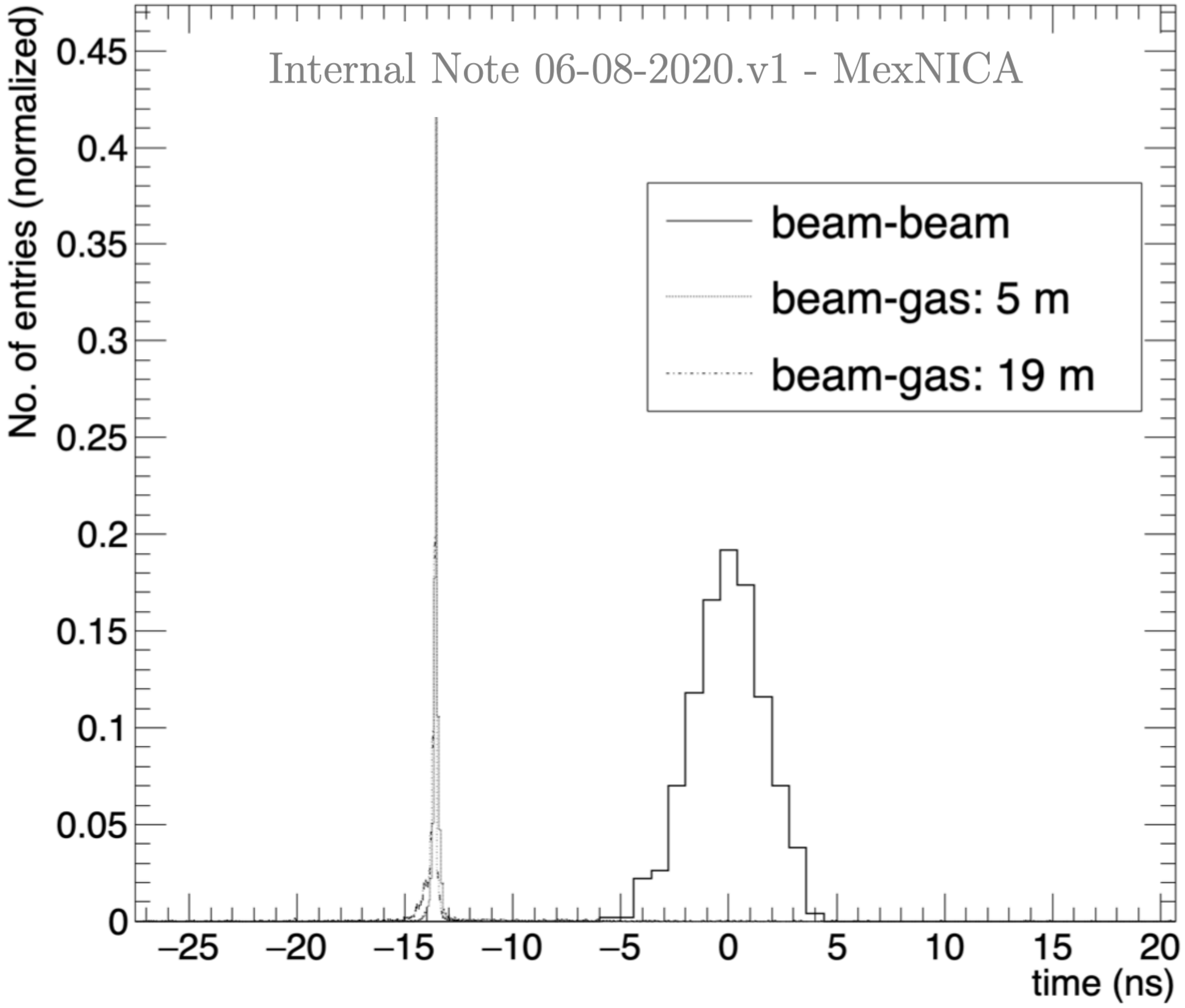
Maximum resolution between 25–45 % of centrality.

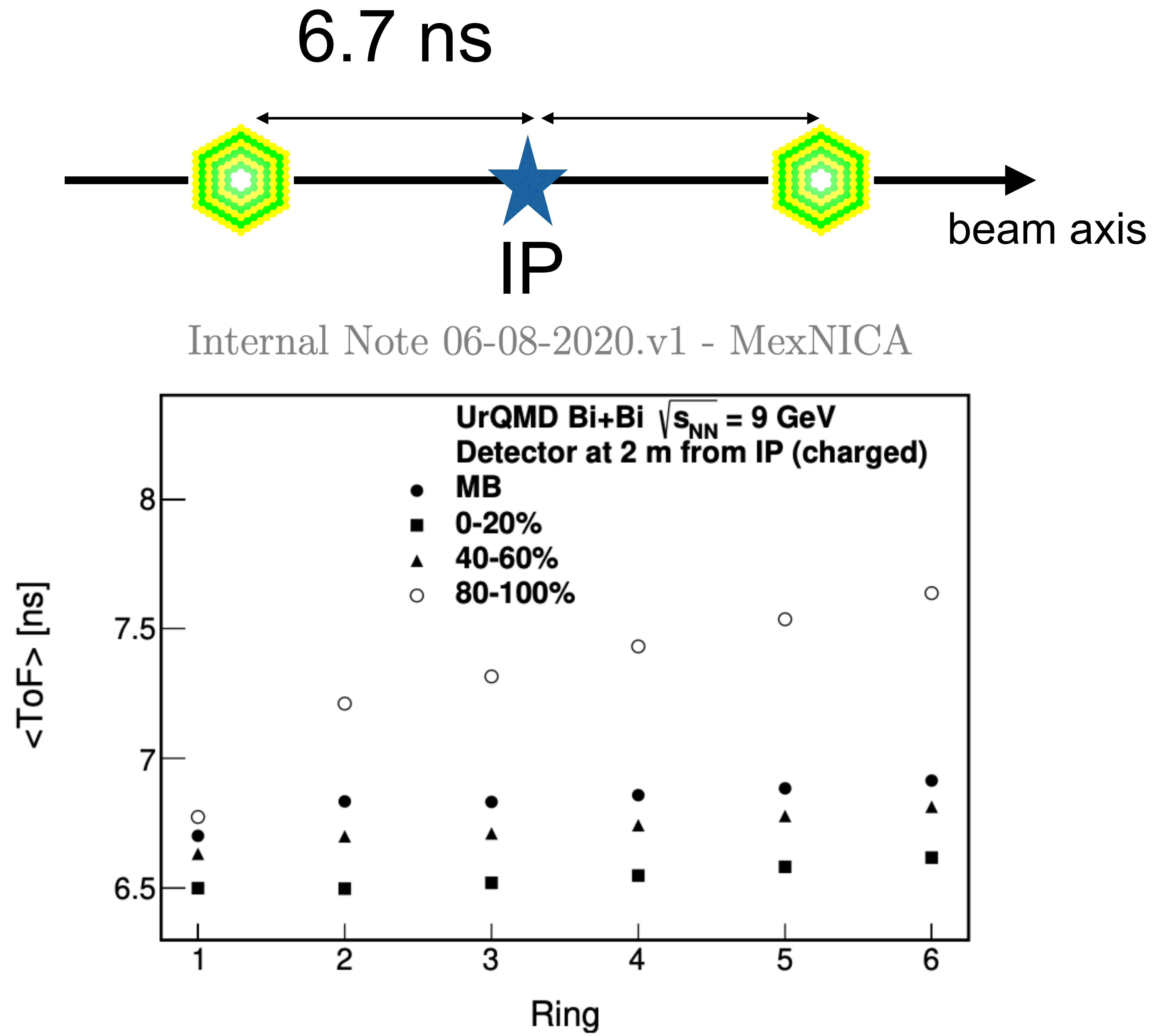
Simulation studies: hexagonal cells



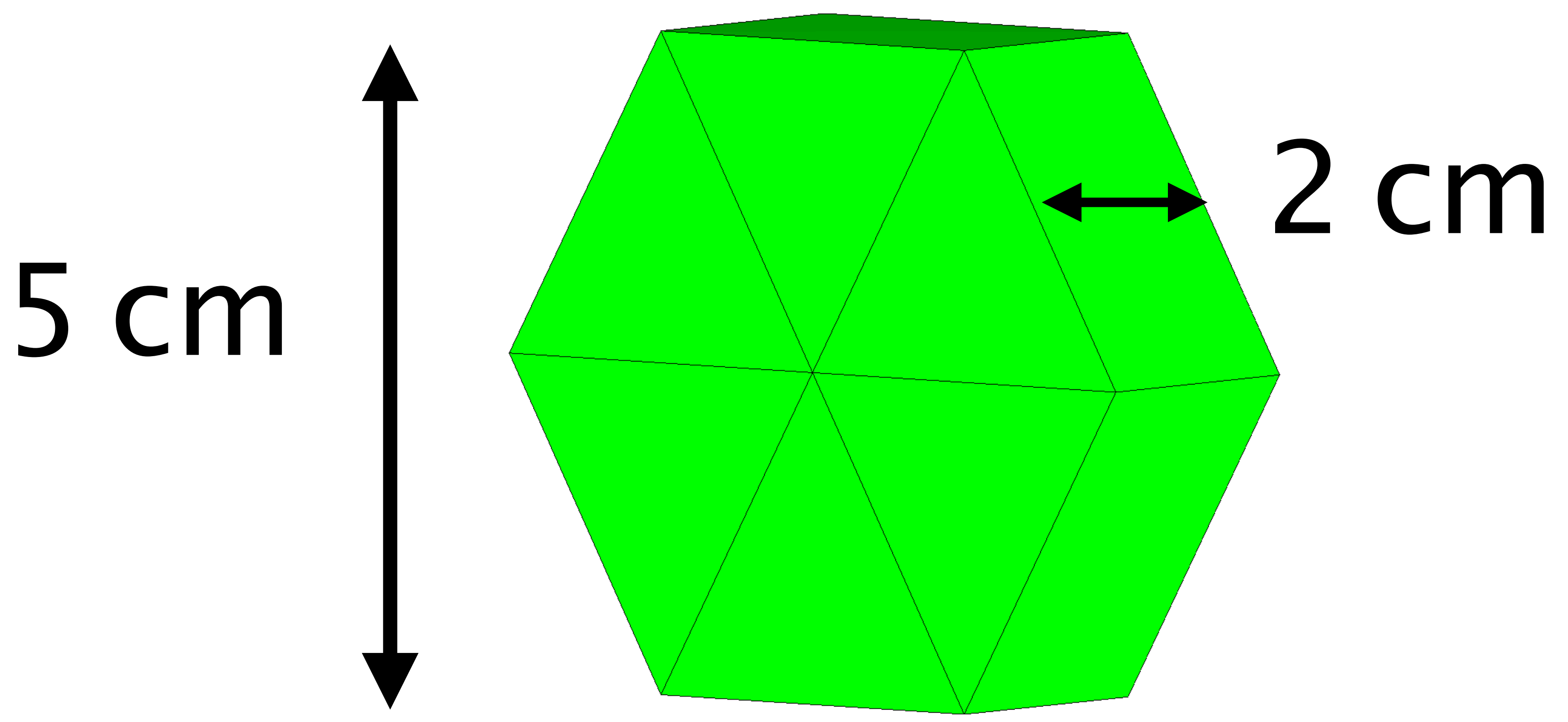
We may have a shadow from FFD

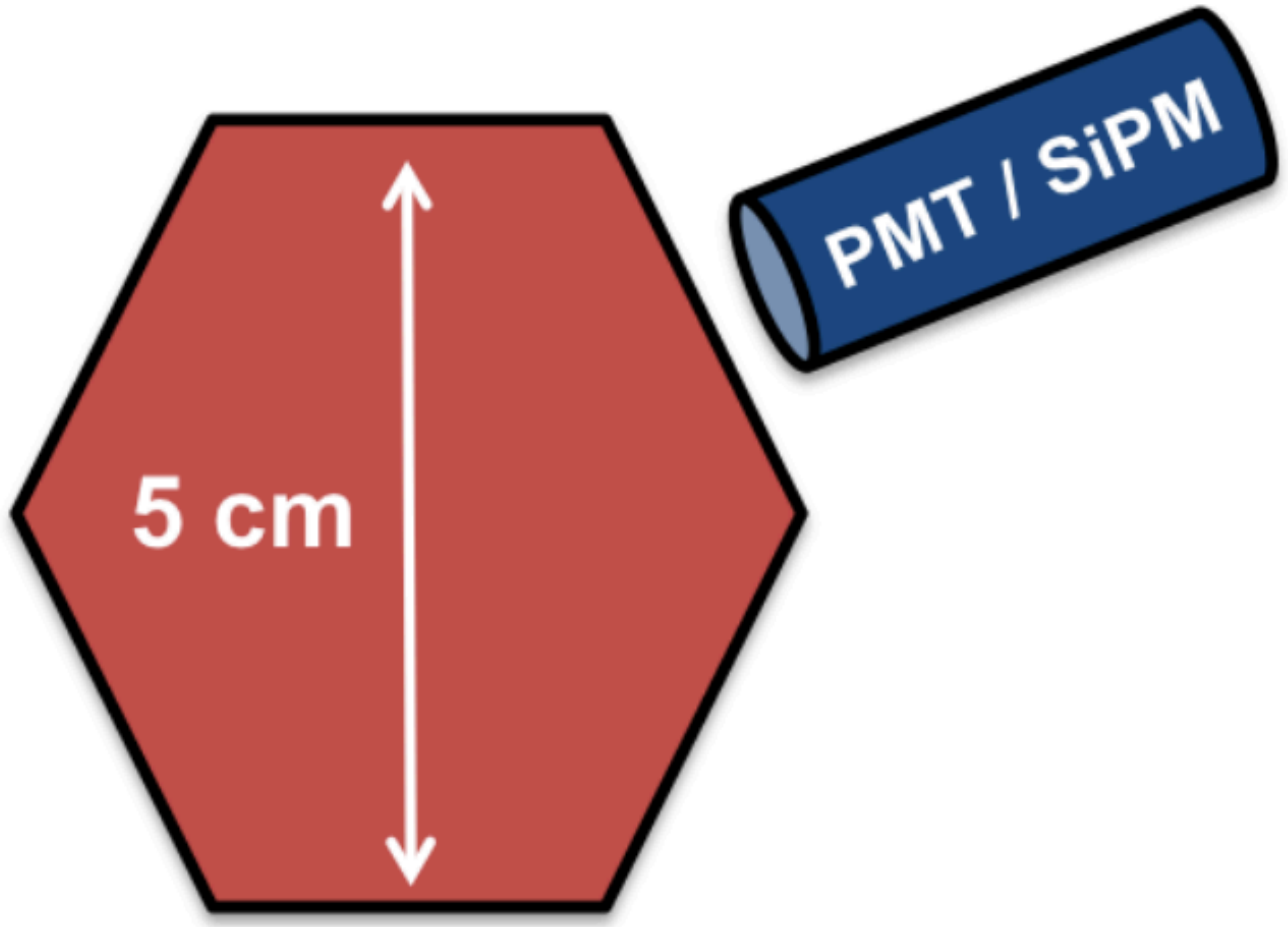
Simulation studies: hexagonal cells





Time resolution studies: hexagonal cells



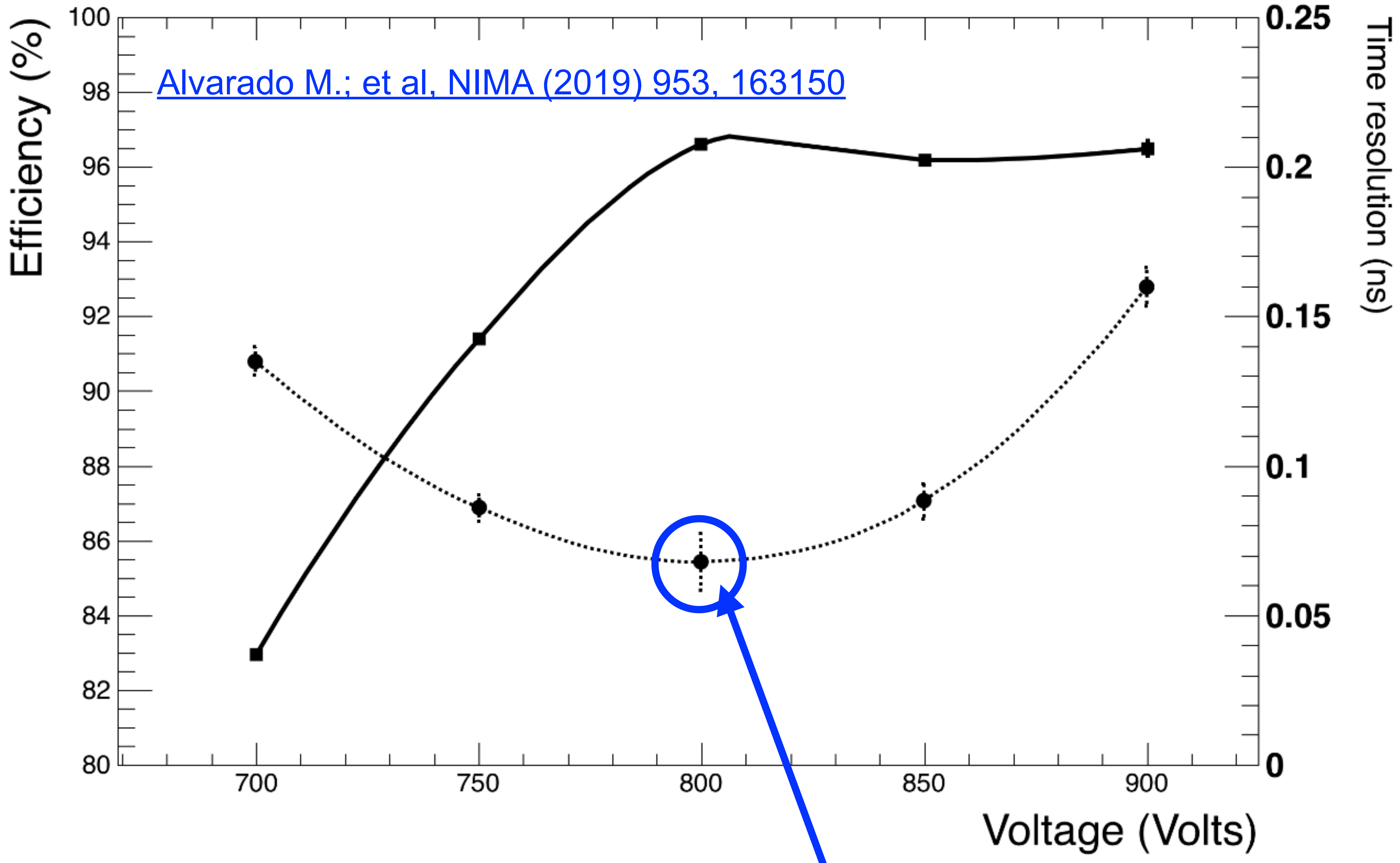


BE-BE prototype:

- hexagonal cell of 5 cm heigh and 2 cm width.
- BC-404 plastic scintillator
- evaluated at T10-CERN beam facilities (**May 2018**)
- DAQ provided by AD/VZERO ALICE groups. Same FEE as used in ALICE data taking.

Time resolution studies: hexagonal cells

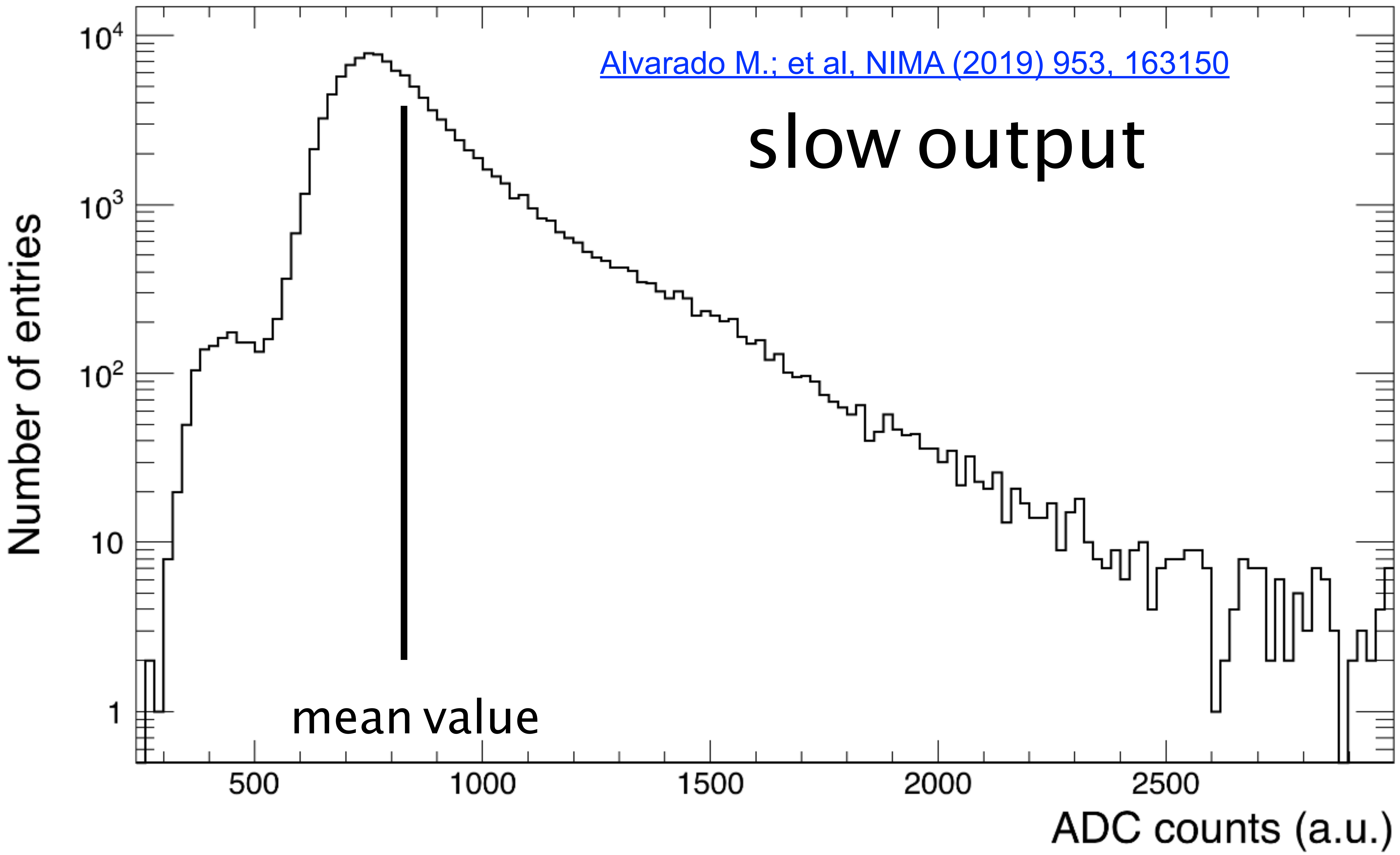
Time resolution of BE_BE prototype coupled to Hamamatsu PMT R6249



Voltage (V)	700	750	800	850	900
Time resolution (ps)	135 ± 5	86 ± 4	68 ± 5	88 ± 6	160 ± 7
χ^2/ndf	33.32/24	13.42/19	23.26/19	19.82/19	27.68/23

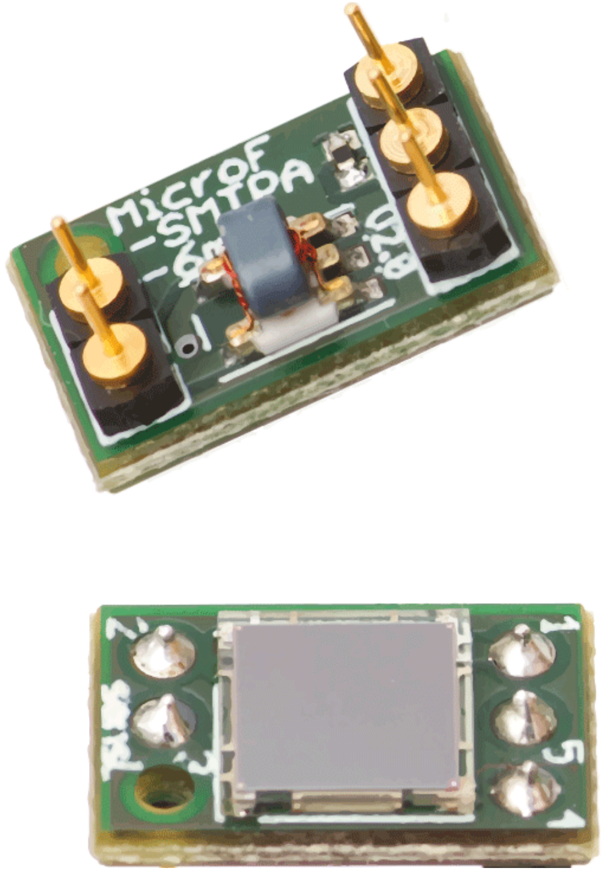
Time resolution studies: hexagonal cells

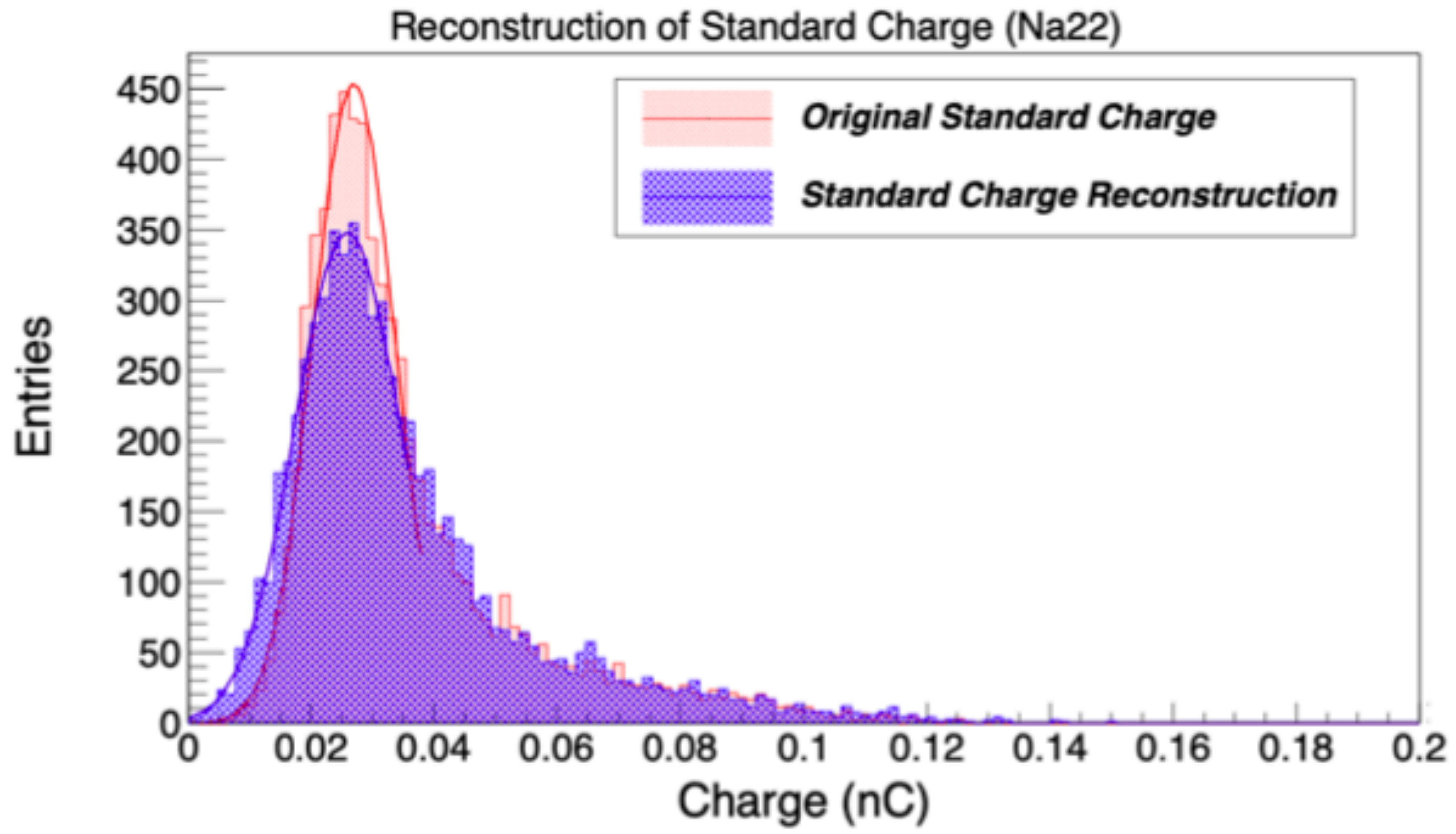
SensL (C-60035-4P-EVB) SiPM



Several ADC ranges, for slow(charge) output, were considered to compute the time resolution of BB_{p2}

1. 850 - 870
2. 840-880
3. 830-880
4. 830-890
5. 800-920
6. 700-900



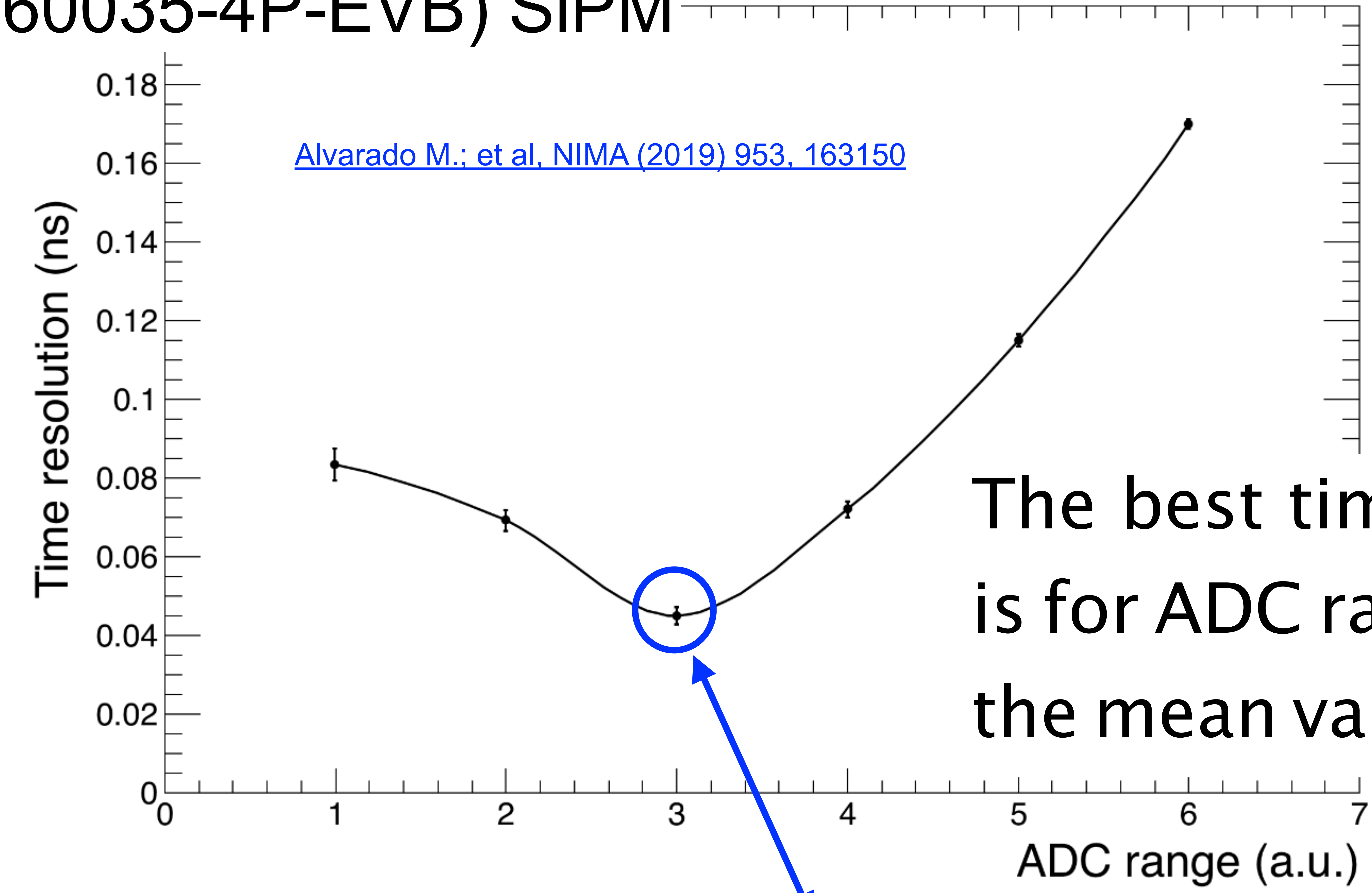


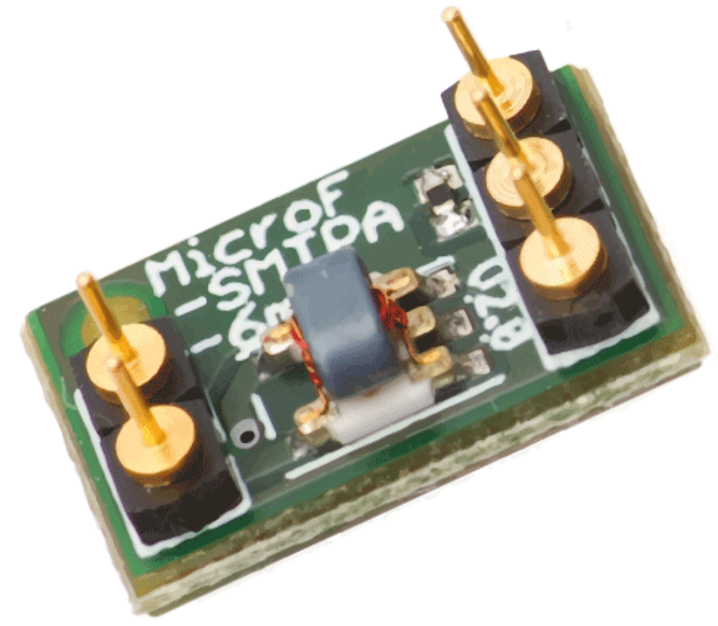
C.H. Zepeda-Fernández *et al* 2020 *JINST* **15** P09008

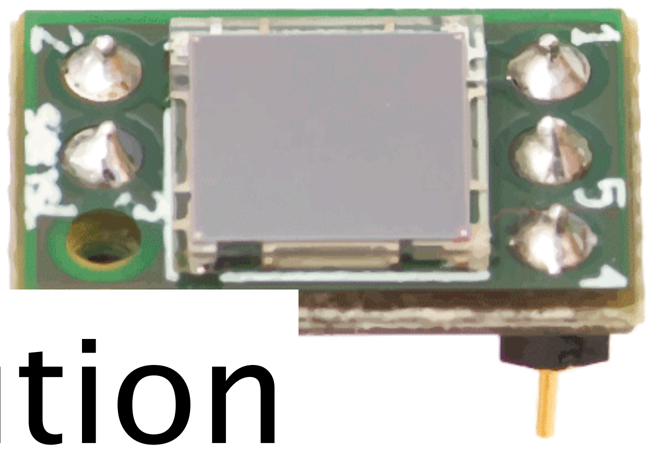
Two outputs: fast (timing) and slow (charge)

Time resolution studies: hexagonal cells

SensL (C-60035-4P-EVB) SiPM







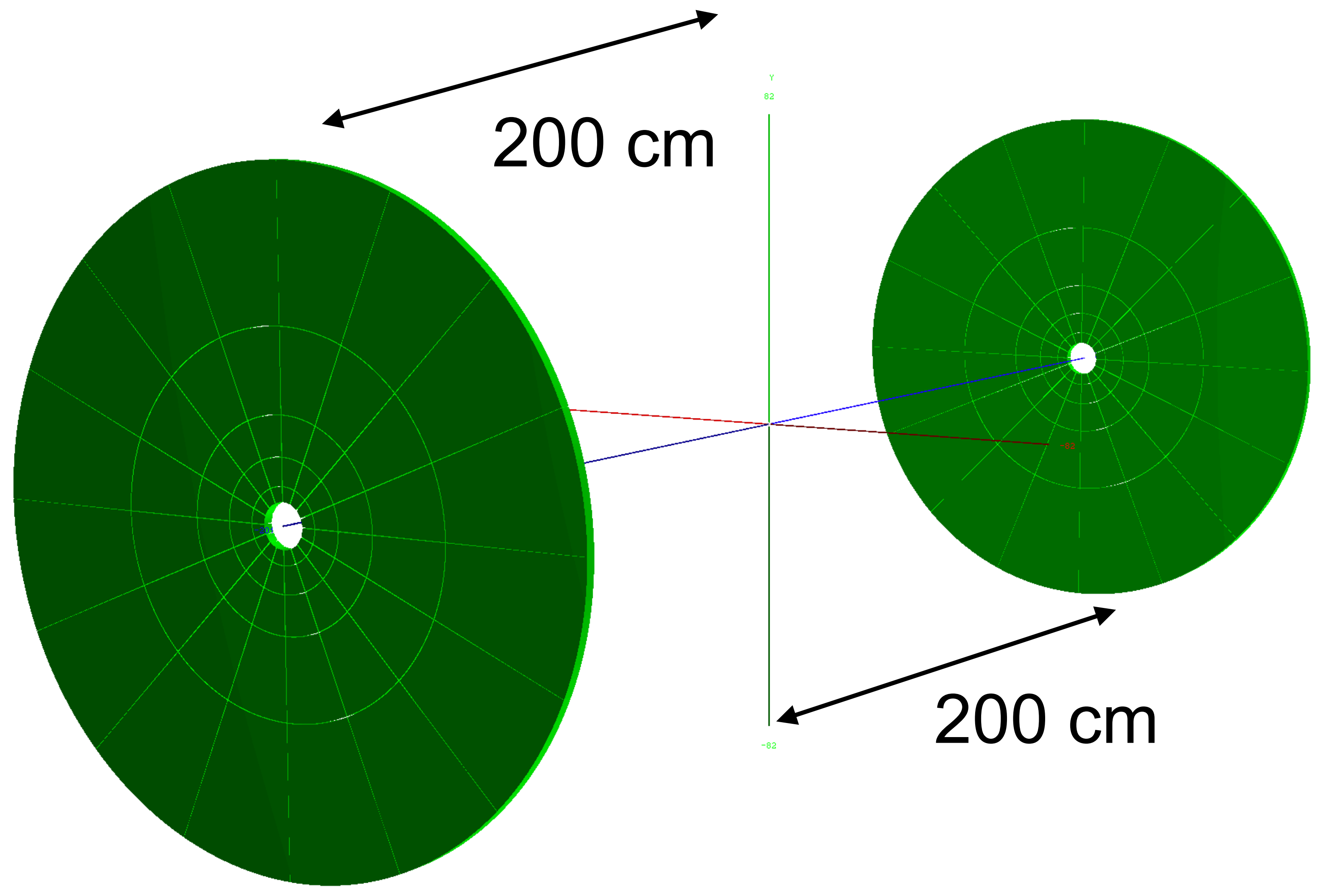
The best time resolution is for ADC ranges around the mean value

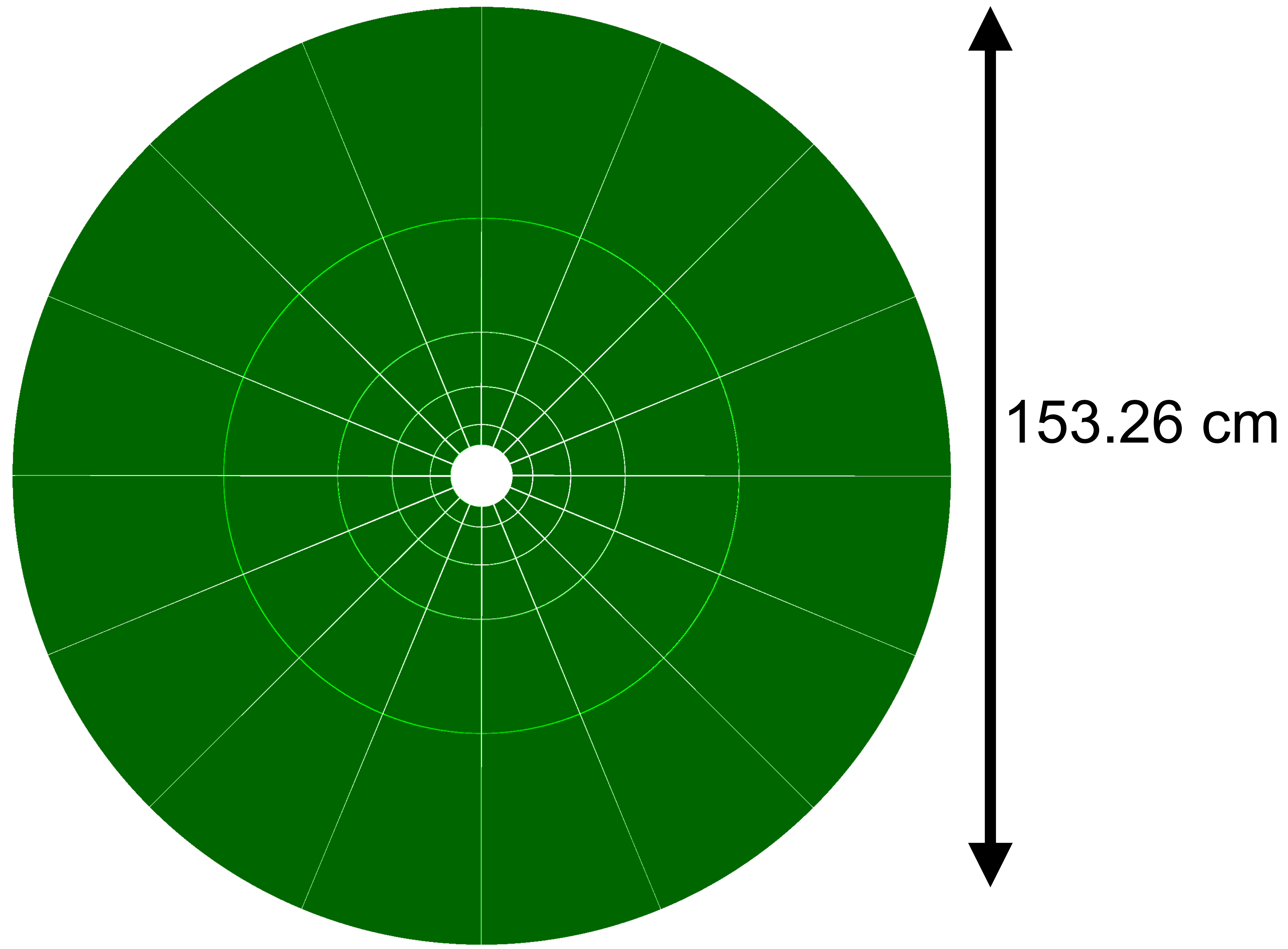
ADC range (a.u.)	850-870 (1)	840-880 (2)	830-880 (3)	830-890 (4)	800-920 (5)	700-900 (6)
Time resolution (ps)	83 ± 4	69 ± 3	45 ± 2	72 ± 2	115 ± 2	170 ± 1
χ^2**/ndf**	27.24/20	60.09/24	82.22/25	65.14/25	150.3/28	140.2/31

Detector concept: disk cells

BeBe detector

- 80 cells per side (1 cm width)
- five concentric rings
- plastic scintillator BC404
- $1.68 < |\eta| < 4.36$
- photosensors: SiPM or PMT (do be decided)

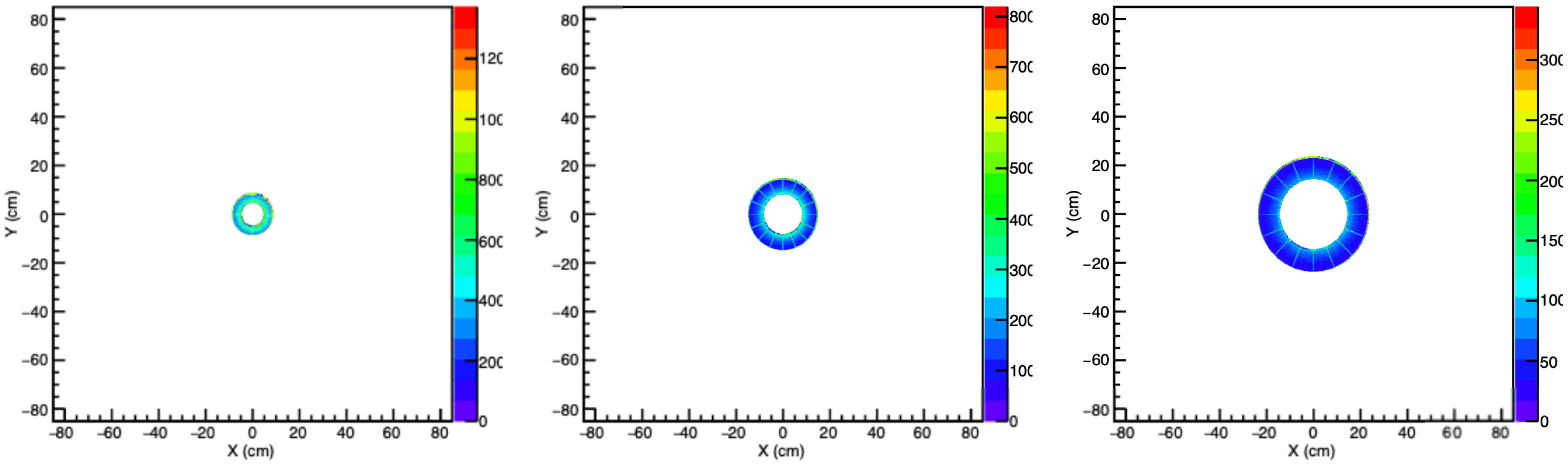


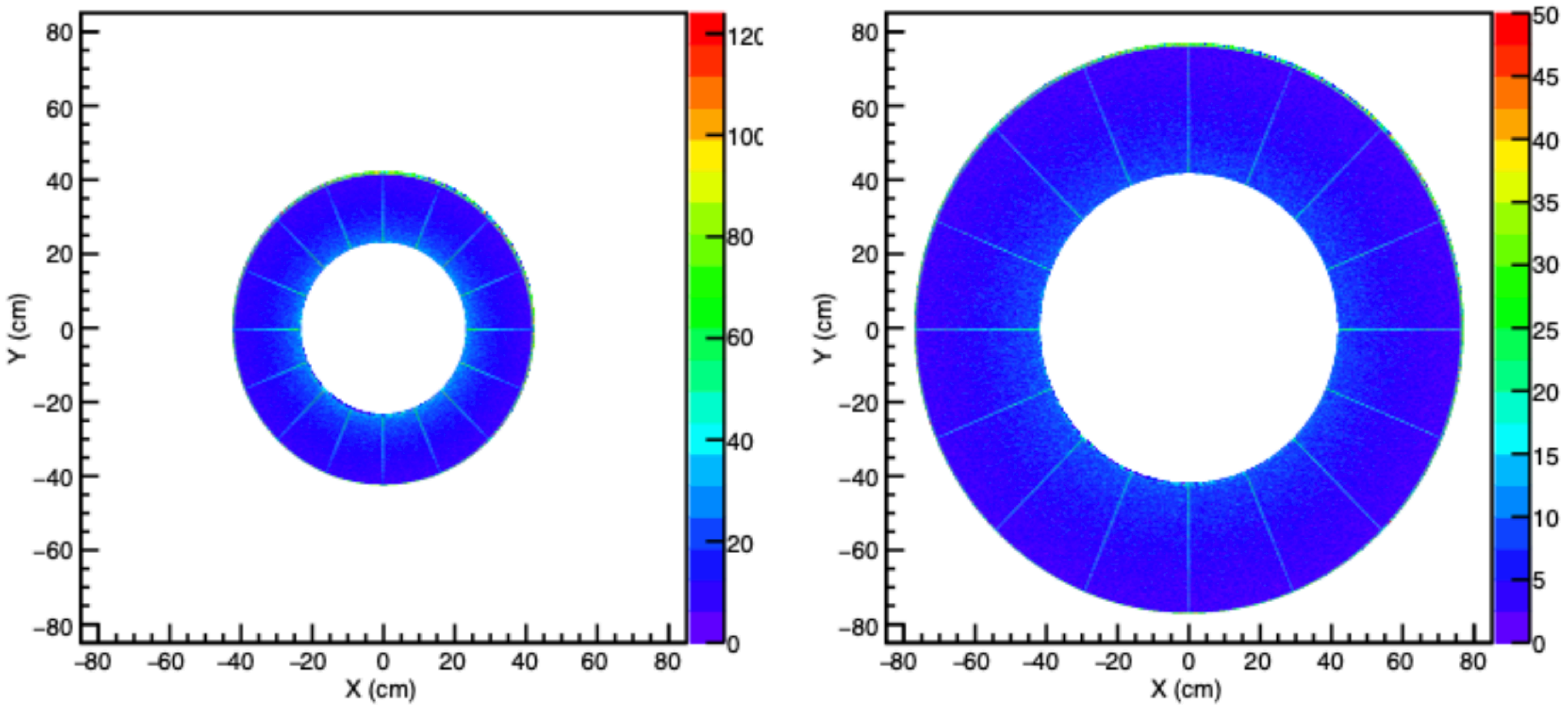


The construction of centrality classes and beam-gas studies with this geometry is a work in progress. A similar physics performance w.r.t. hexagonal geometry is expected.

Simulation studies: disk cells

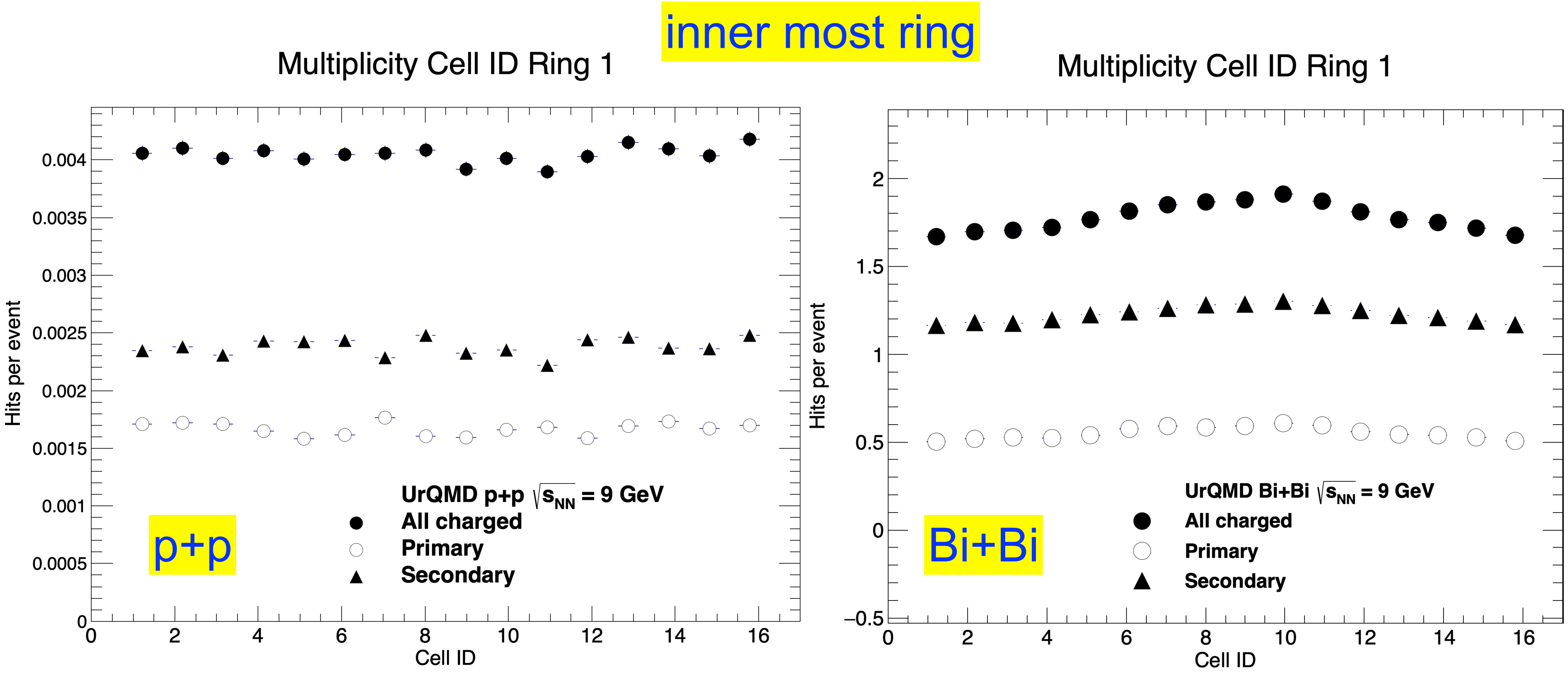
inner most ring





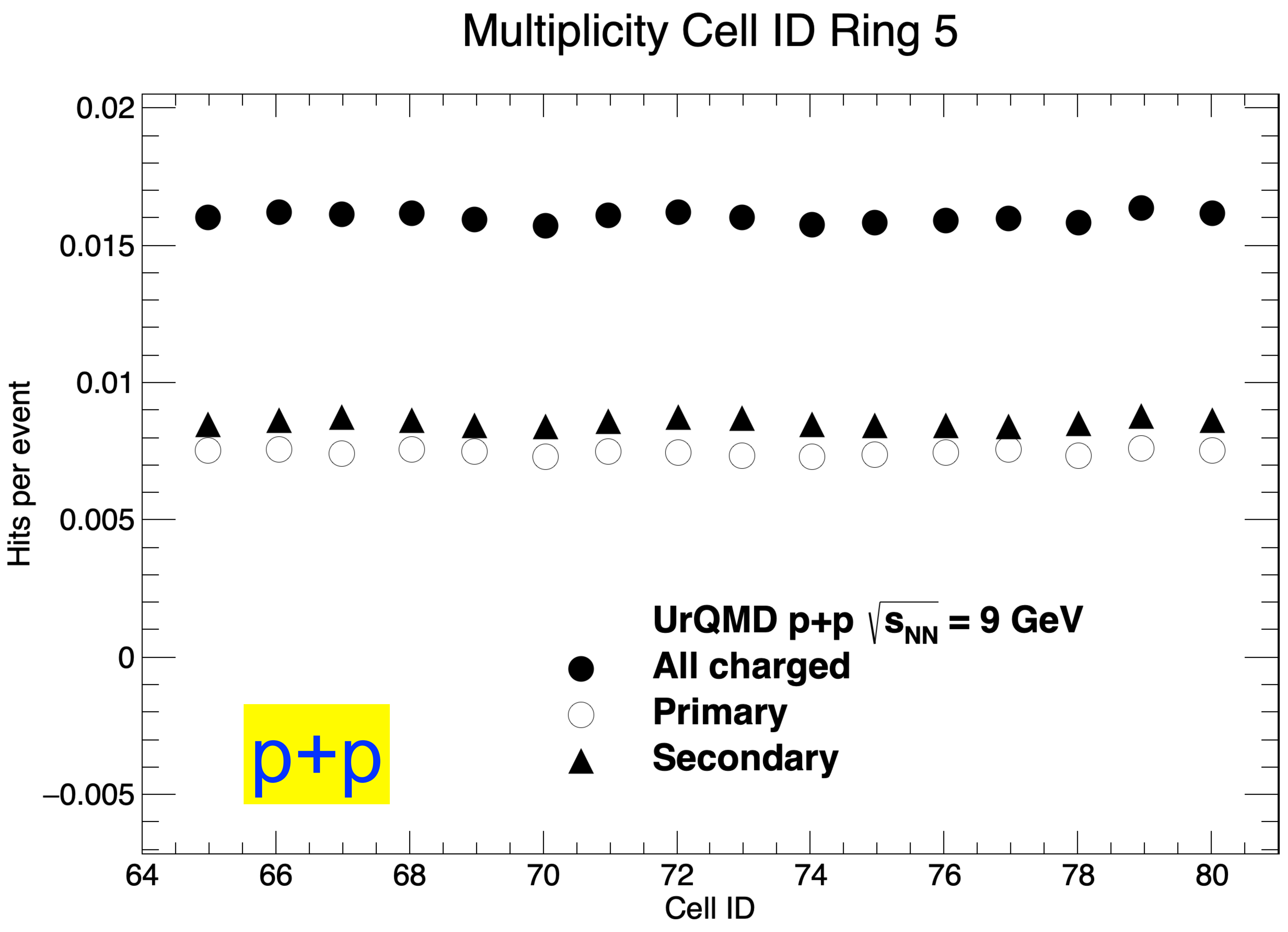
outer most ring

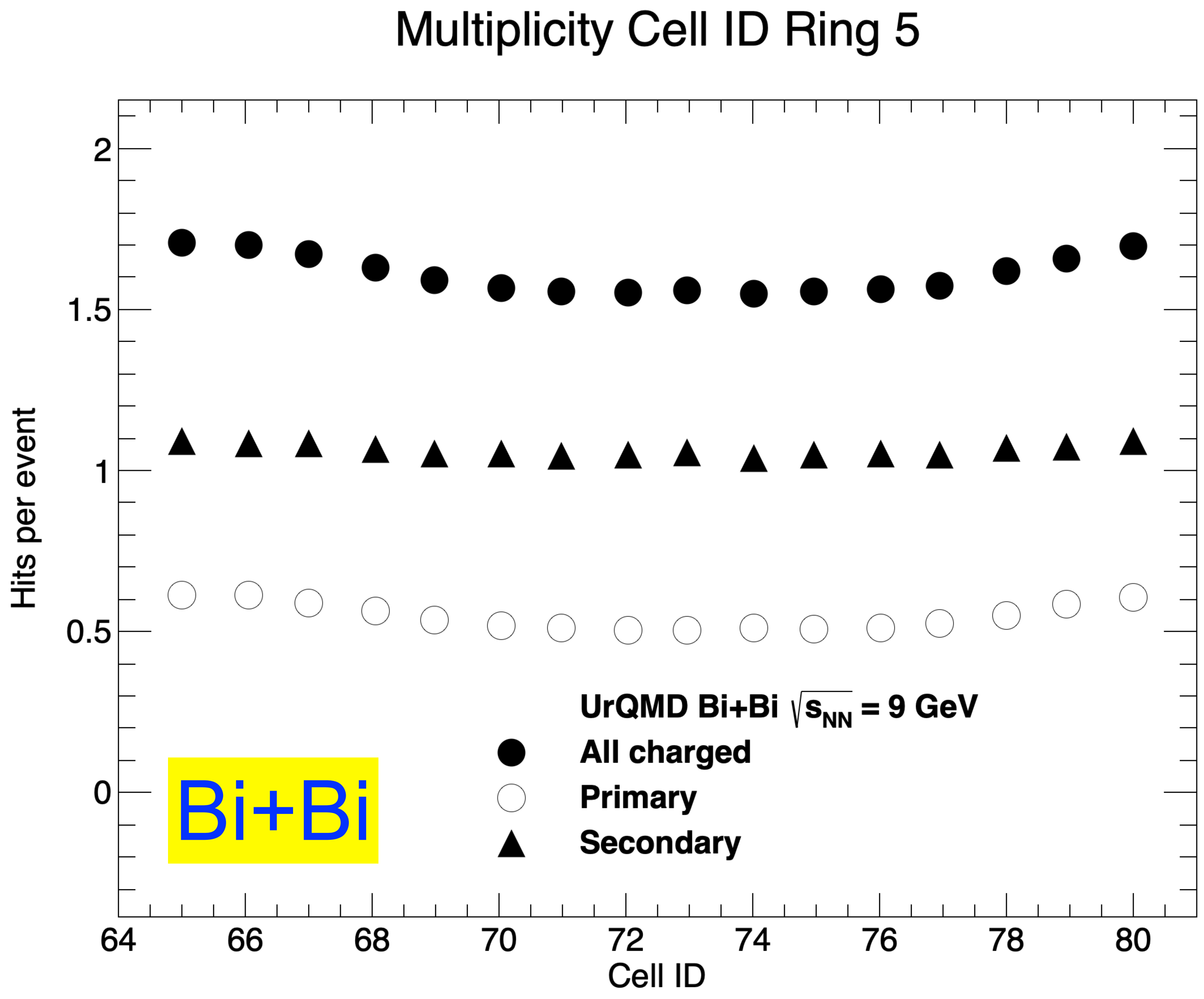
Simulation studies: disk cells



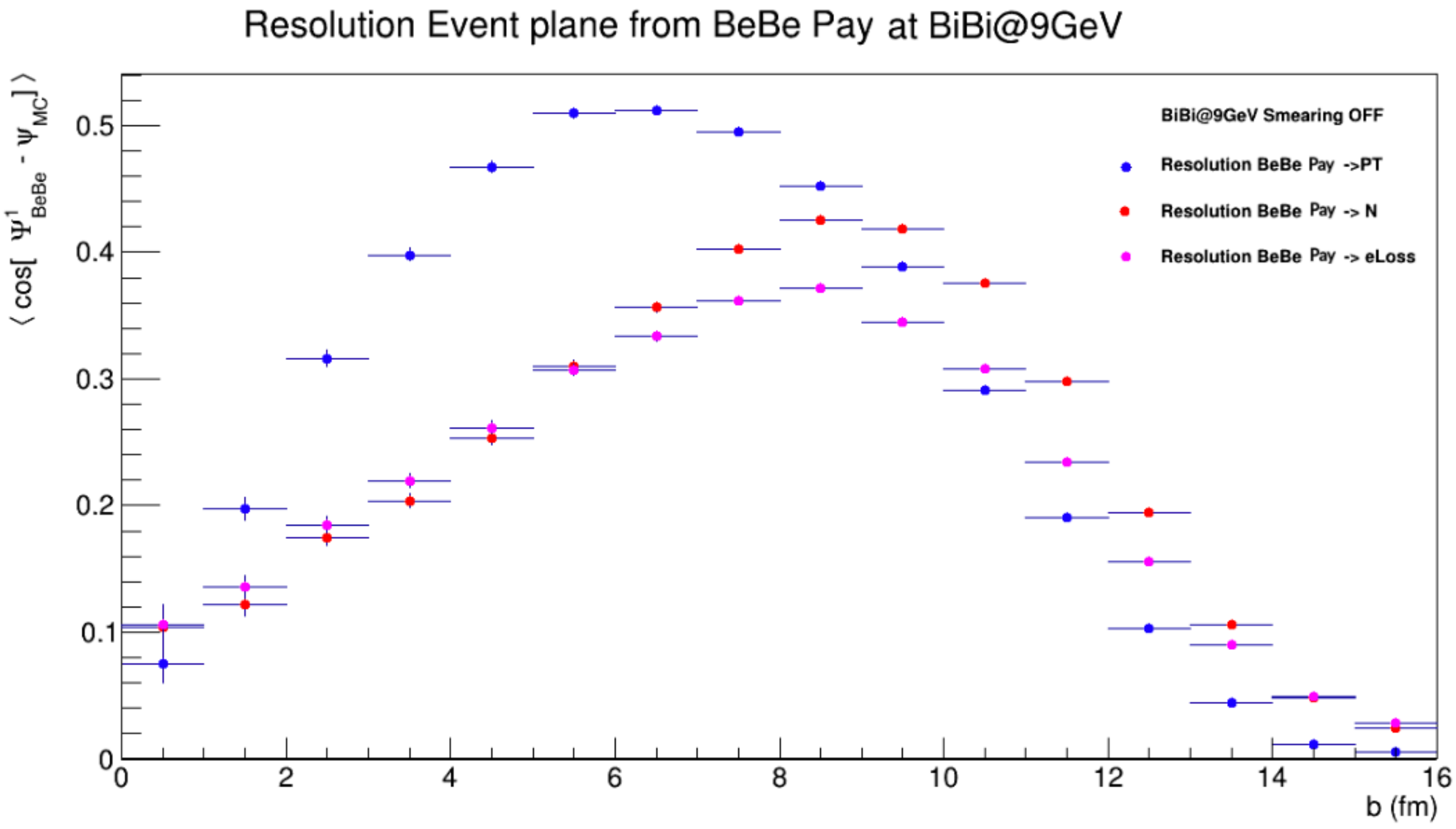
Simulation studies: disk cells

outer most ring



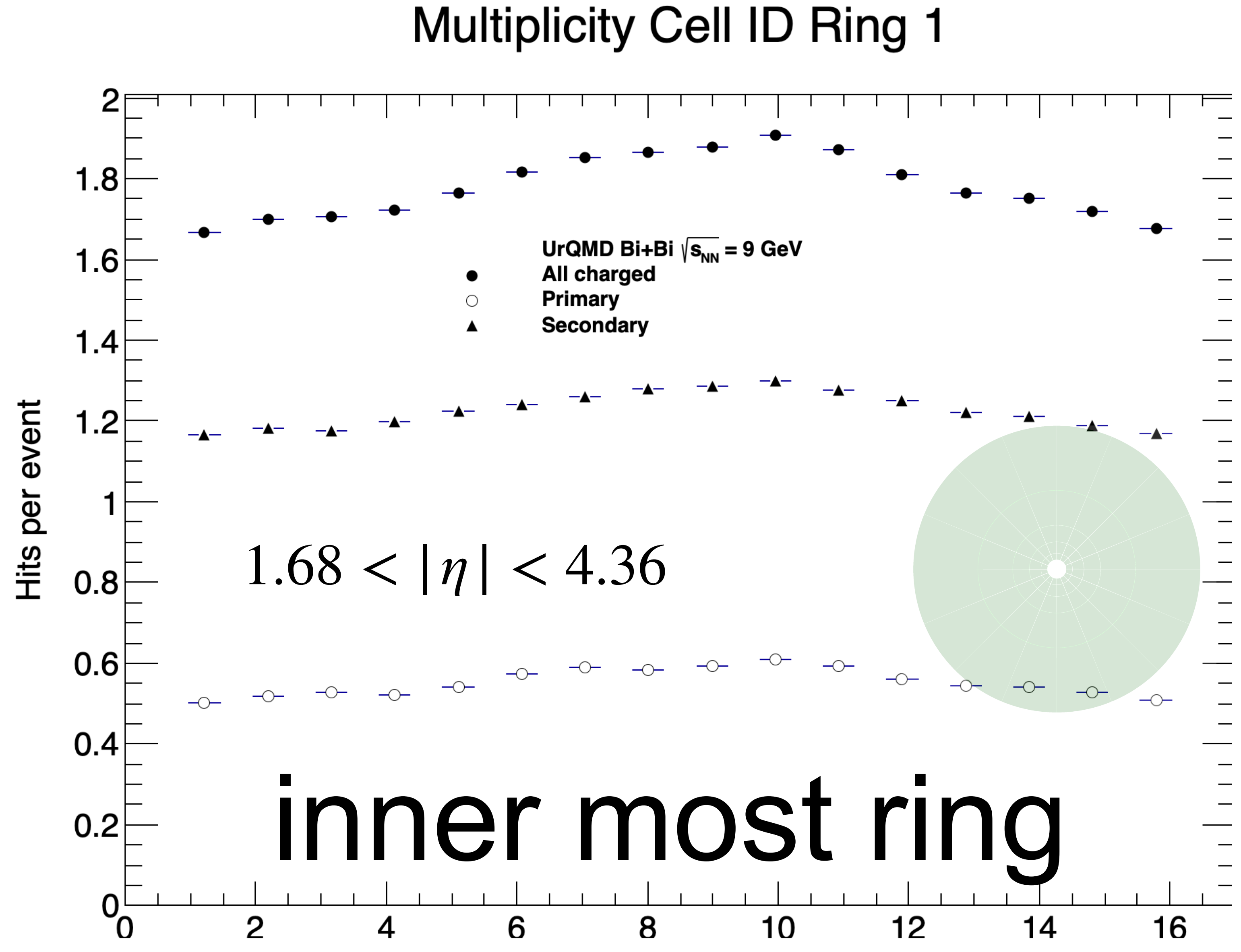


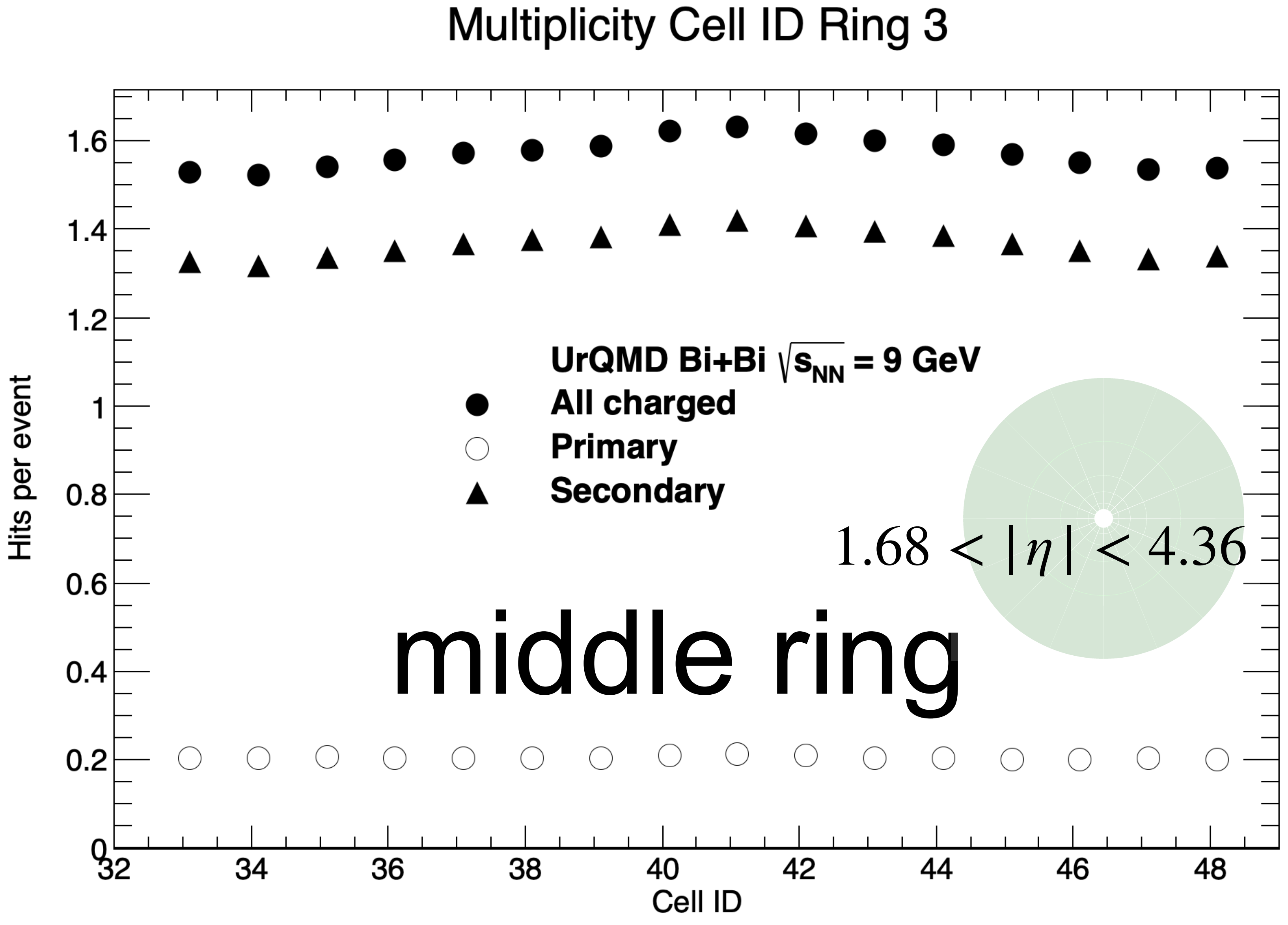
Simulation studies: disk cells

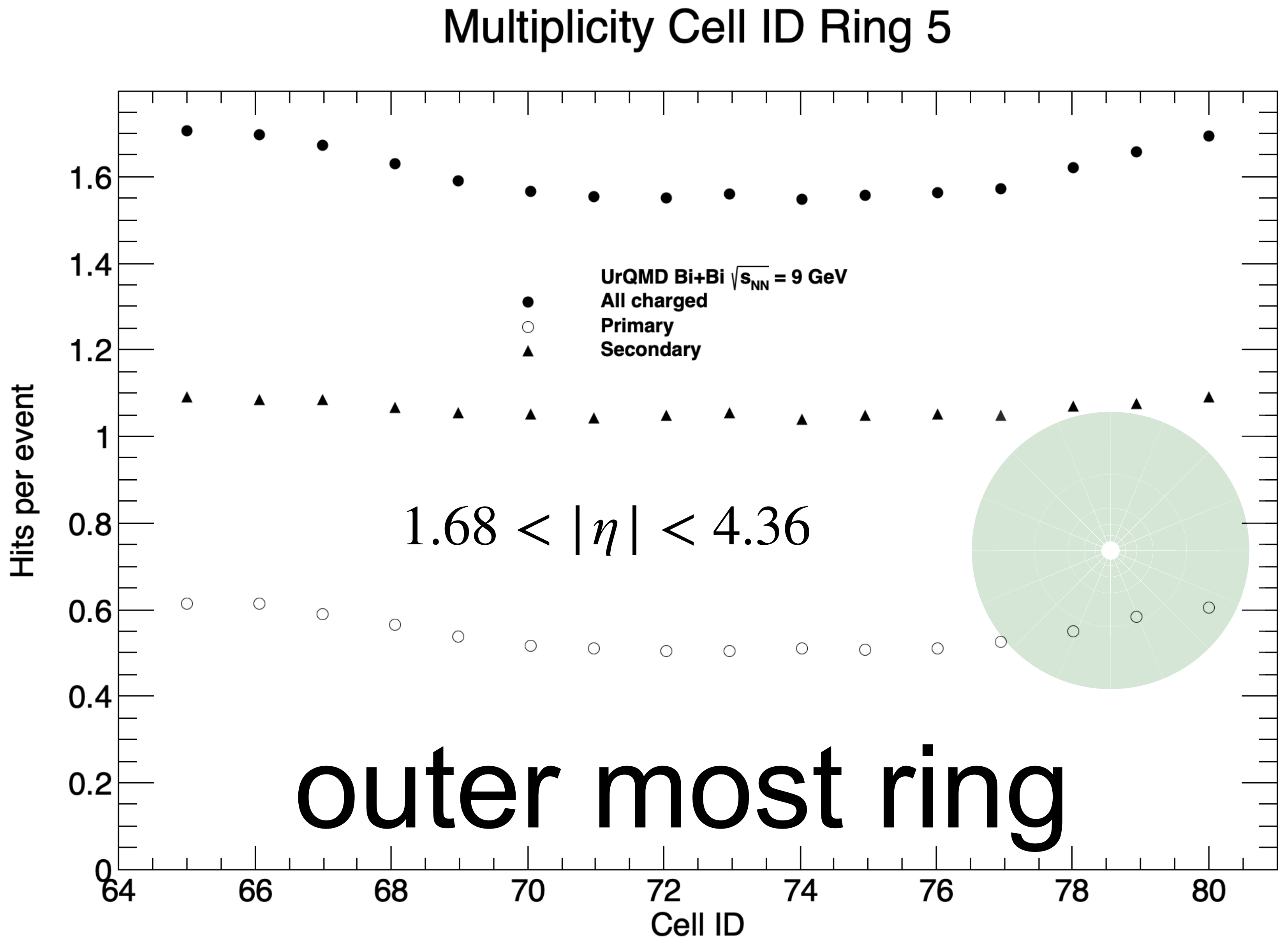


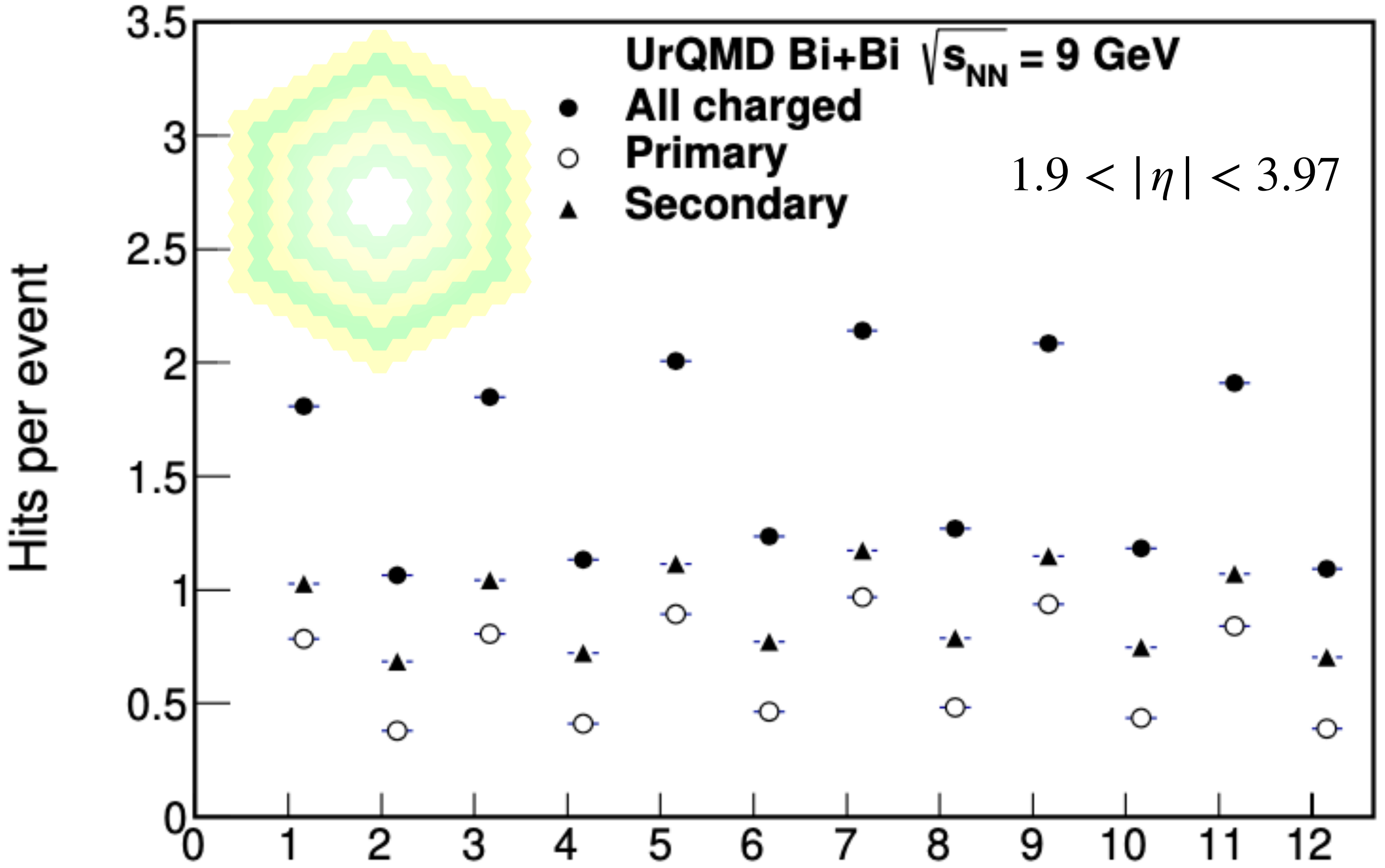
Simulation studies: disk VS hexagonal cells

Bi+Bi

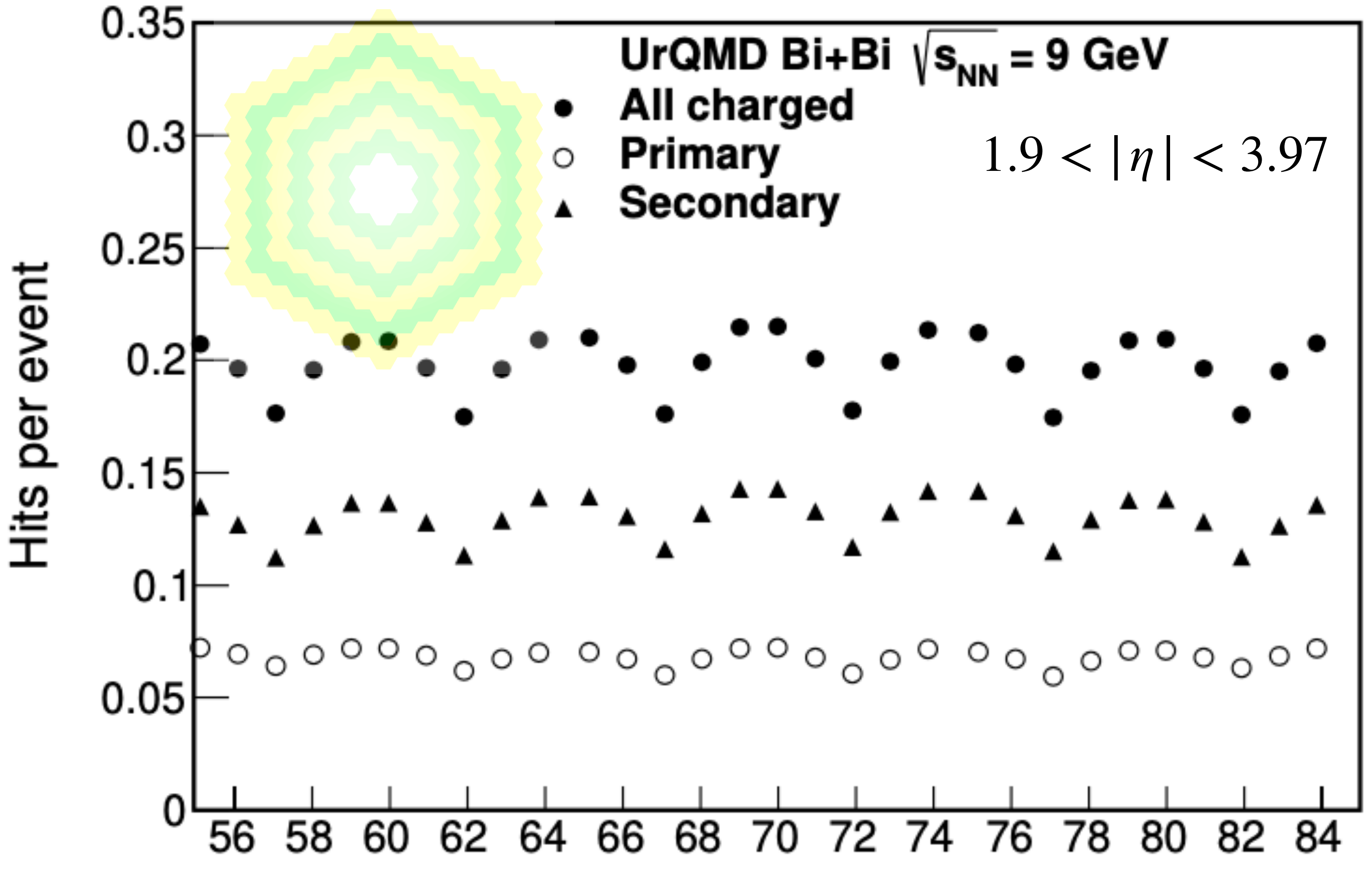




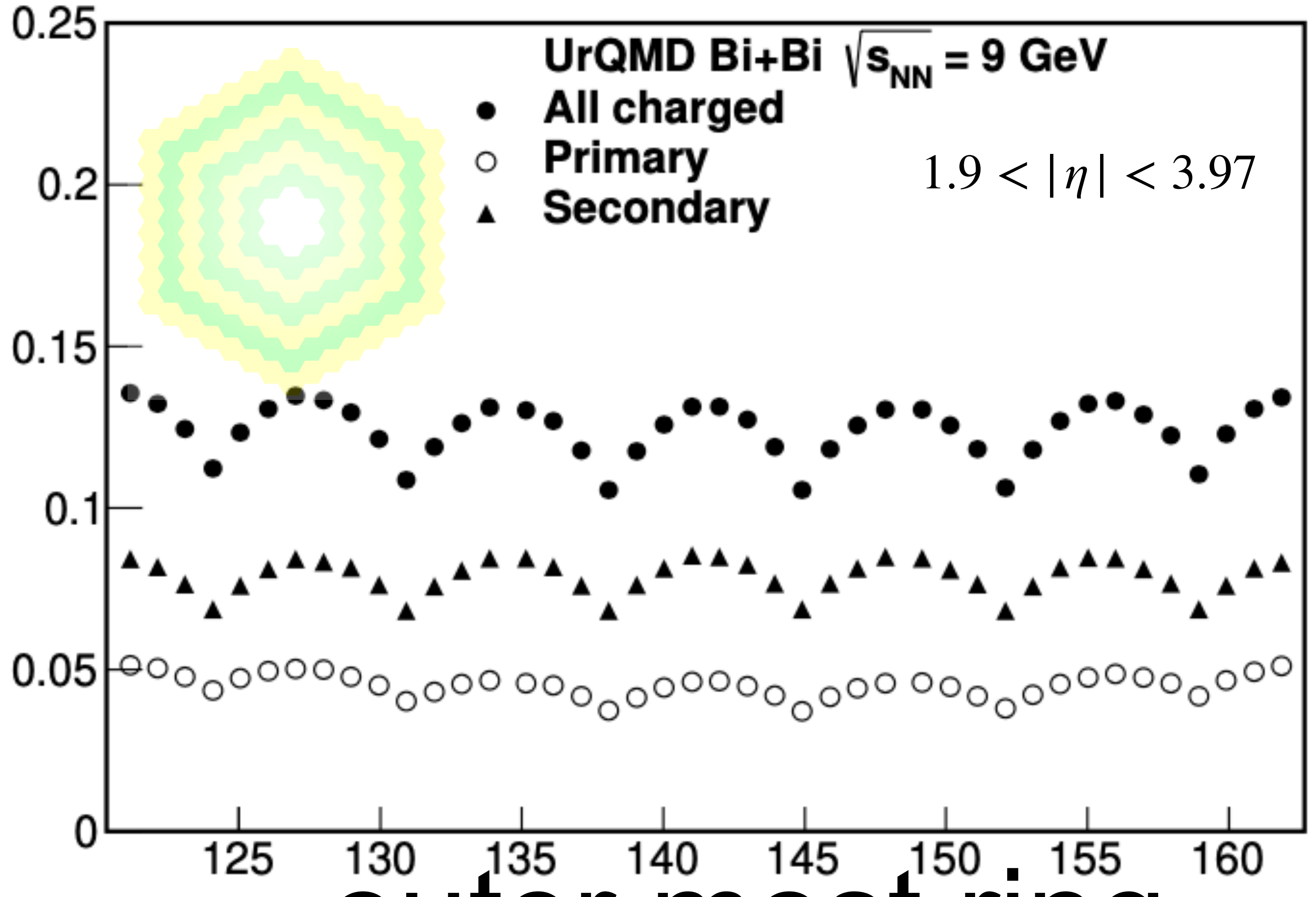




inner most ring

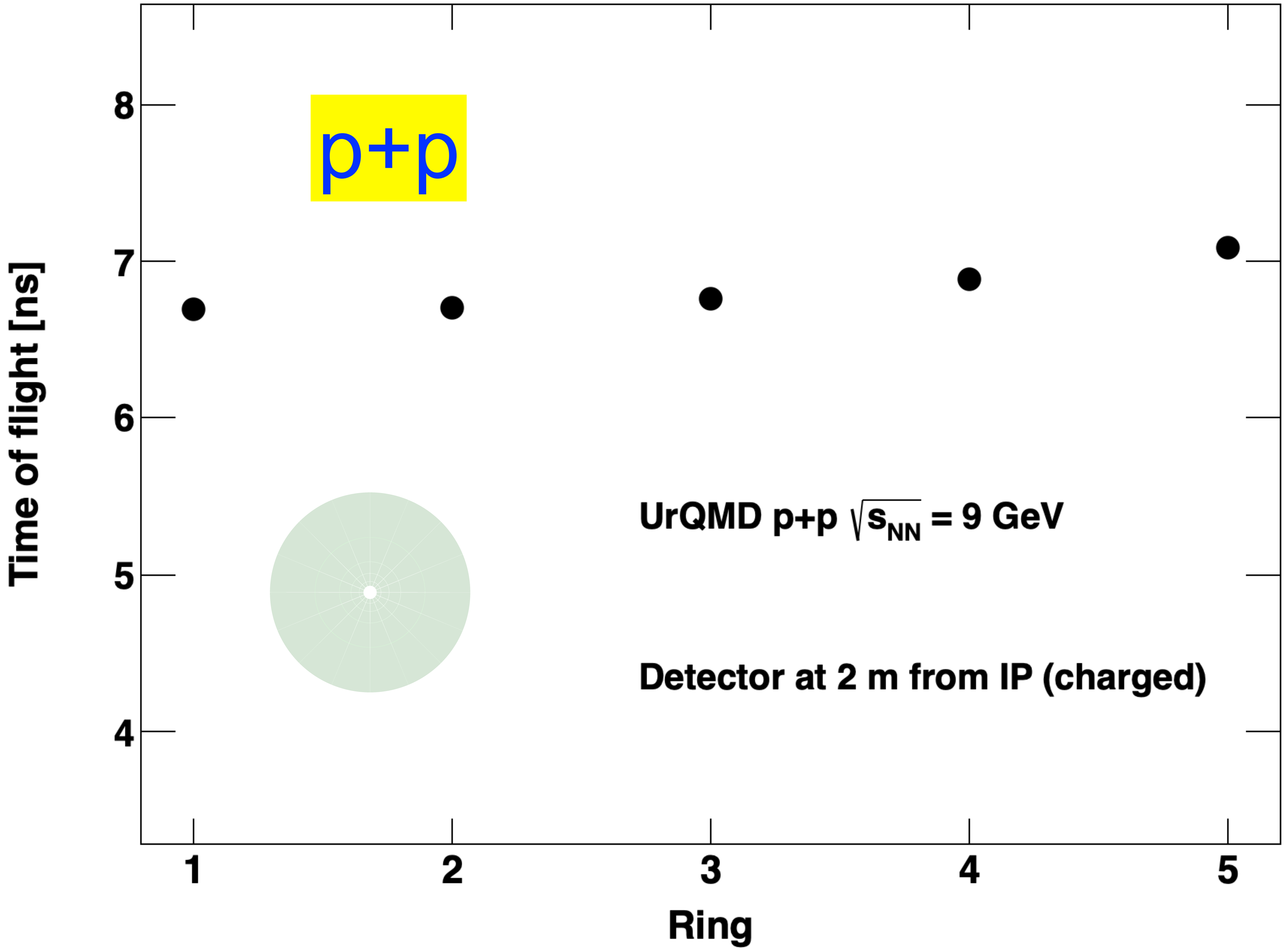


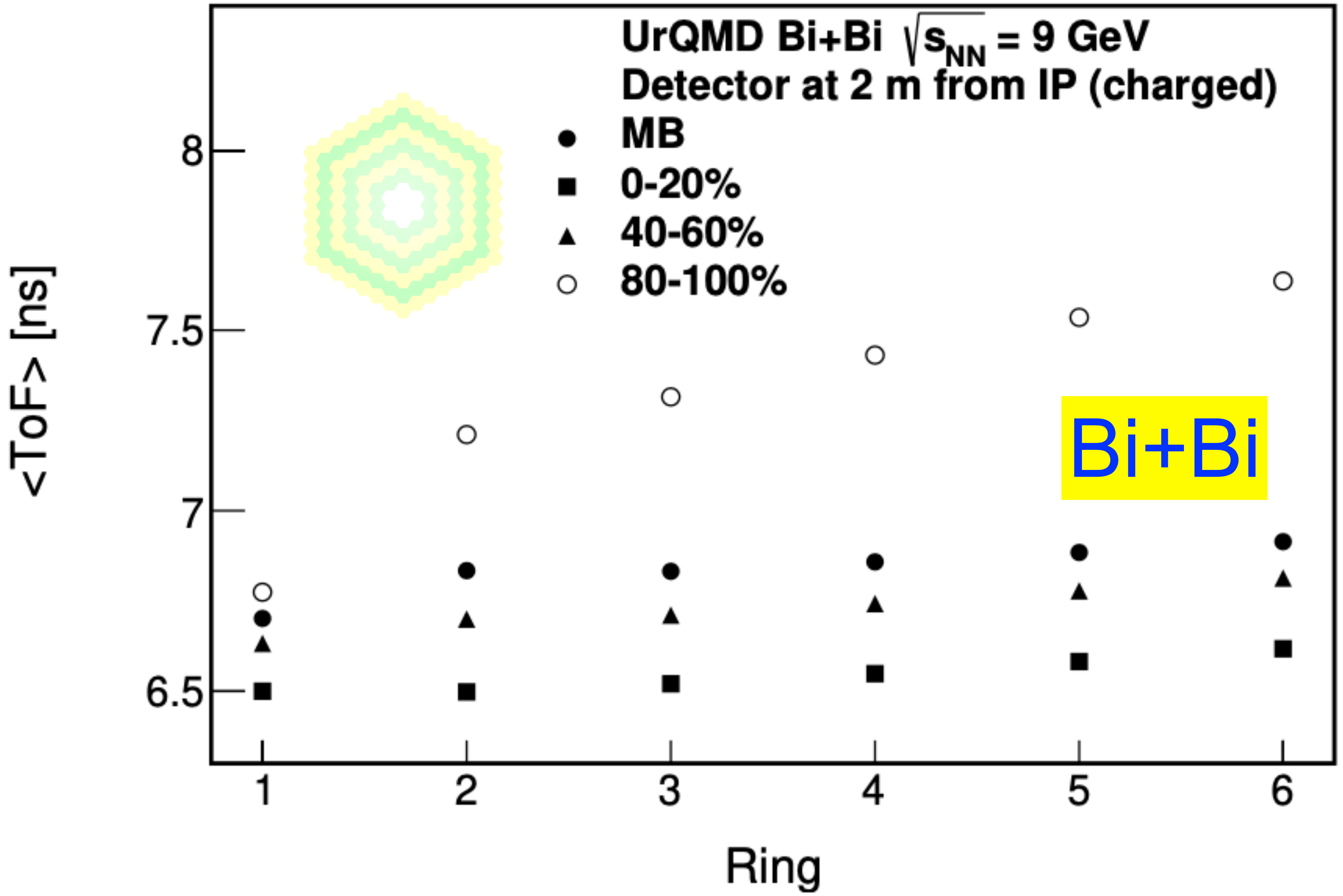
middle ring



outer most ring

Simulation studies: disk VS hexagonal cells

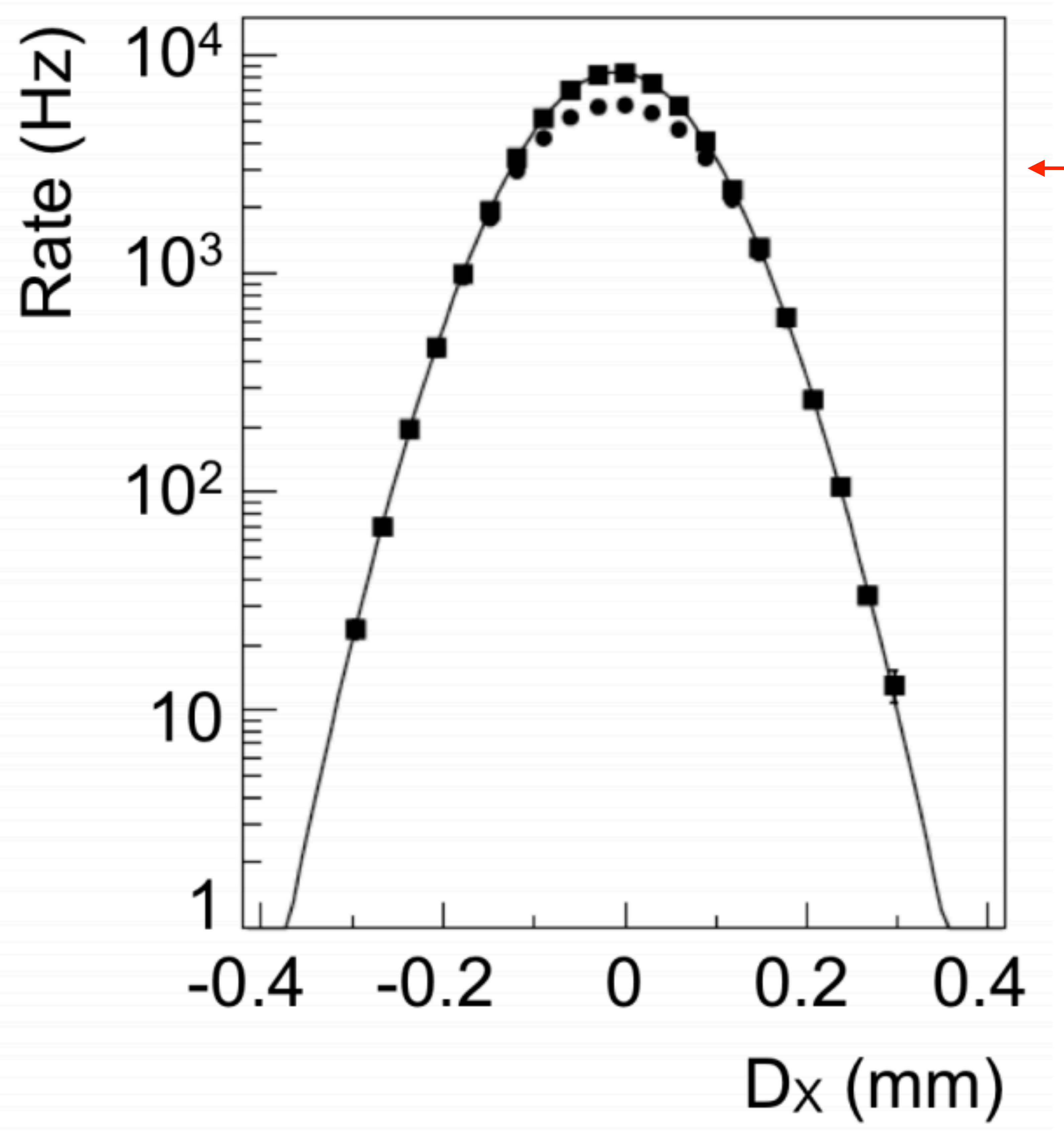




With the time information, either disks or hexagons, we can define a time window to set a beam-beam trigger (BB) for both BeBe hodoscopes (Z>0 and Z<0). This is crucial for beam monitoring tasks.

¿BeBe for luminosity measurements?

In ALICE, the on-line monitoring of the luminosity uses a time coincidence between the two VZERO arrays.



time resolution of VZERO system: 1 ns

The rate corresponding to the coincidence between VZERO-A and VZERO-C signals is named MBAND. The luminosity and therefore the rate of $MB_{AND}(Dx,Dy)$ are functions of the transverse displacements Dx and Dy of the beams.

$$\mathscr{L} = k_b f N_1 N_2 Q_x Q_y \quad \text{and} \quad \sigma_{\mathrm{MB_{AND}}} = \mathrm{MB_{AND}}(0,0)/\mathscr{L},$$

N_1 and N_2 beams intensities

k_b is the number of colliding bunches

$f = 11.2455$ kHz the LHC revolution frequency.

Key issue: trigger efficiency of the Minimum Bias trigger.

JINST 8 (2013) P10016

¿BeBe for luminosity measurements?

http://cds.cern.ch/record/1281333/files/ATLAS-CONF-2010-060.pdf

ATLAS

3.2 LUCID

Online luminosity values from LUCID measurements are obtained from the LUMAT card. At present there are four algorithms implemented in the LUMAT firmware:

- LUCID_Zero_AND, the number of events per BCID when no hits are found in either detector arm;
- LUCID_Zero_OR, the number of events per BCID when at least one of the two detector arms has no hits or when neither arm contains any hit;
- LUCID_Hit_AND, the number of hits when there is at least one hit in each of the two detector arms;
- LUCID_Hit_OR, the number of hits when there is at least one hit in the 32 tubes of both detector arms.

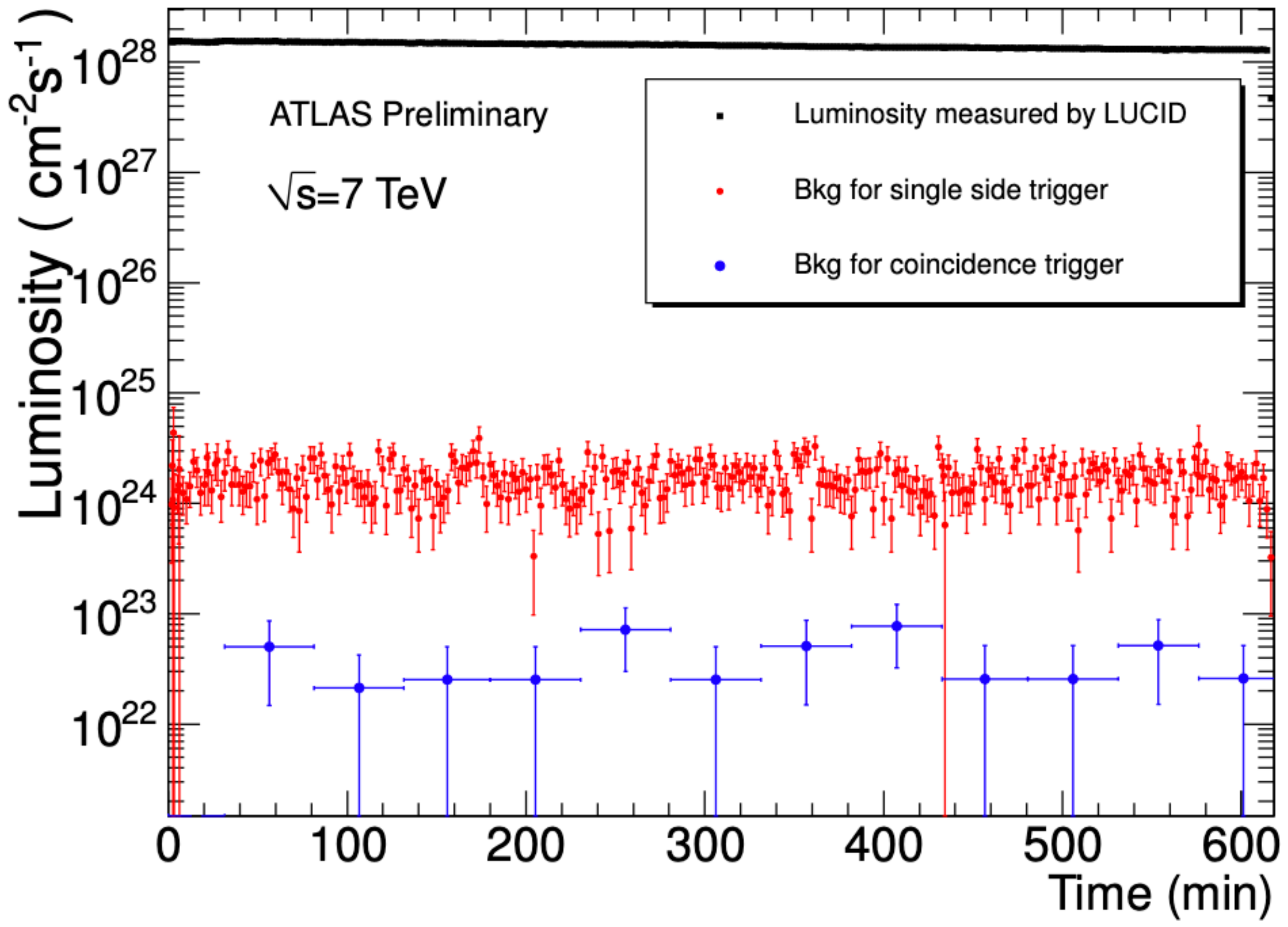
$$\mathscr{L} = \frac{\mu n_b f_r}{\sigma_{inel}} = \frac{\mu^{meas} n_b f_r}{\varepsilon \sigma_{inel}} = \frac{\mu^{meas} n_b f_r}{\sigma_{vis}}$$

- LUCID_Event_AND, the number of events with at least one hit in each detector arm. The LUCID_Event_AND probability per beam crossing $P^{\text{LUCID\_Event\_AND}}$ is related to the LUCID_Zero_OR probability per beam crossing $P^{\text{LUCID\_Zero\_OR}}$:

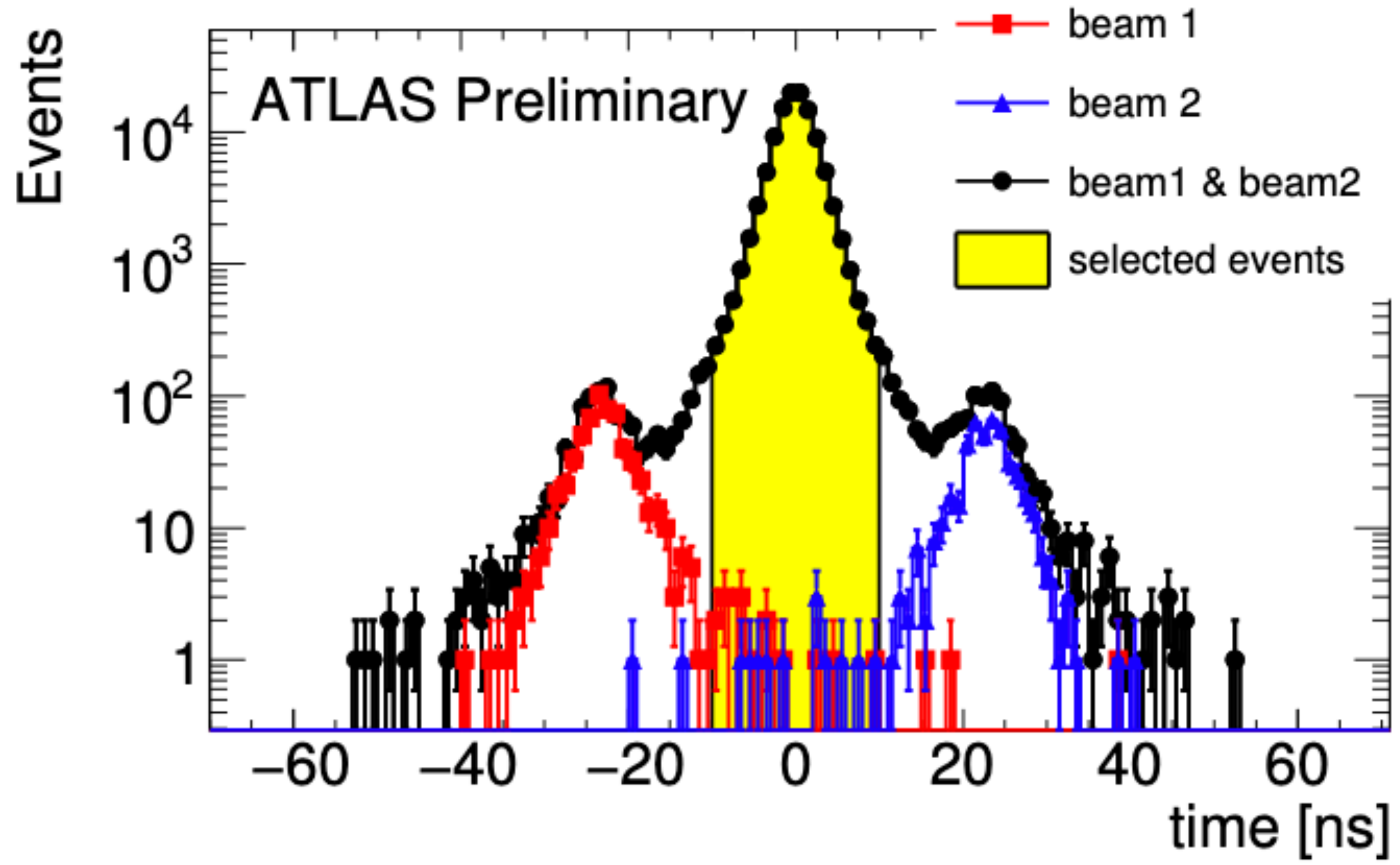
$$P^{\text{LUCID\_Event\_AND}} = 1 - P^{\text{LUCID\_Zero\_OR}}$$

- LUCID_Event_OR, the number of events for which the sum of hits in both detector arms is larger or equal to one. The LUCID_Event_OR probability per beam crossing $P^{\text{LUCID\_Event\_OR}}$ is related to the LUCID_Zero_AND probability per beam crossing $P^{\text{LUCID\_Zero\_AND}}$:

$$P^{\text{LUCID\_Event\_OR}} = 1 - P^{\text{LUCID\_Zero\_AND}}$$



Key issue: trigger efficiency of the Minimum Bias trigger.

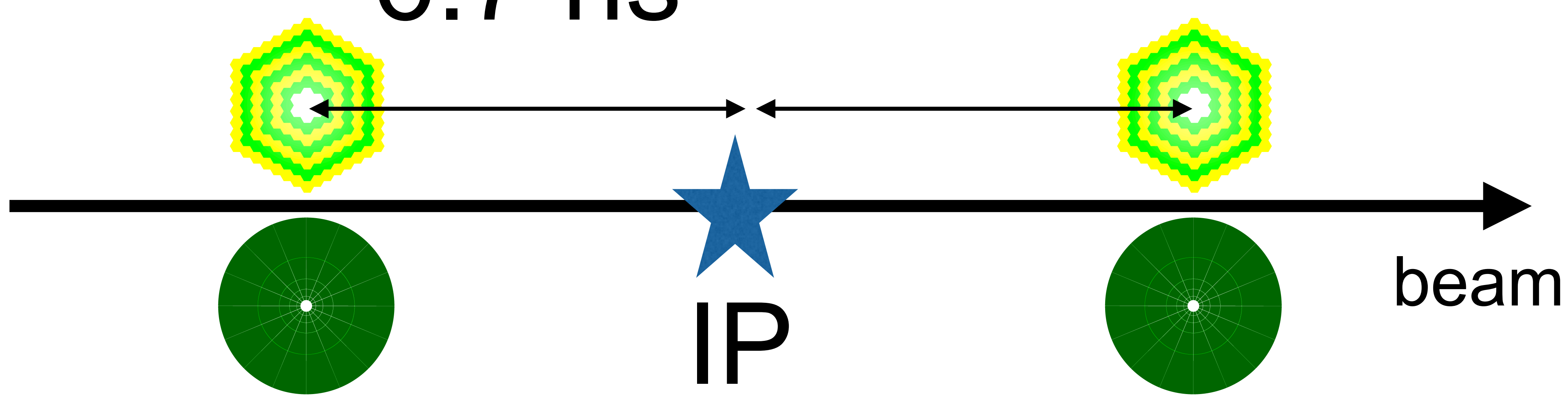


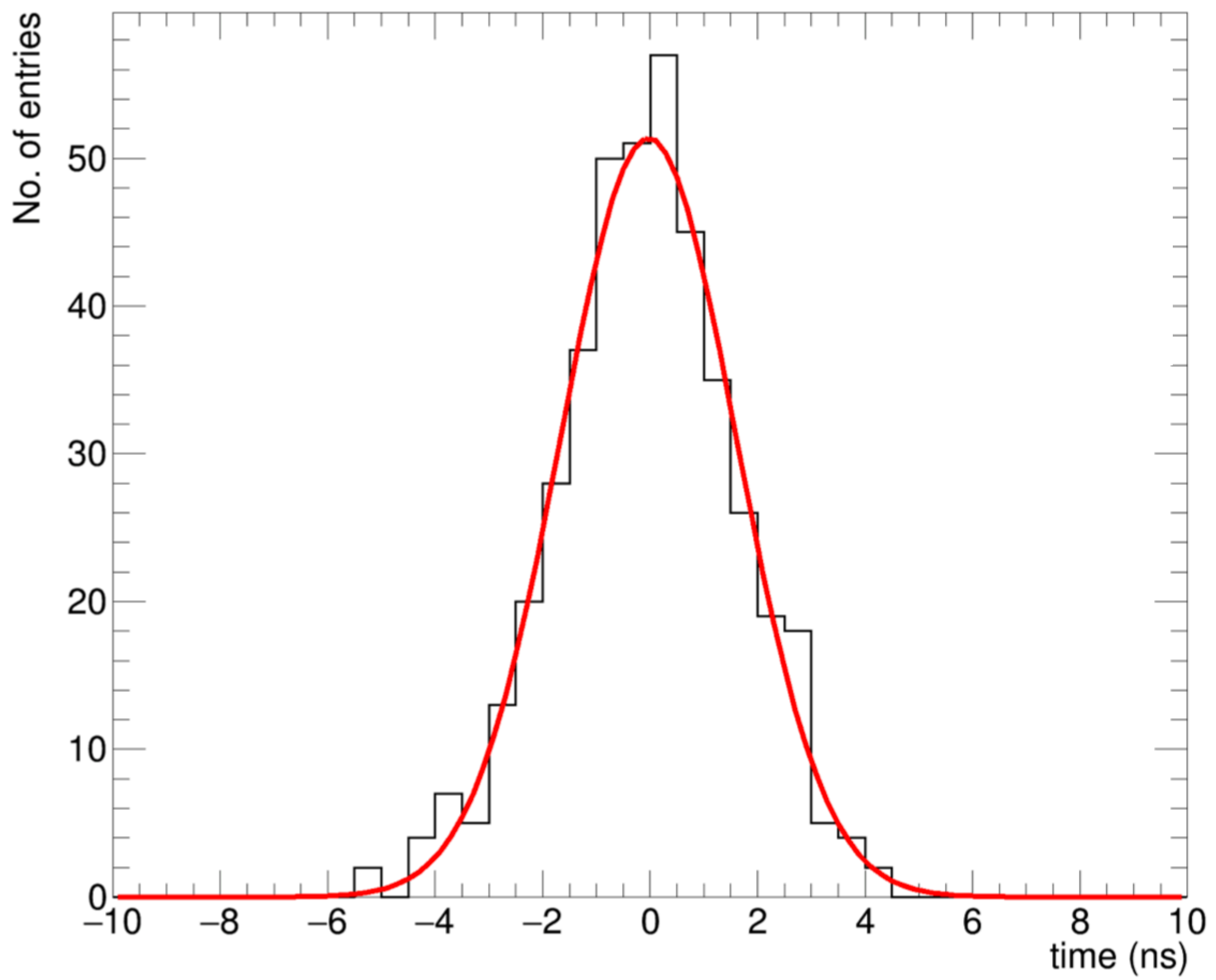
¿BeBe for luminosity measurements?

Particles created in p+p collisions will arrive at the BeBe hodoscopes around 6.7 ns after the primary collision. As a first approach, we centered the time window at 6.7 ns for both hodoscopes (see slide 26) and try to determine the BeBe trigger efficiencies.

BeBe triggers:

- A: BeBeLeft (Z>0)
- B: BeBeRight (Z<0)
- OR: BeBeLeft OR BeBeRight
- AND: BeBeLeft AND BeBeRight



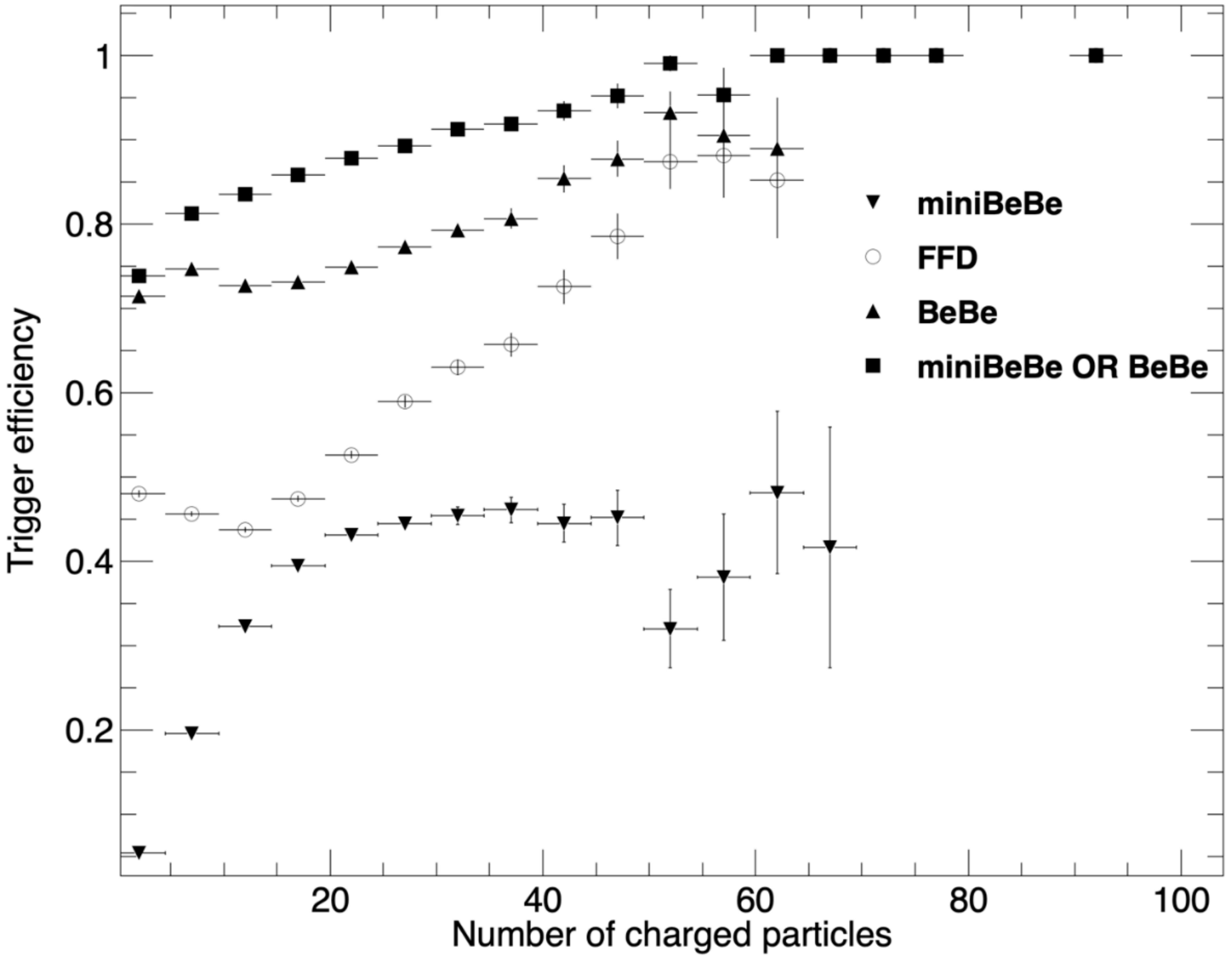


time difference BeBeLeft - BeBeRight

¿BeBe for luminosity measurements?

p+p @ 10 GeV / EPOS 1.99	BeBe trigger efficiencies (%)			
Time window (ns)	A	B	OR	AND
4 - 10	59.8	59.8	96.5	23
4.5 - 7.5	48.7	48.7	85.9	11.4
5.5 - 6.5	25.2	25	48.5	1.7

p+p @ 9 GeV / UrQMD	BeBe trigger efficiencies (%)			
Time window (ns)	A	B	OR	AND
4 - 10	55.9	56	95.1	16.8



BeBe detector may increase the trigger capabilities of MPD for low multiplicity p+p collisions events

See the talk of Maria Elena Tejeda of this session for more details of miniBeBe detector

¿BeBe for luminosity measurements?

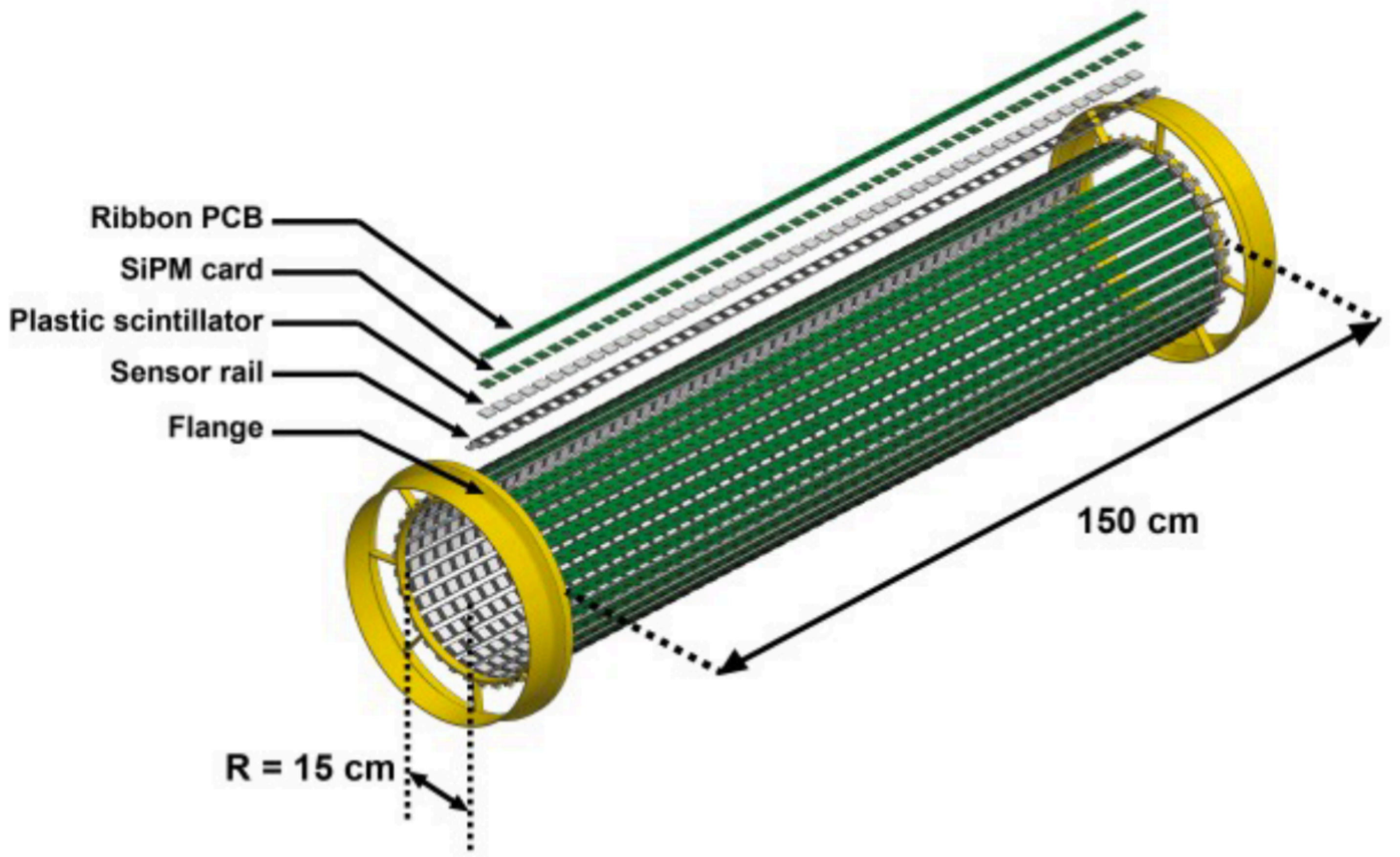
Bi+Bi @ 9 GeV / UrQMD	BeBe trigger efficiencies (%)			
Time window (ns)	A	B	OR	AND
4 - 10	98.7	98.3	99.6	97.3
4.5 - 7.5	86.1	84.7	97.8	73.1
5.5 - 6.5	70.1	70	93.5	46.6

Au+Au @ 11 GeV / UrQMD	BeBe trigger efficiencies (%)			
Time window (ns)	A	B	OR	AND
4 - 10	100	100	100	100
4.8 - 8.8	99.6	99.7	99.9	99.4
5 - 9	99.7	99.7	99.9	99.5

miniBeBe

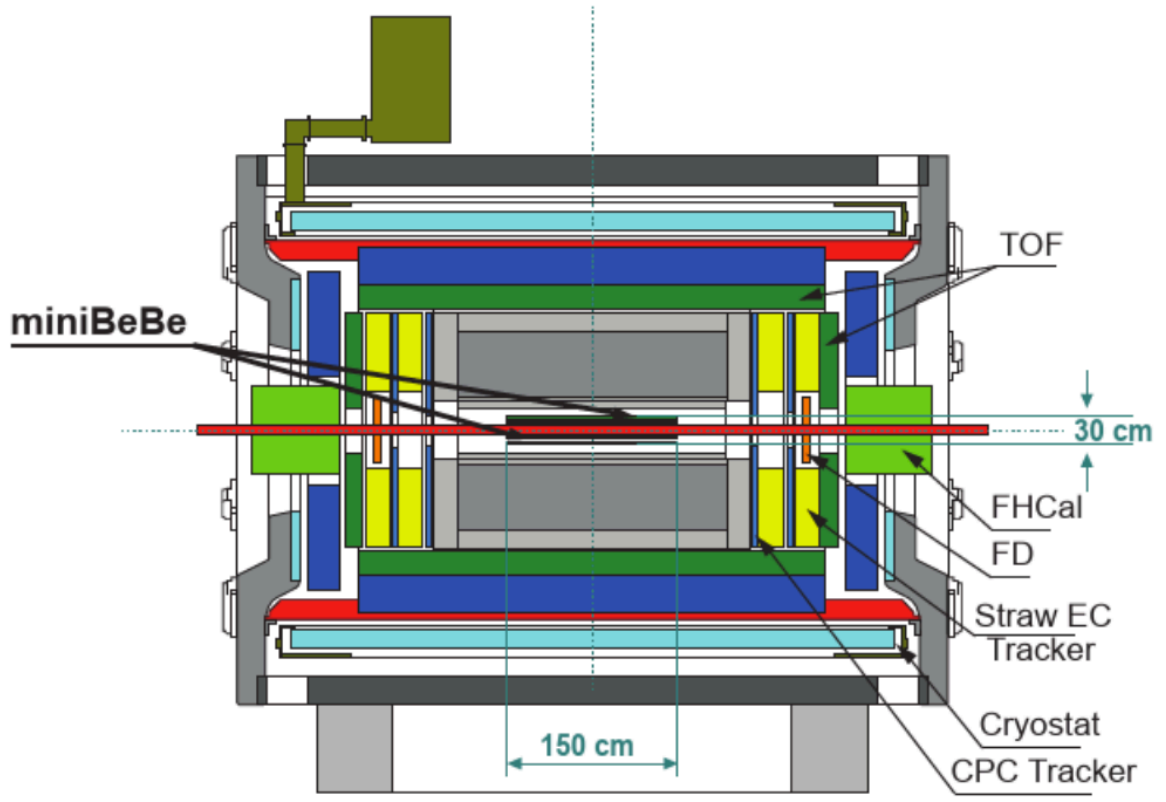
MiniBeBe (Mini Beam-Beam Counter)

MexNICA Collaboration



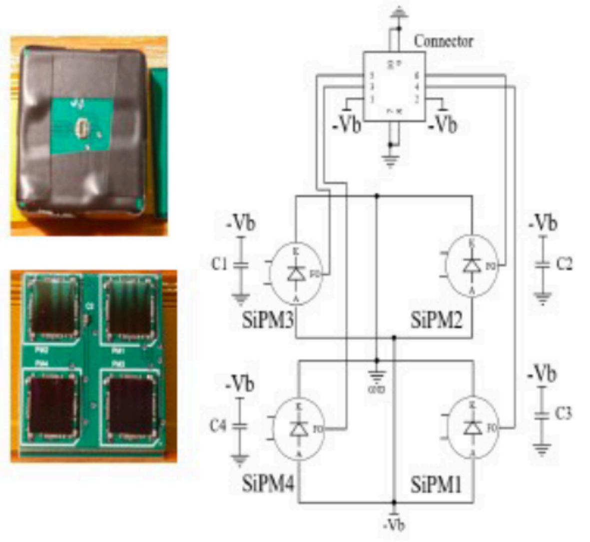
Main requirement:

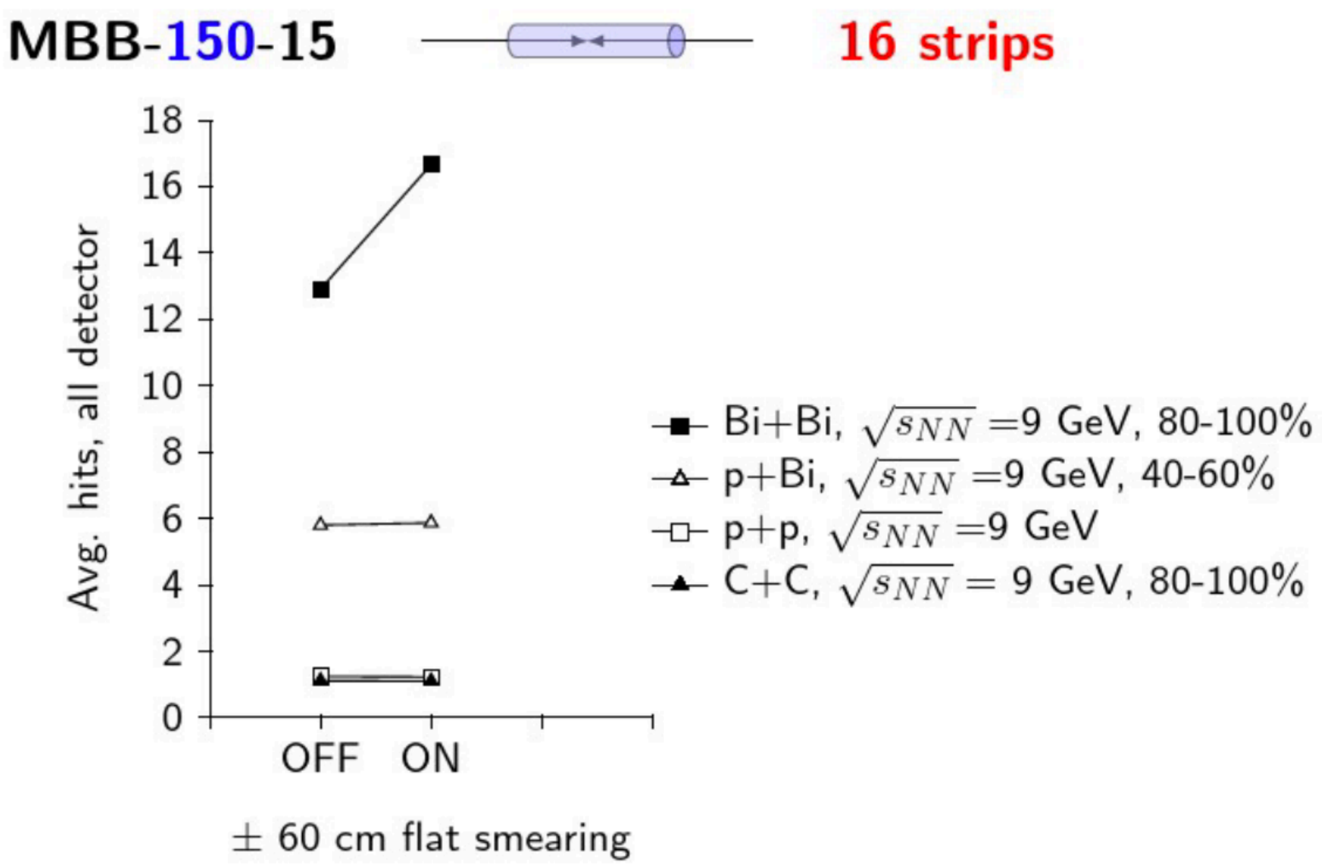
- Provide fast wake-up signal for TOF and reference time for TOF measurement with time resolution of ~30 ps
- Improve trigger efficiency for p+p, p-A and low multiplicity A-A
- Provide possibility to perform luminosity measurements at Phase 0 of NICA operation



Basic cell with four SiPMs & electronics

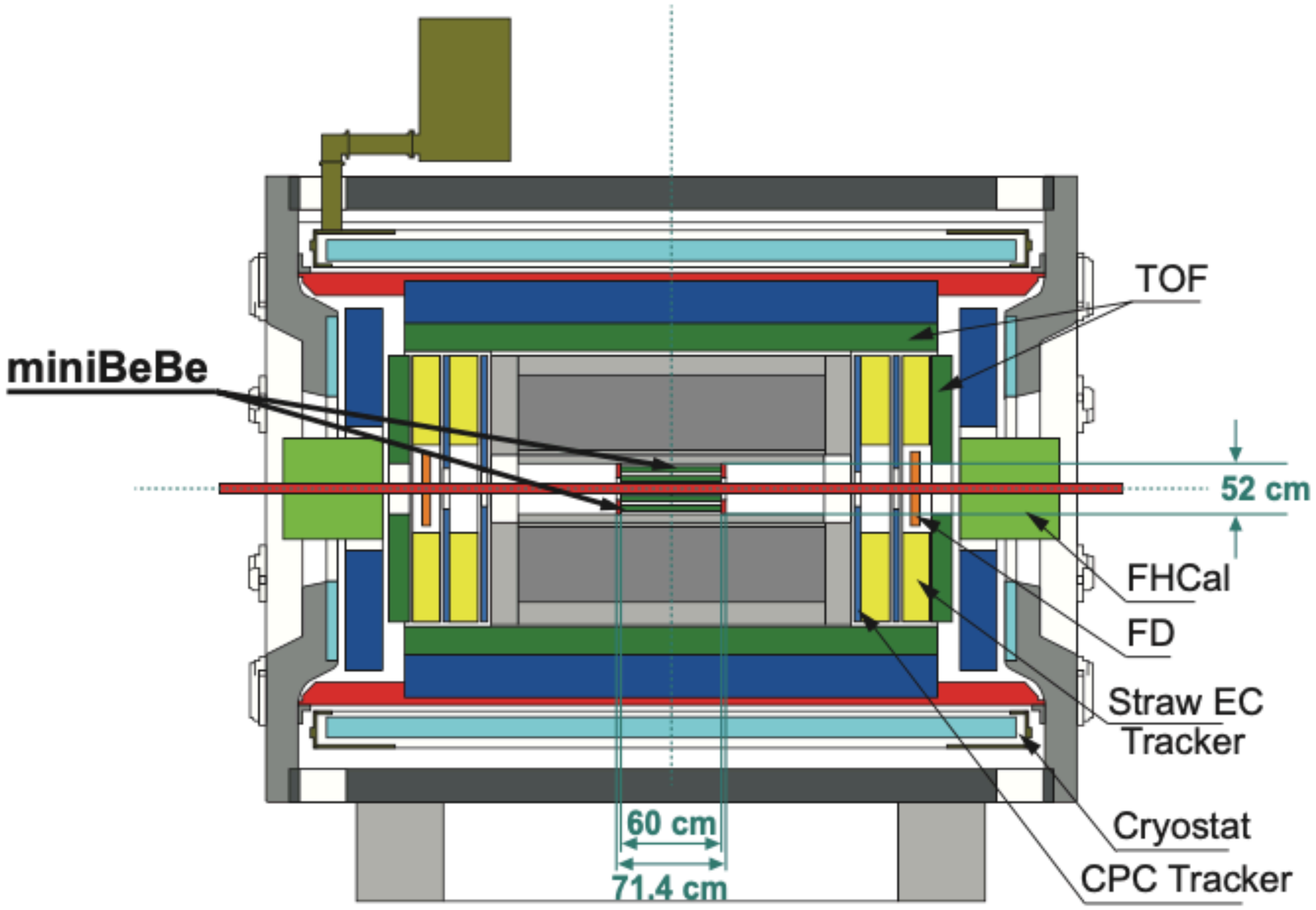
- 20x20 mm²
- 4 SiPMs card attached to BC404 plastic scintillator
- Fast outputs to "connector" (micro mezzannine)
- DC decoupling capacitors

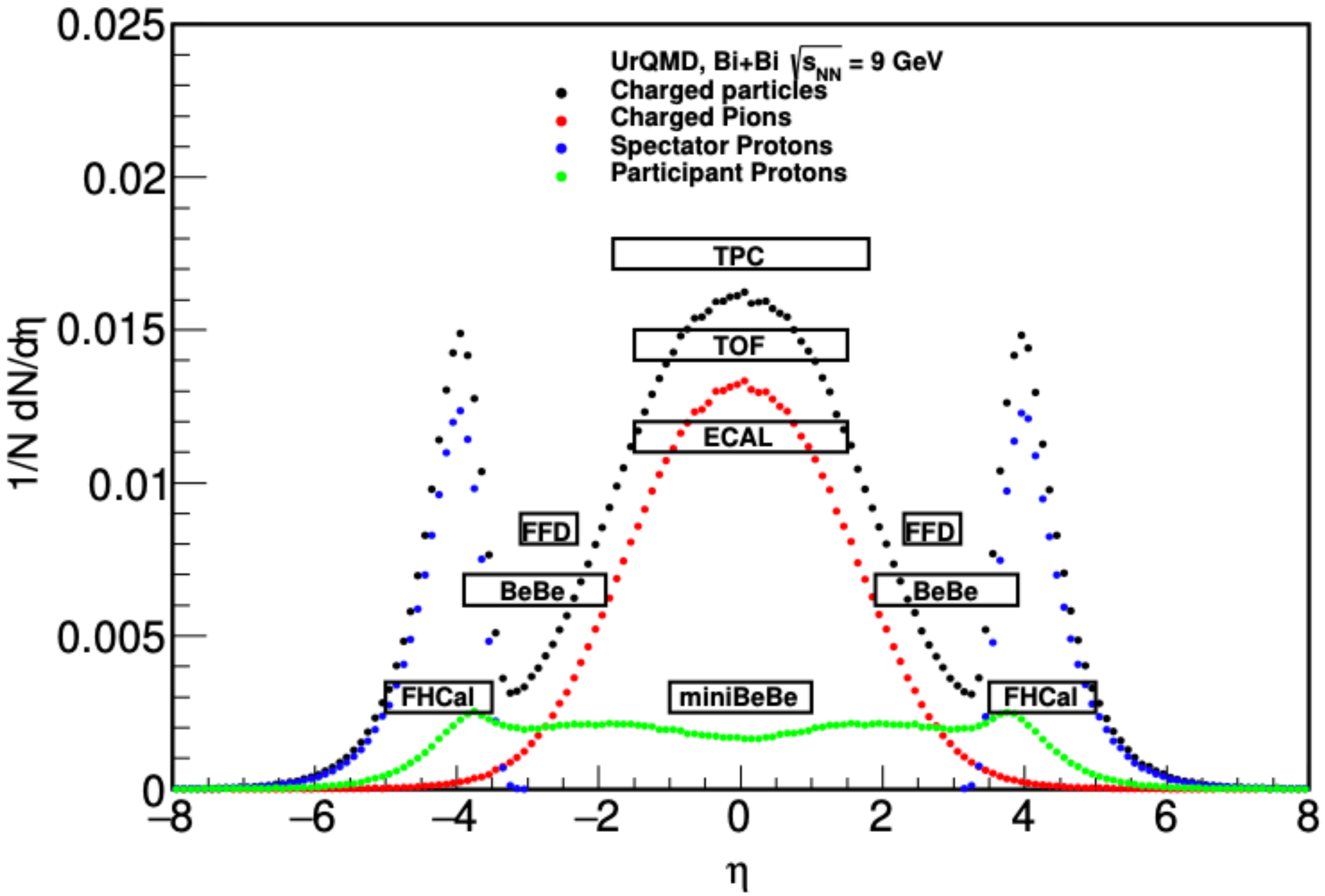




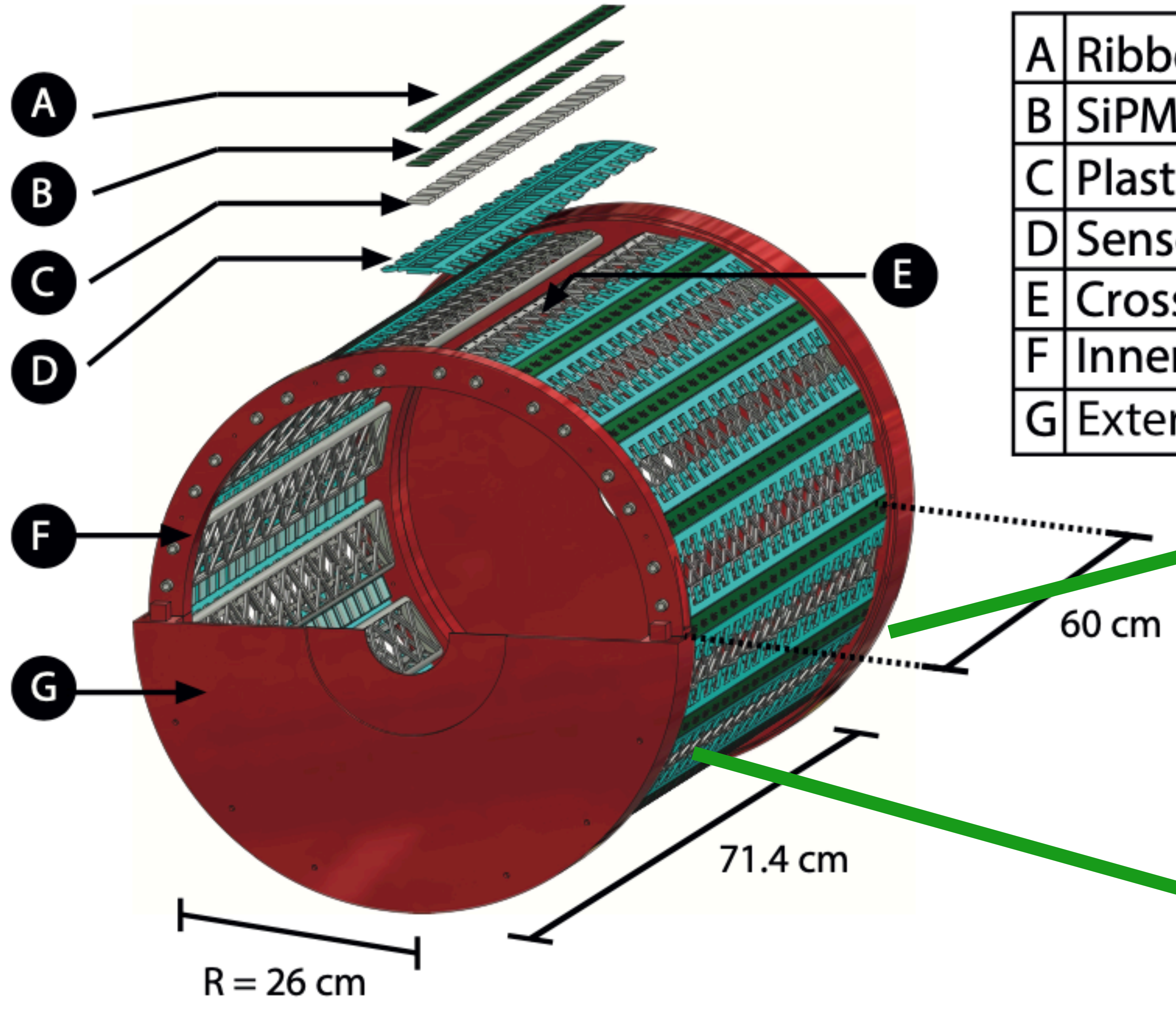
Adam Kisiel, JINR/WUT MexNICA Collaboration Winter Meeting, 16 Dec 2020 18/29

miniBeBe

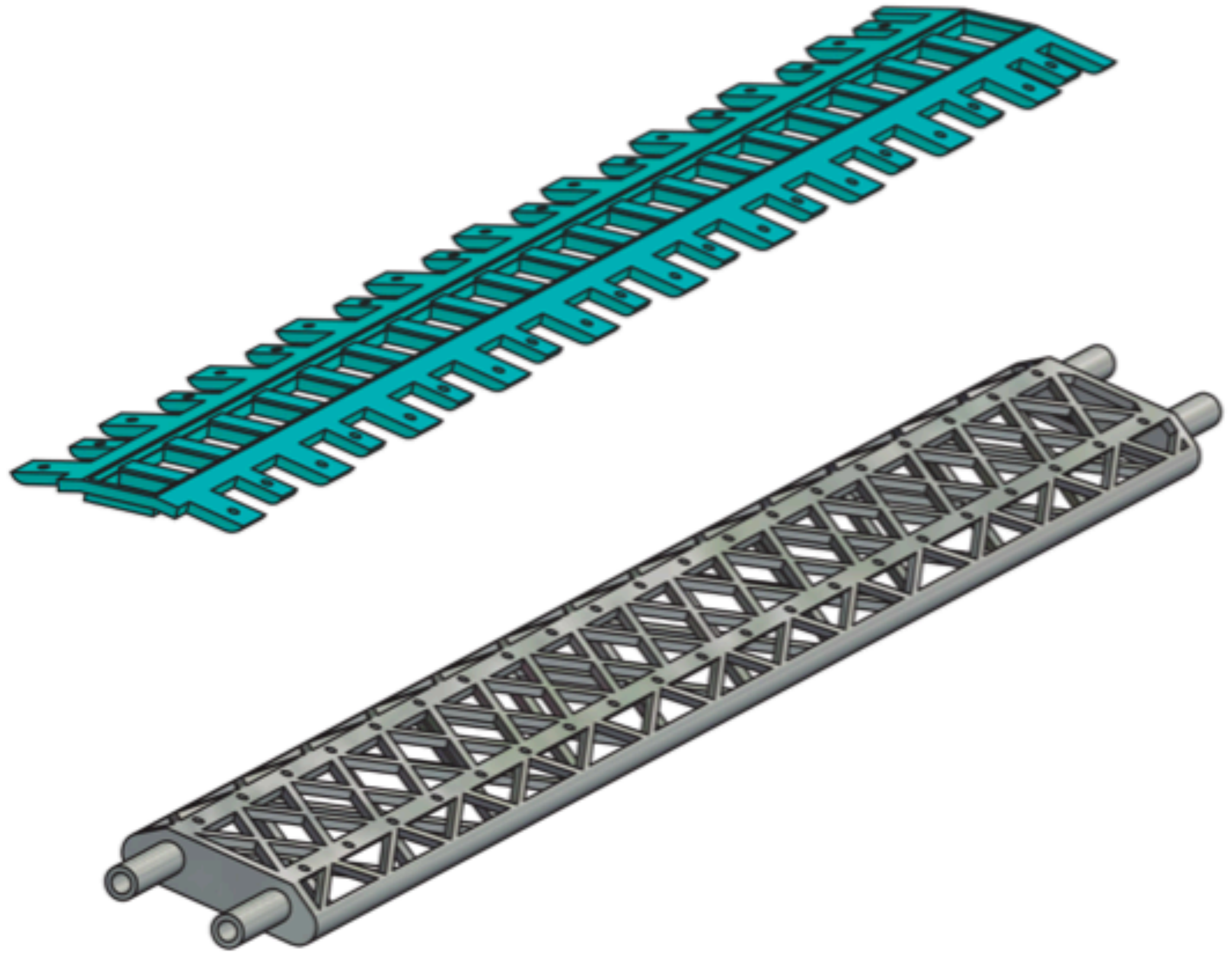

TOF
miniBeBe
52 cm
FHCal
FD
Straw EC
Tracker
Cryostat
CPC Tracker
60 cm
71.4 cm


UrQMD, Bi+Bi $\sqrt{s_{NN}}$ = 9 GeV
Charged particles
Charged Pions
Spectator Protons
Participant Protons
TPC
TOF
ECAL
FFD
FFD
BeBe
BeBe
FHCal
miniBeBe
FHCal
1/N dN/dη
η
0.025
0.02
0.015
0.01
0.005
0
−8
−6
−4
−2
0
2
4
6
8

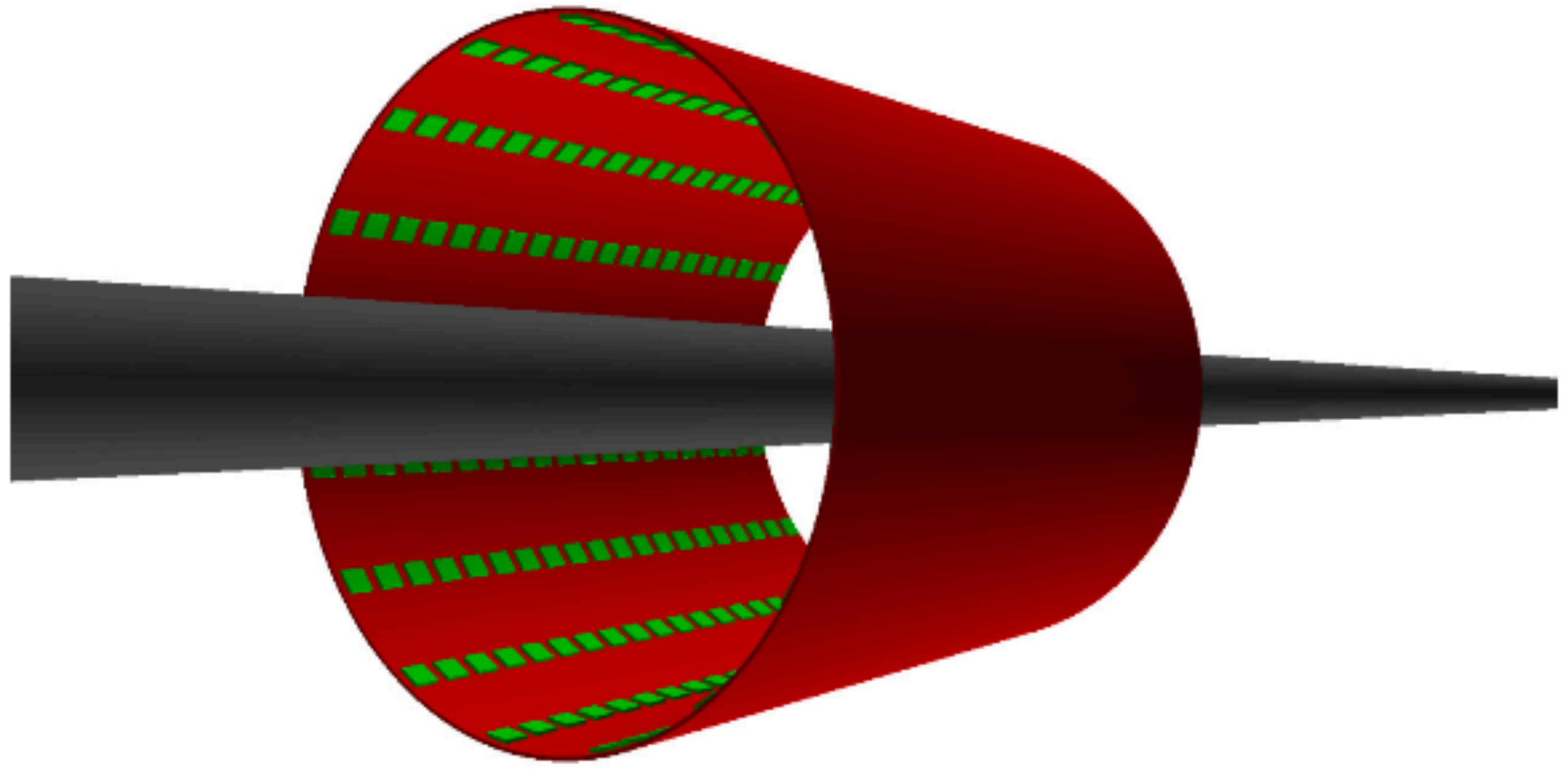
miniBeBe

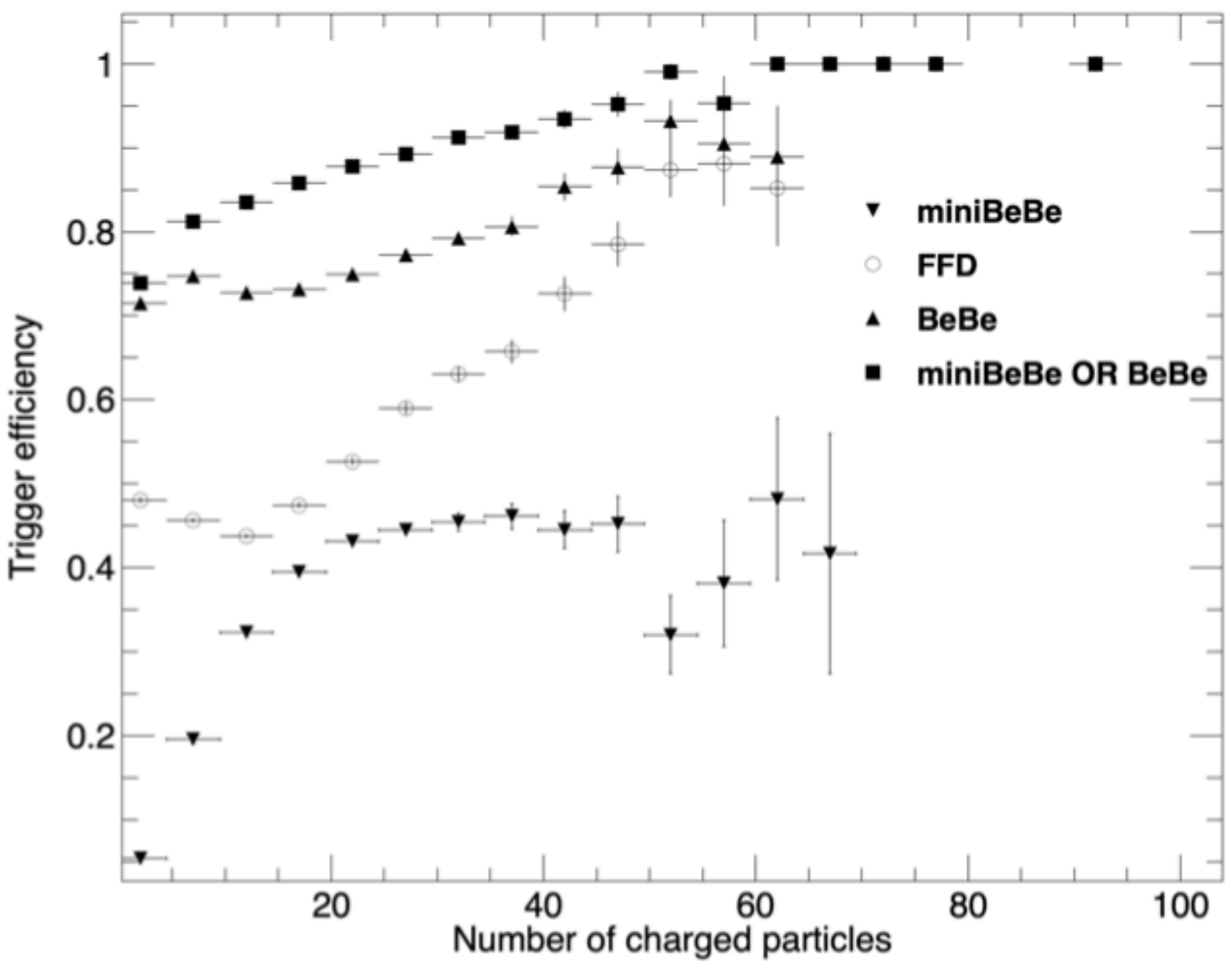


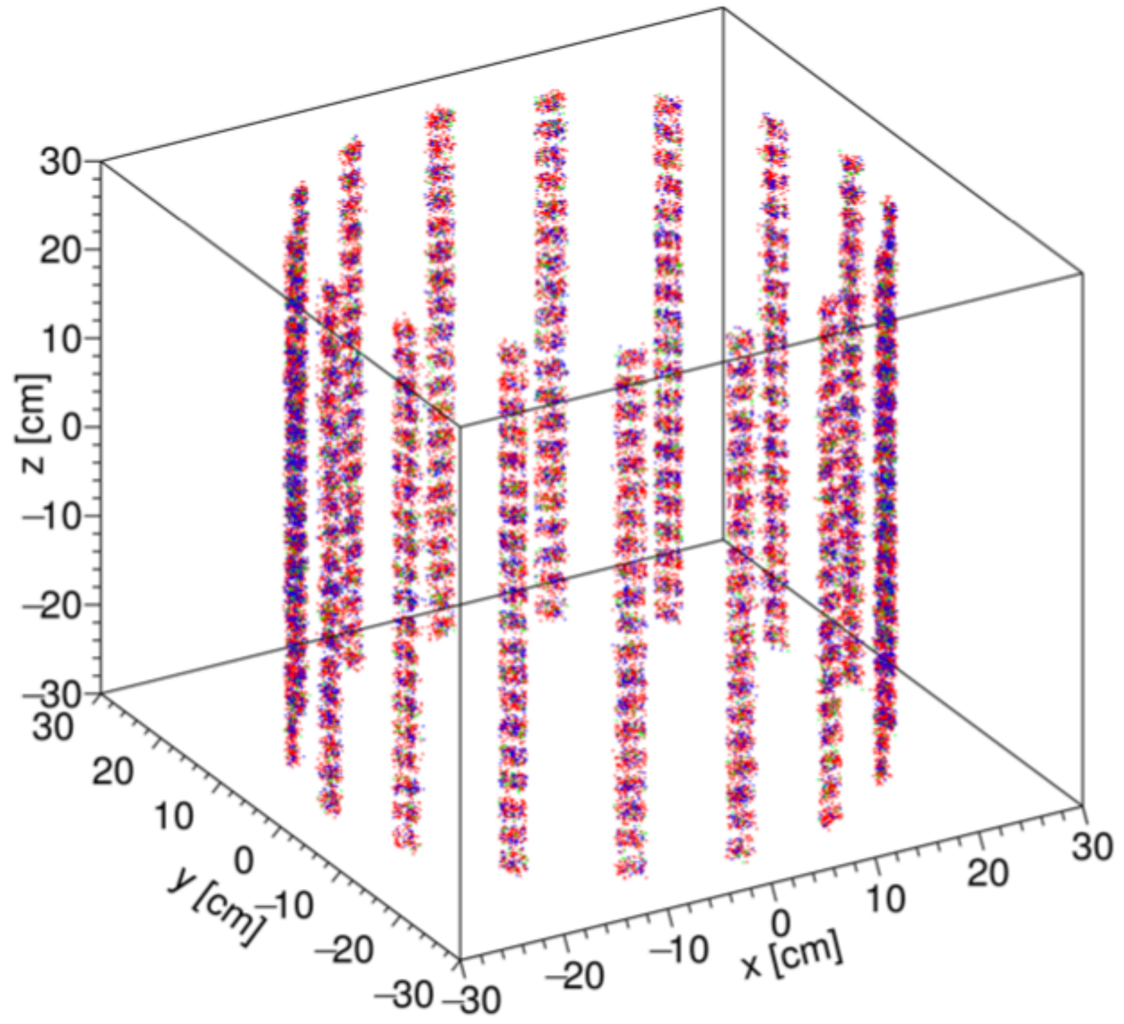
A	Ribbon PCB
B	SiPM card
C	Plastic scintillator
D	Sensor rail
E	Cross bar
F	Inner ring
G	External flange

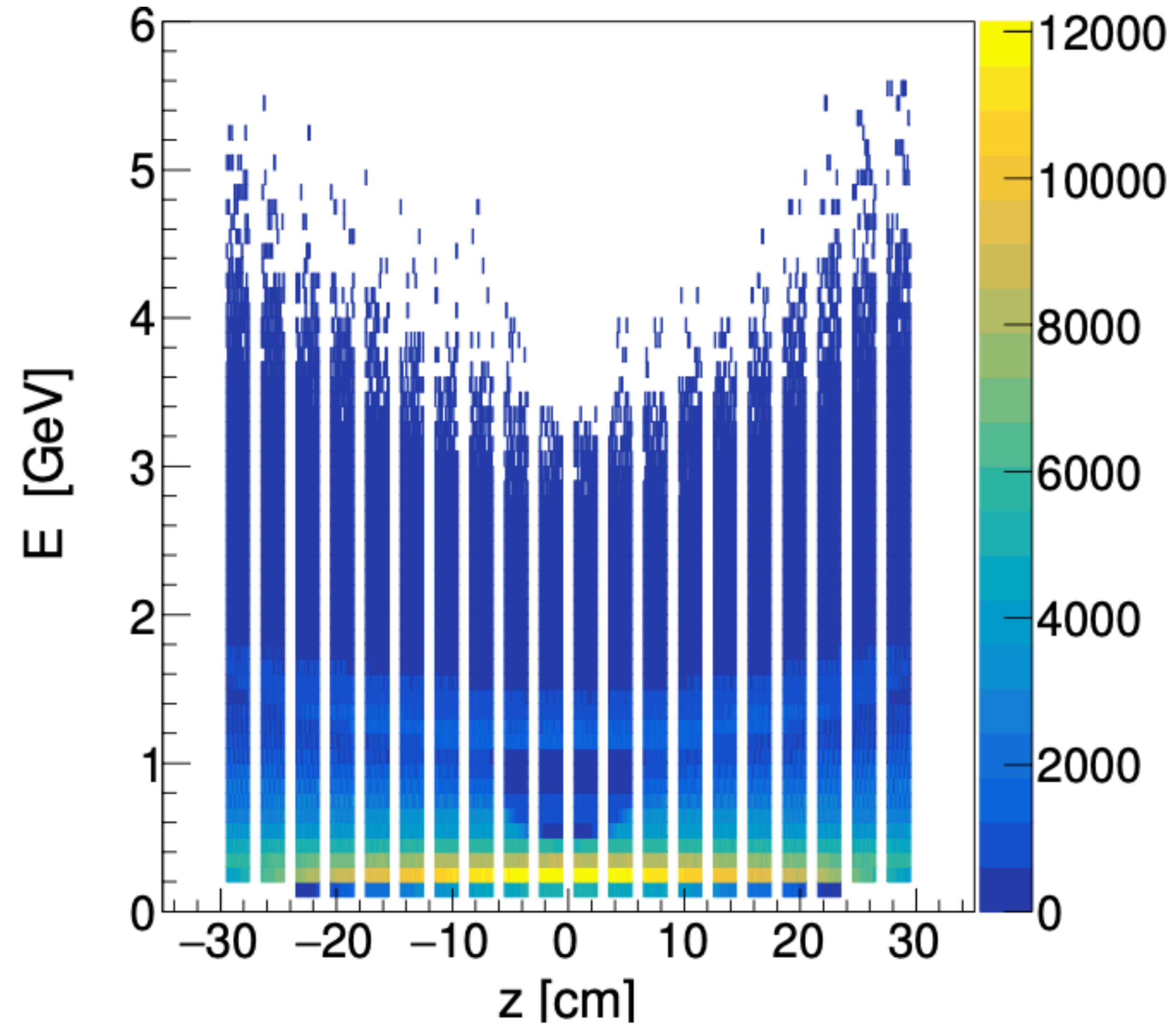


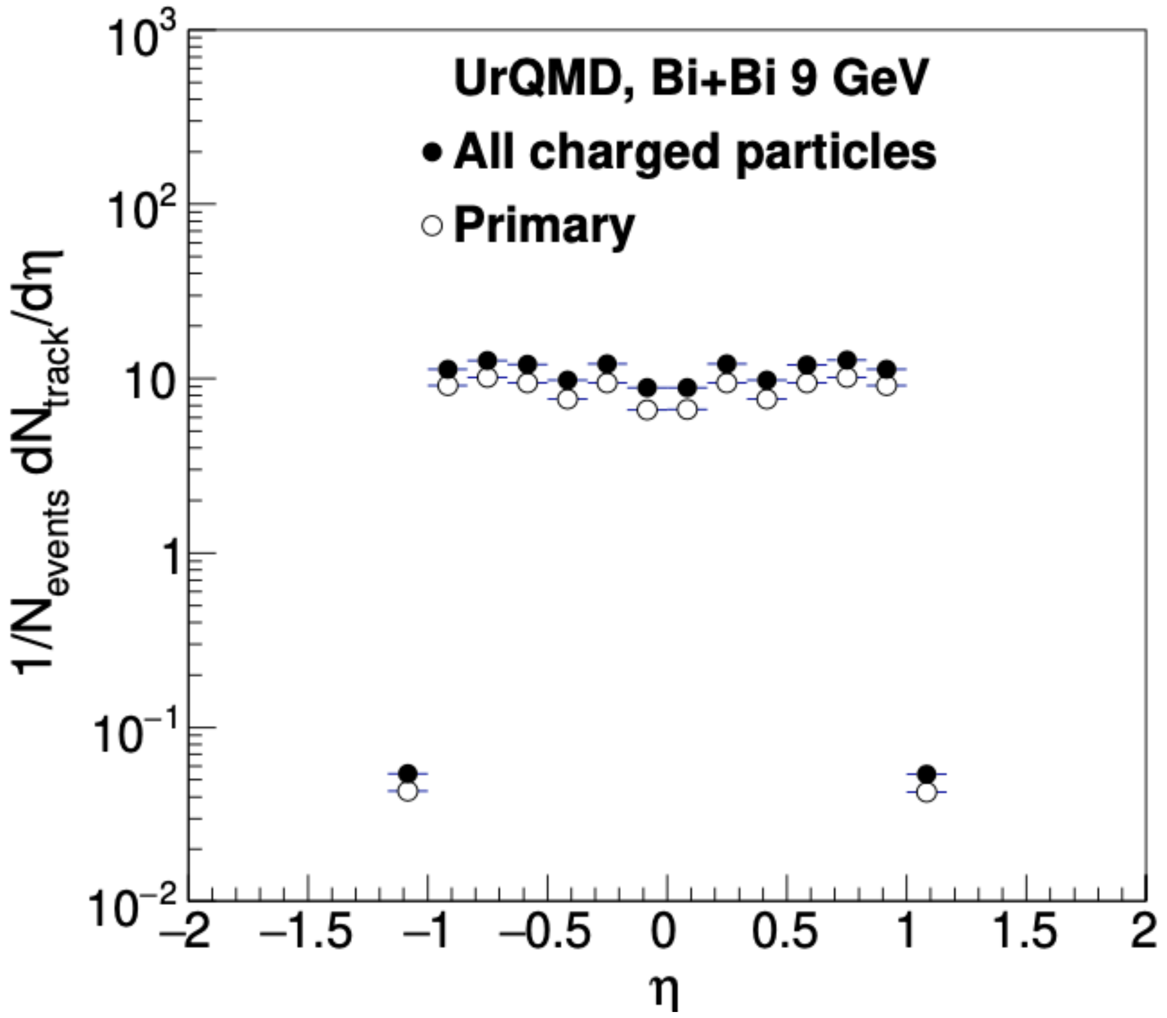
miniBeBe

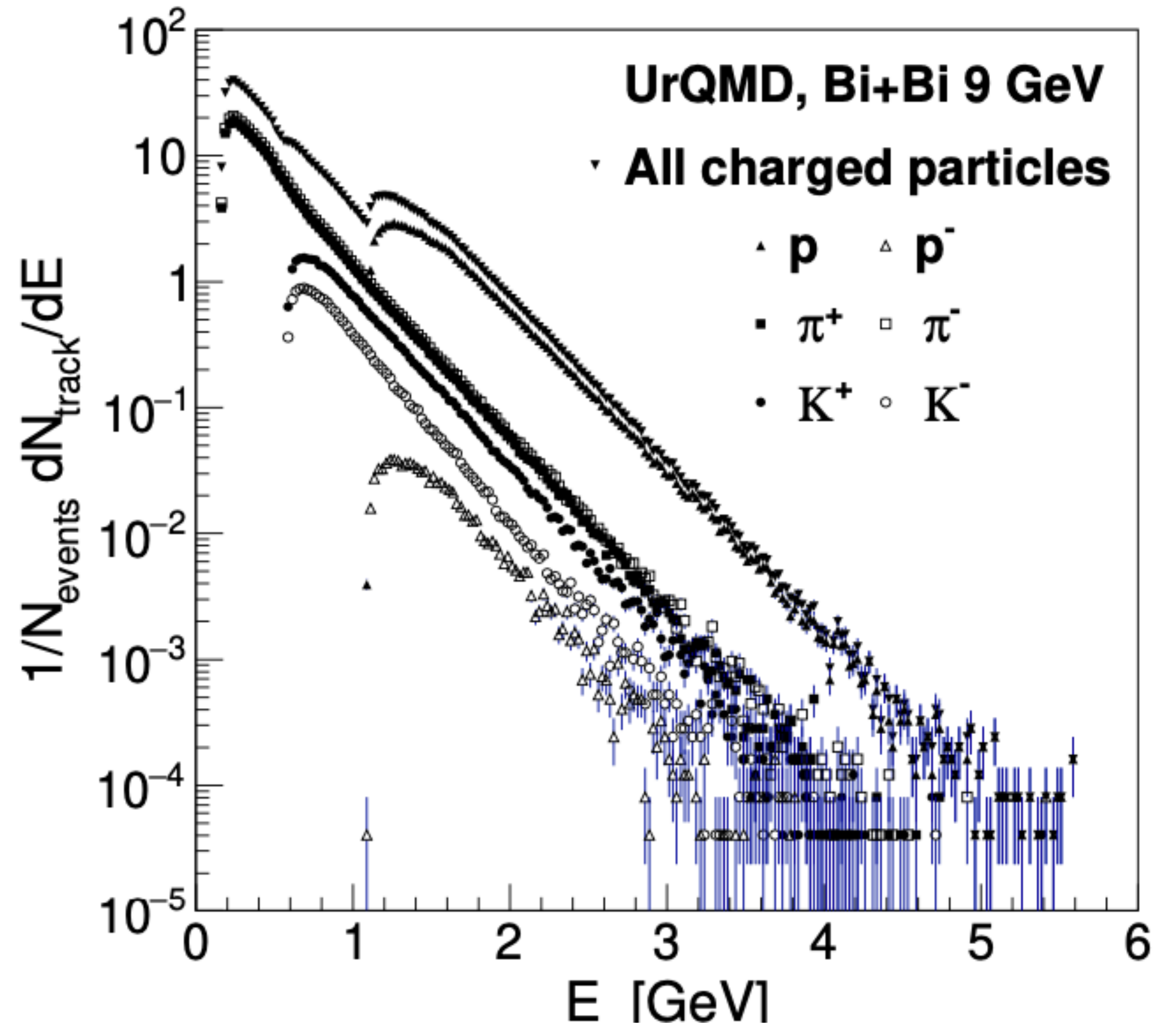



Trigger efficiency
Number of charged particles
miniBeBe
FFD
BeBe
miniBeBe OR BeBe

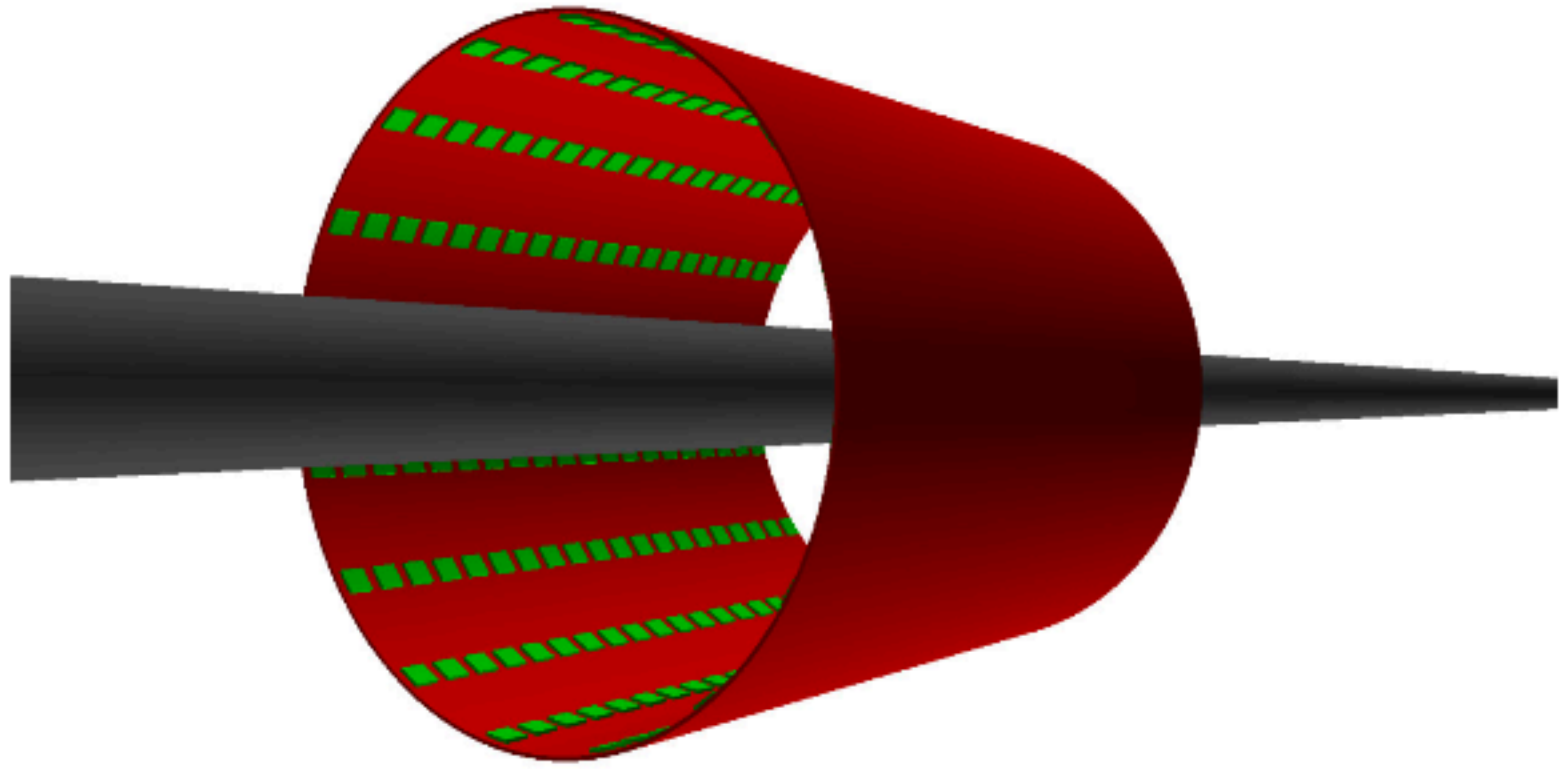

z [cm]
y [cm]
x [cm]

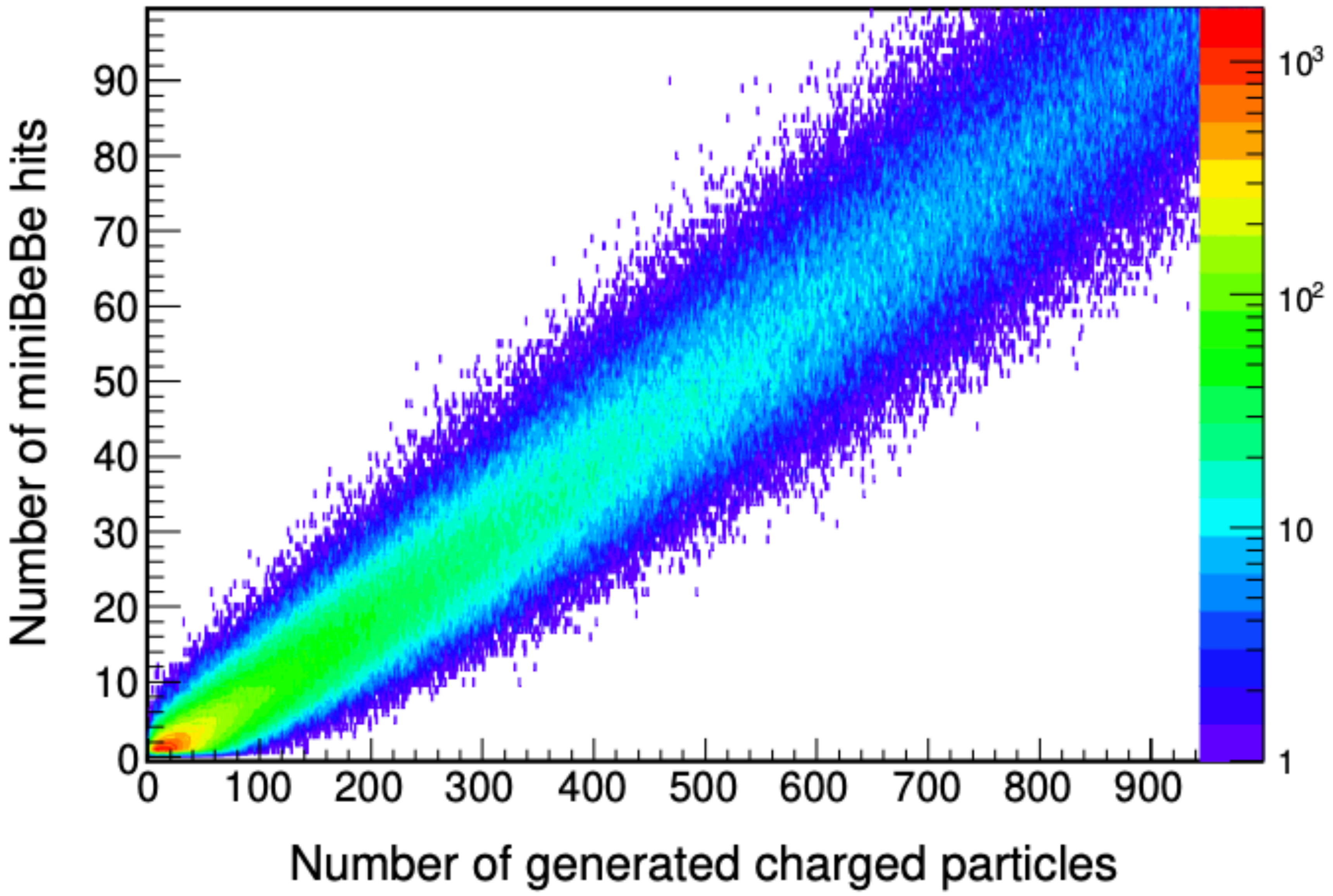

E [GeV]
z [cm]


UrQMD, Bi+Bi 9 GeV
All charged particles
Primary
$1/N_{events}\ dN_{track}/d\eta$
η

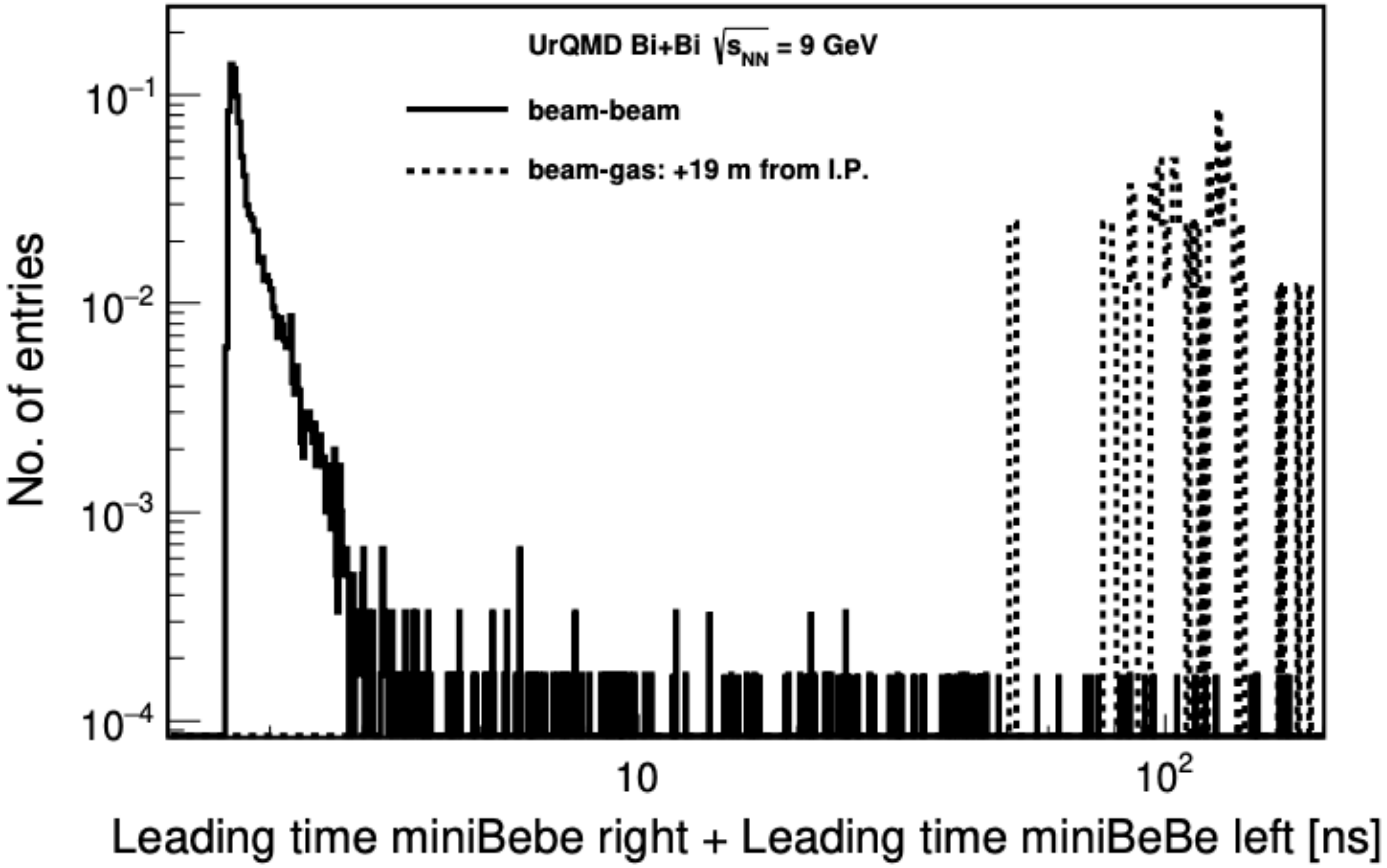

UrQMD, Bi+Bi 9 GeV
All charged particles
p
p̄
π^+
π^-
K^+
K^-
$1/N_{events}\ dN_{track}/dE$
E [GeV]

miniBeBe

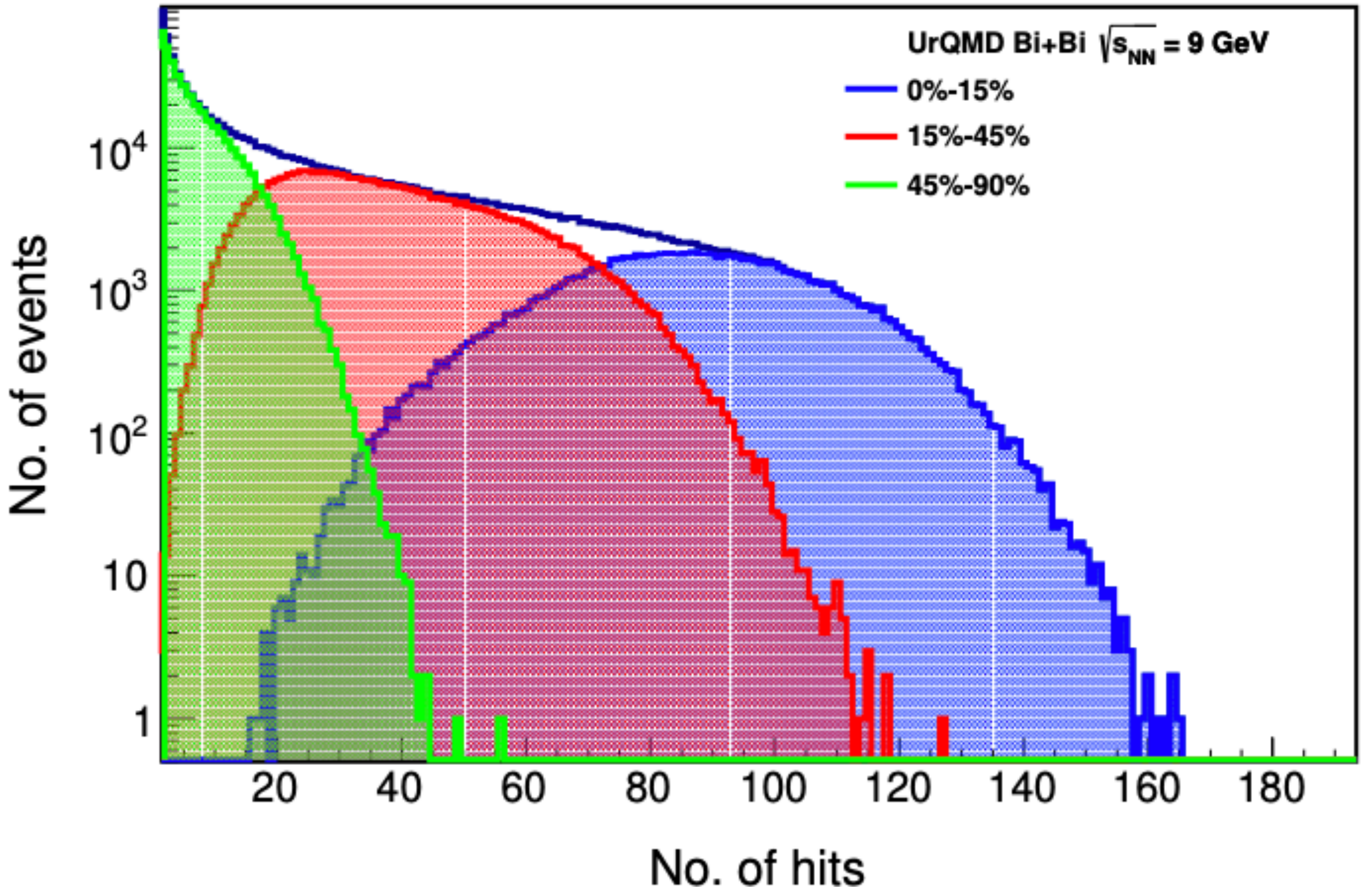




Number of miniBeBe hits
Number of generated charged particles
0
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1
10
10^2
10^3



UrQMD Bi+Bi $\sqrt{s_{NN}}$ = 9 GeV
beam-beam
beam-gas: +19 m from I.P.
No. of entries
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10
10^2
Leading time miniBebe right + Leading time miniBeBe left [ns]



UrQMD Bi+Bi $\sqrt{s_{NN}}$ = 9 GeV
0%-15%
15%-45%
45%-90%
No. of events
1
10
10^2
10^3
10^4
20
40
60
80
100
120
140
160
180
No. of hits

Final comments

BUAP

NICA facility has the potential for competitive research in the field of dense baryonic matter

- The MPD detector has many advantages and meets all the ambitious physics
- requirements for exploring phase diagram of strongly interacting matter in a high track multiplicity environment.
- The MPD detector covers a large phase space; it is functional at high interaction rates; comprises high efficiency and excellent particle identification capabilities; it is based on the recent detector developments and has comparatively reasonable cost.

Final comments