Activities at BUAP

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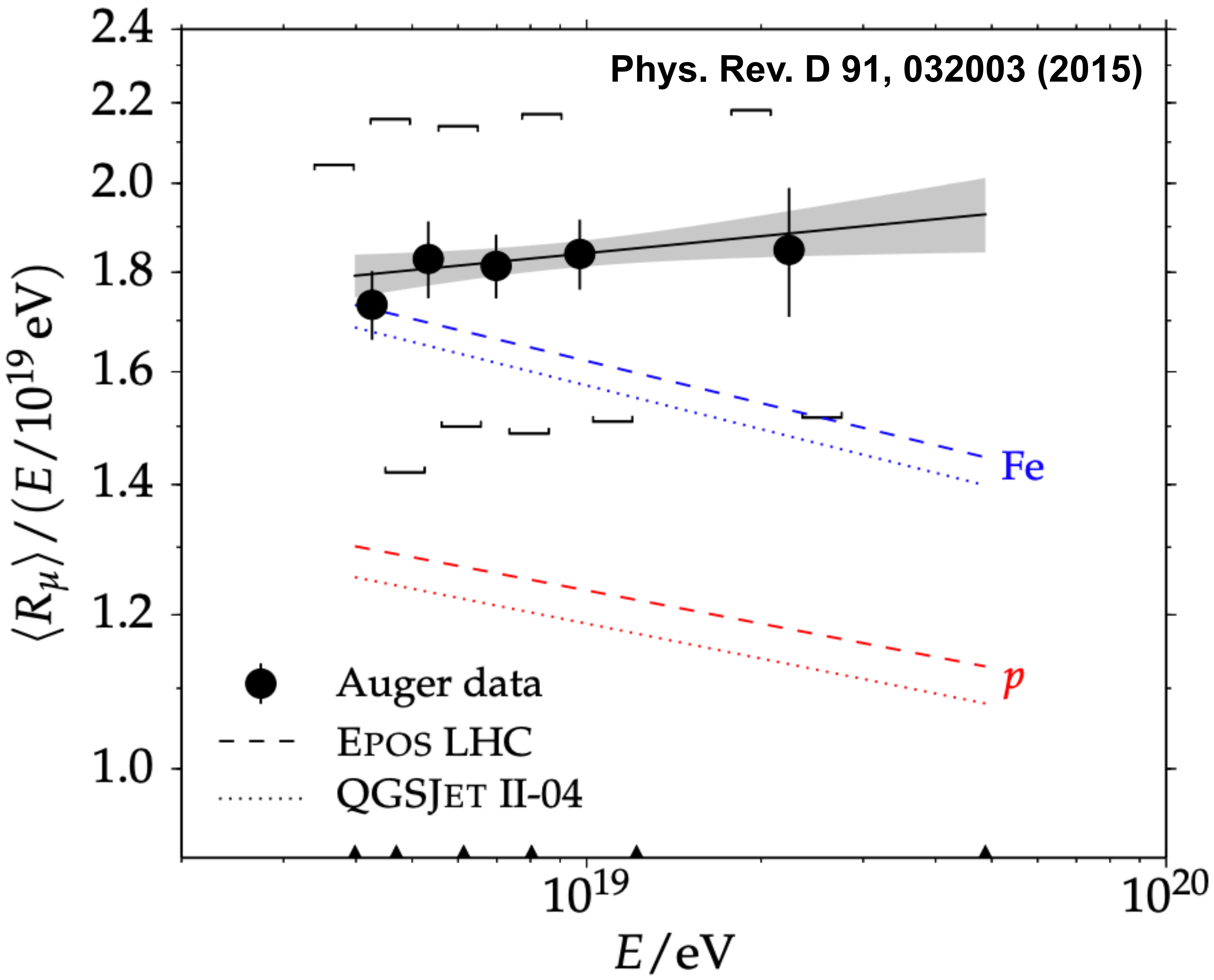
First MuonID / 15.12.2022

- Physics studies
- Detector development

Why to study Cosmic rays (CR) with ALICE?

- One of the main observables that can be useful to understand the characteristics of the primary cosmic ray is the number of muons produced along the EAS.



- Several studies on the muon component of EAS have been carried out with experimental arrangements on the surface.
- For example, the Pierre Auger observatory reported an excess of the muon content for inclined events (Phys. Rev. D 91, 032003 (2015)).
- This result motivated theoretical works: deconfined thermal balls (Phys. Rev. D 95, 063005 (2017)), string percolation (arXiv 209.6474), reduction of the energy transfer from the hadronic to the electromagnetic components of the EAS (PoS(ICRC2013)1182), enhancement of multi-strange hadrons (Phys. Lett. B 810 (2020) 135837)

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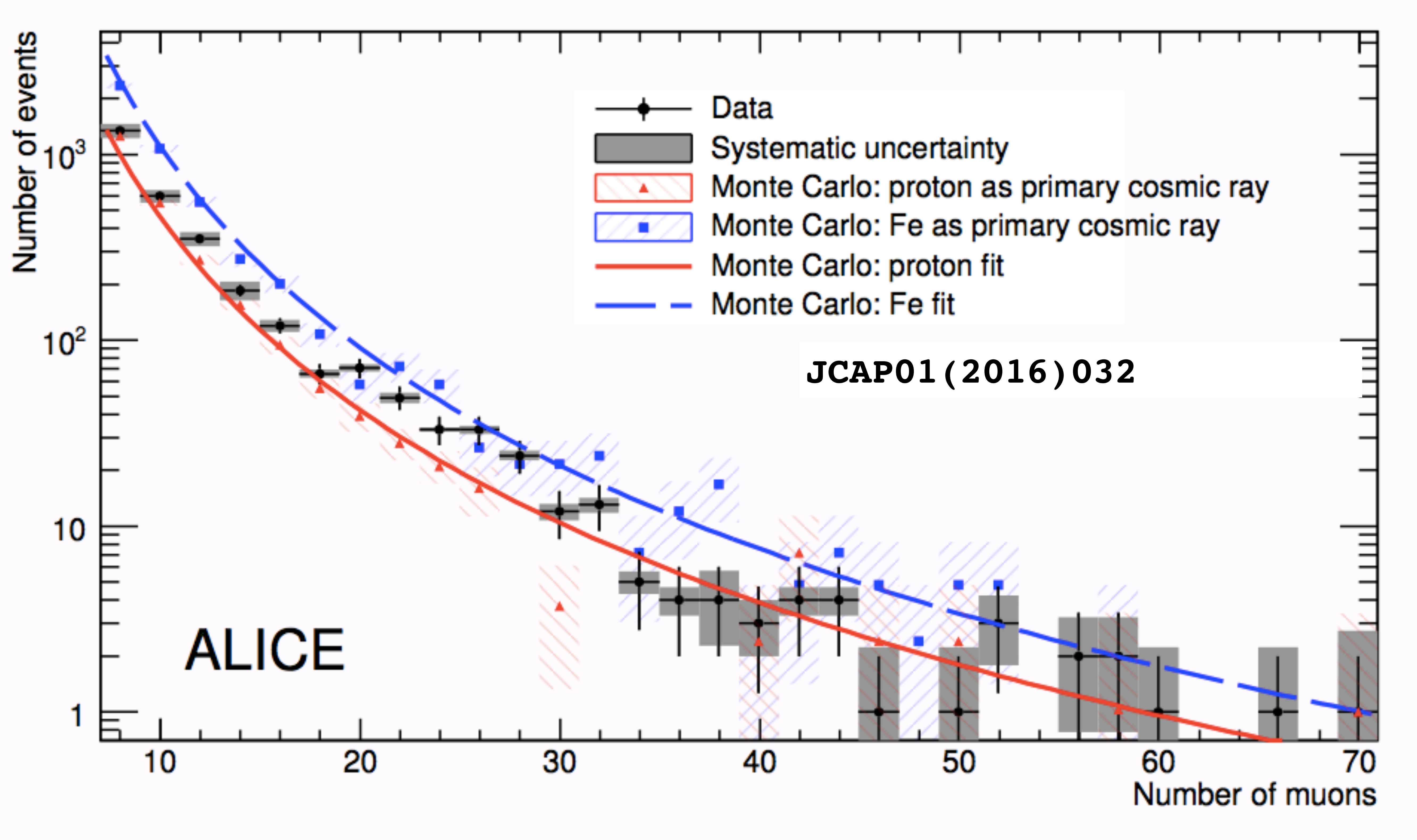
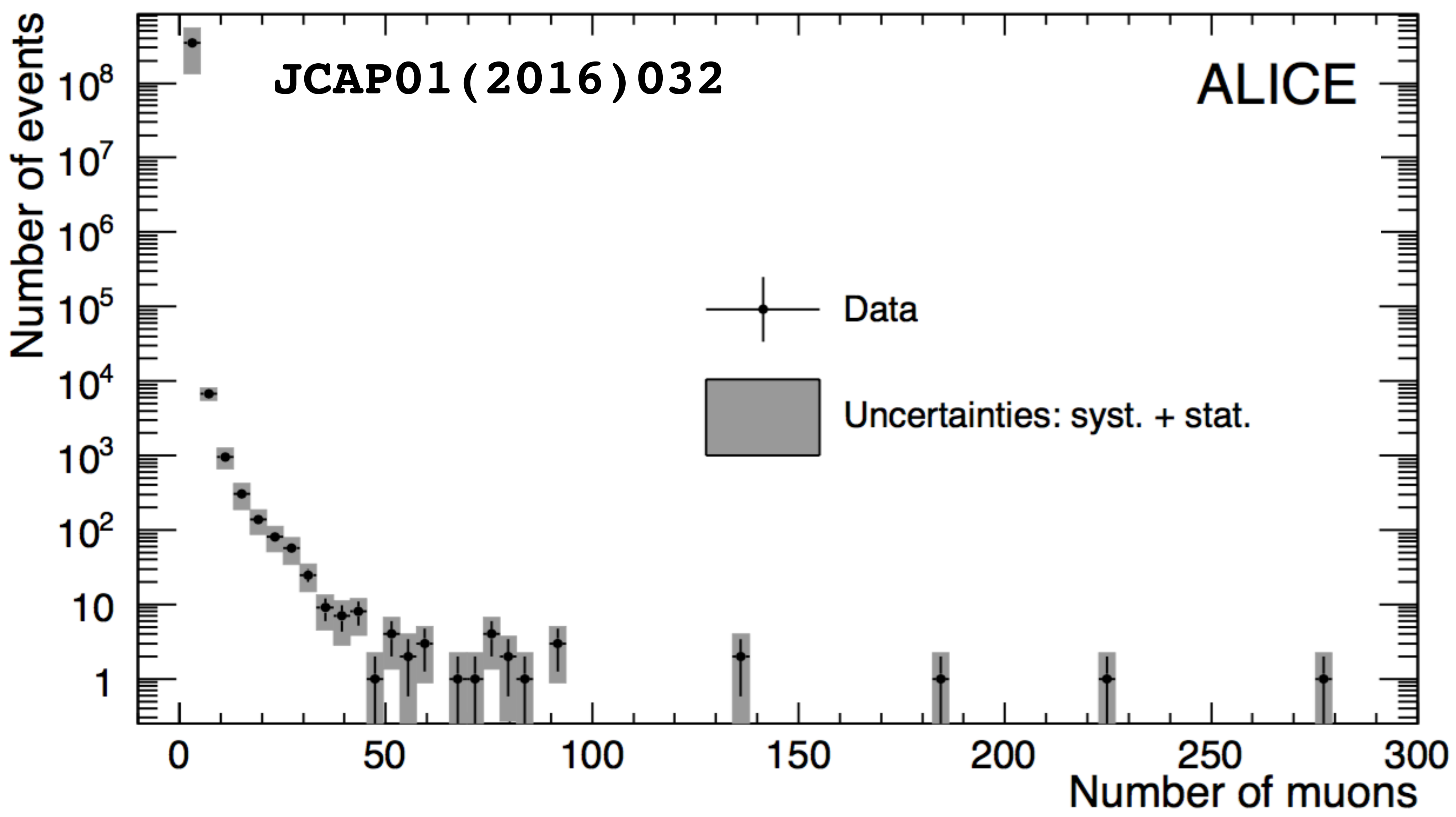


ALICE results on Cosmic Ray Physics



We find a smooth distribution up to #μ < 70 and 5 events with more than 100 atmospheric muons (HMM)

Why to study Cosmic rays (CR) with ALICE?

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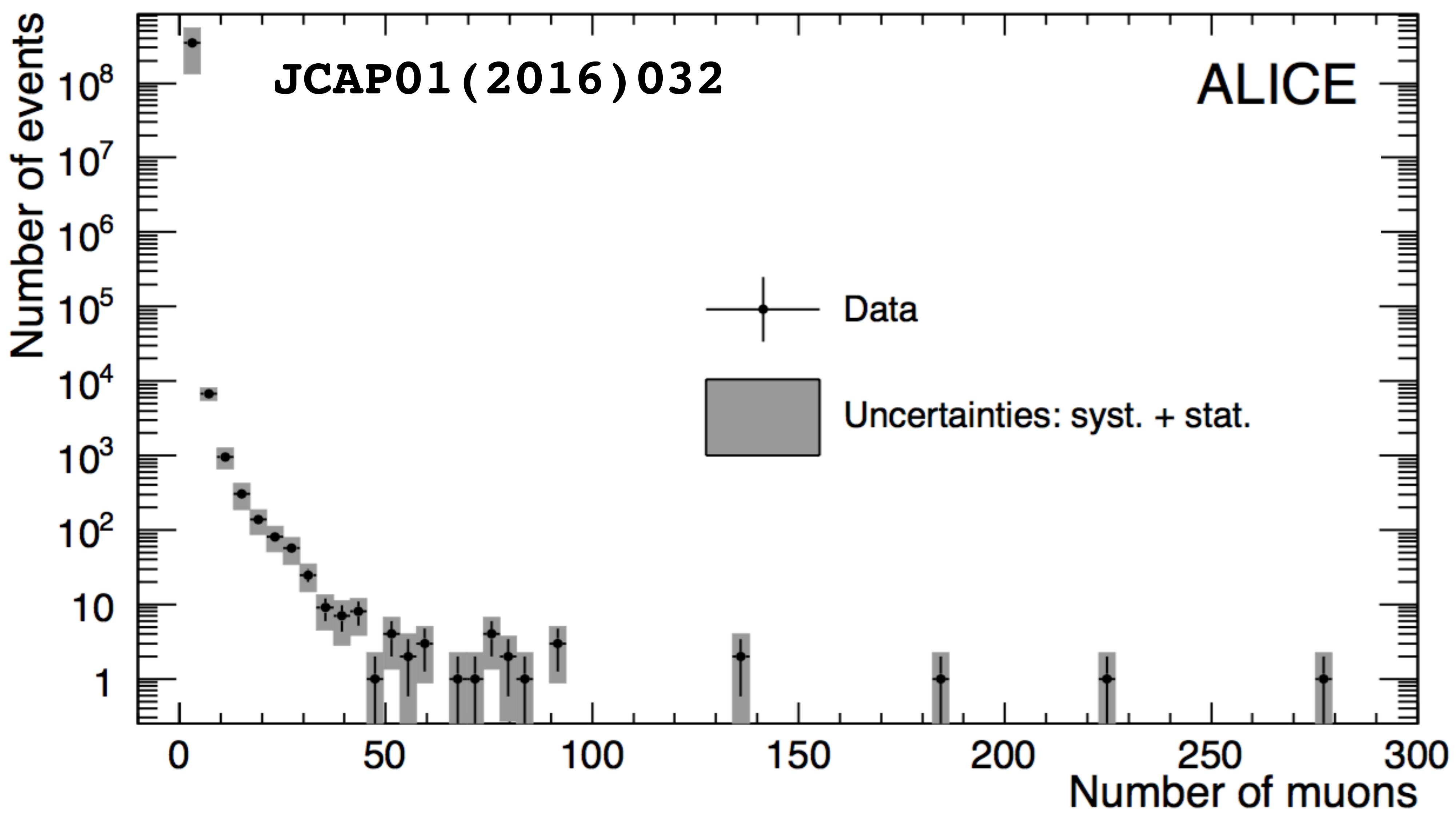
JCAP01(2016)032

HMM events	CORSIKA 6990 QGSJET II-03 proton	CORSIKA 6990 QGSJET II-03 iron	CORSIKA 7350 QGSJET II-04 proton	CORSIKA 7350 QGSJET II-04 iron	Data
Period [days per event]	15.5	8.6	11.6	6.0	6.2
Rate [$\times 10^{-6}$ Hz]	0.8	1.3	1.0	1.9	1.9
Uncertainty (%) (syst + stat)	13	16	8	20	49

- Pure **iron** sample simulated with **QGSJET II-04** model reproduces HMM event rate in close agreement with the measured value.
- Independent of the version model, the rate of HMM events with pure proton cosmic-ray composition is more difficult to reproduce.
- This result is compatible with recent measurements which suggest that the composition of the primary cosmic-ray spectrum with energies larger than 10^{16} eV is dominated by heavier elements: Phys. Rev. Lett. **107** (2011) 171104.

ALICE results on Cosmic Ray Physics



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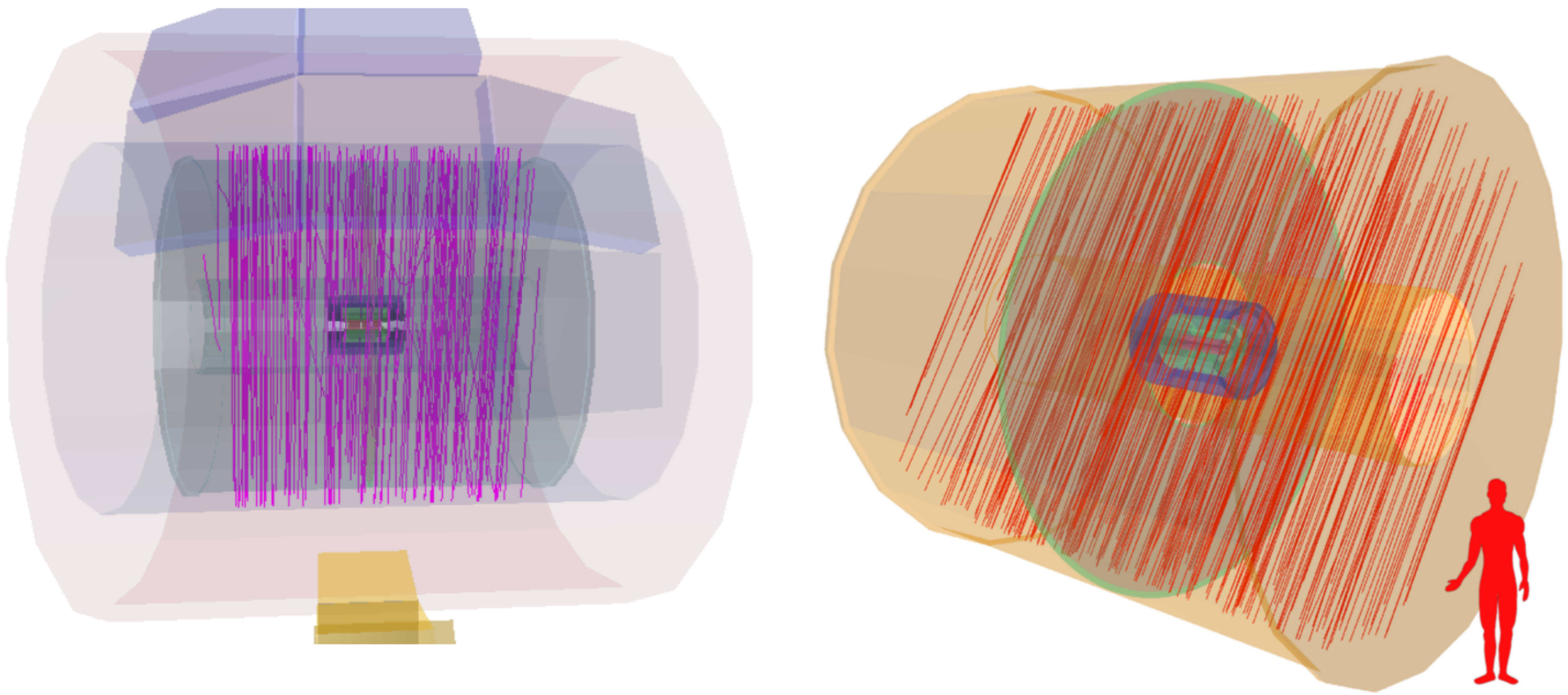
- One of the main observables that can be useful to understand the characteristics of the primary cosmic ray is the number of muons produced along the EAS.

JCAP01(2016)032



- In 30.8 days (Run 1 data), ALICE collected 5 events with more than 100 muons.
- In ALICE's cosmic paper, we reported that the frequency of such kind of events can be reproduced with the QGSJET II-04 hadronic interaction model (tuned with LHC data).
- These events are originated due to EAS from primary cosmic rays whose composition is dominated by a heavy component (Fe) with energies larger than 10^{16} eV.
- The core of the EAS is located very close from the ALICE at LHC with a zenith angles less than 50 degrees.
- This result may put significant constraints on alternative, more exotic, production mechanisms (e.g. QGP in cosmic ray showers Astropart.Phys.17:355-365,2002).

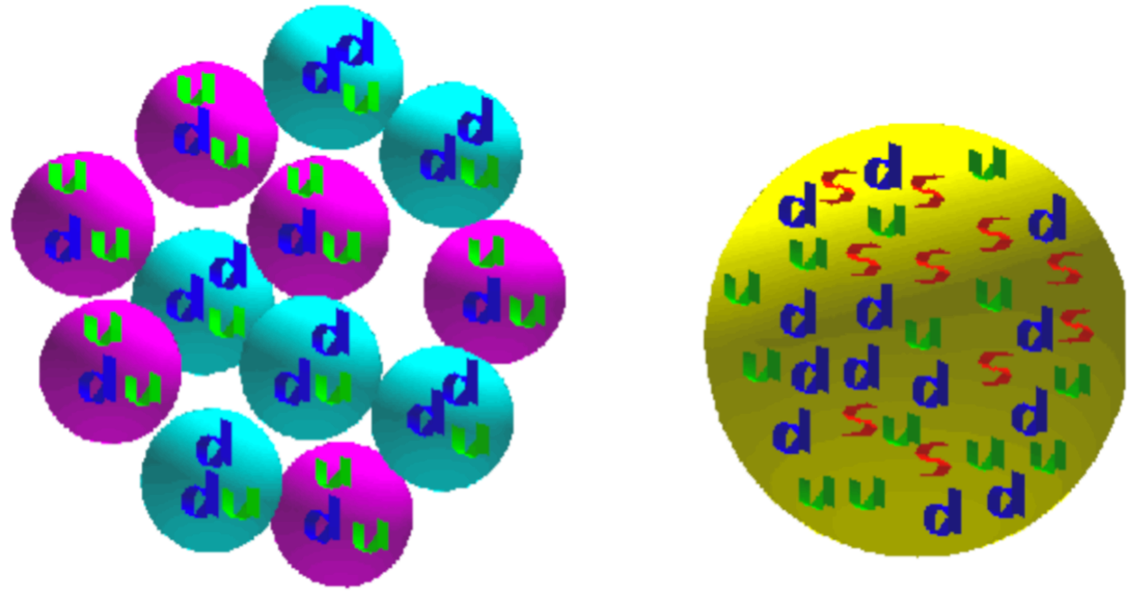
Why to study Cosmic rays (CR) with ALICE?

- One of the main observables that can be useful to understand the characteristics of the primary cosmic ray is the number of muons produced along the EAS.

The ALICE results on high muon multiplicity events motivated some theoretical work: ApJ 839, 31 (2017)

Strange quark matter

Roughly equal numbers of u, d, s quarks in a single 'bag' of cold hadronic matter.



Nucleus (^{12}C)
Z=6, A=12
Z/A = 0.5

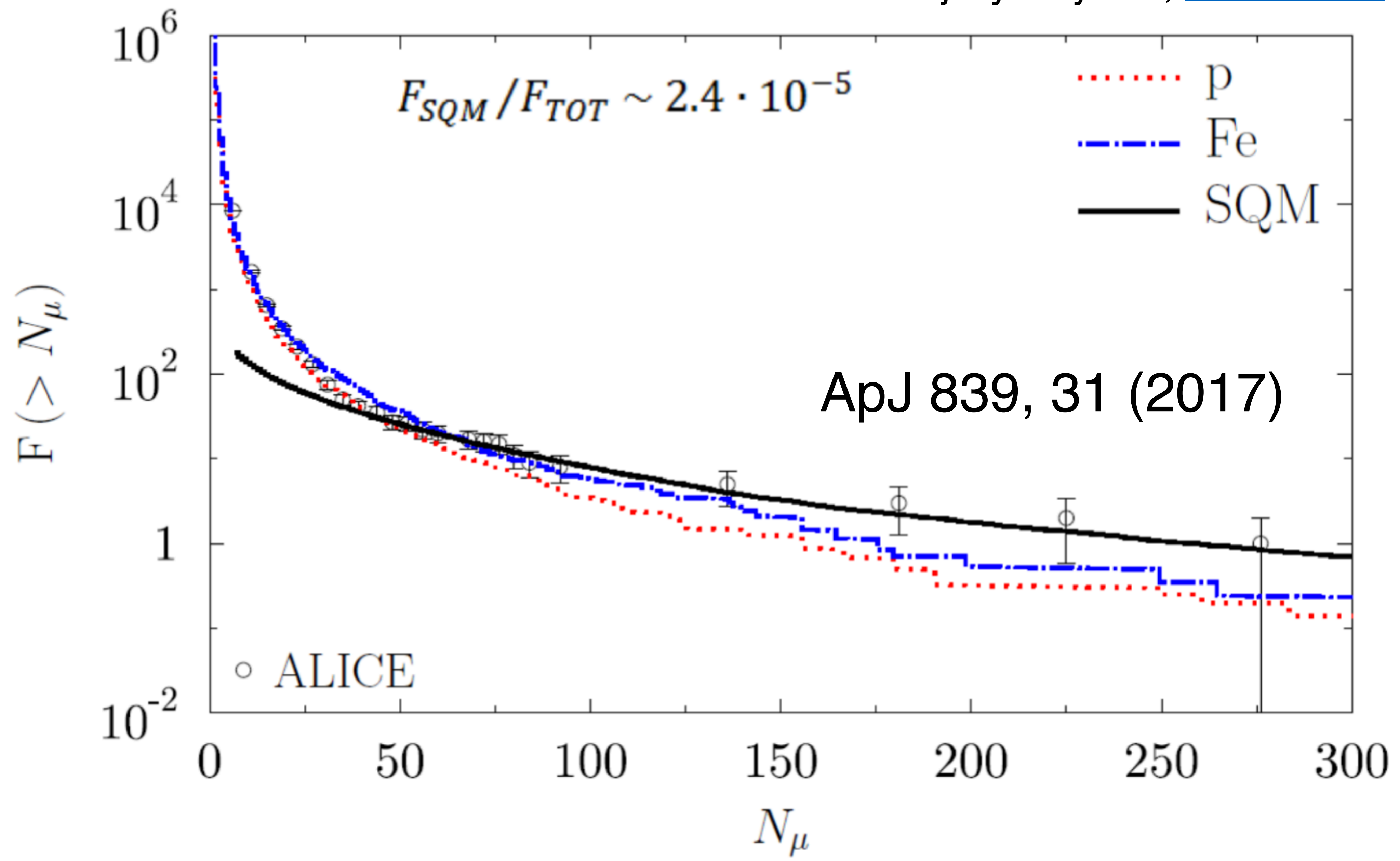
Strangelet*
A=12 (36 quarks)
Z/A = 0.083

From Maciej Rybczyński, ISMD 2017

*small lump of Strange Quark Matter

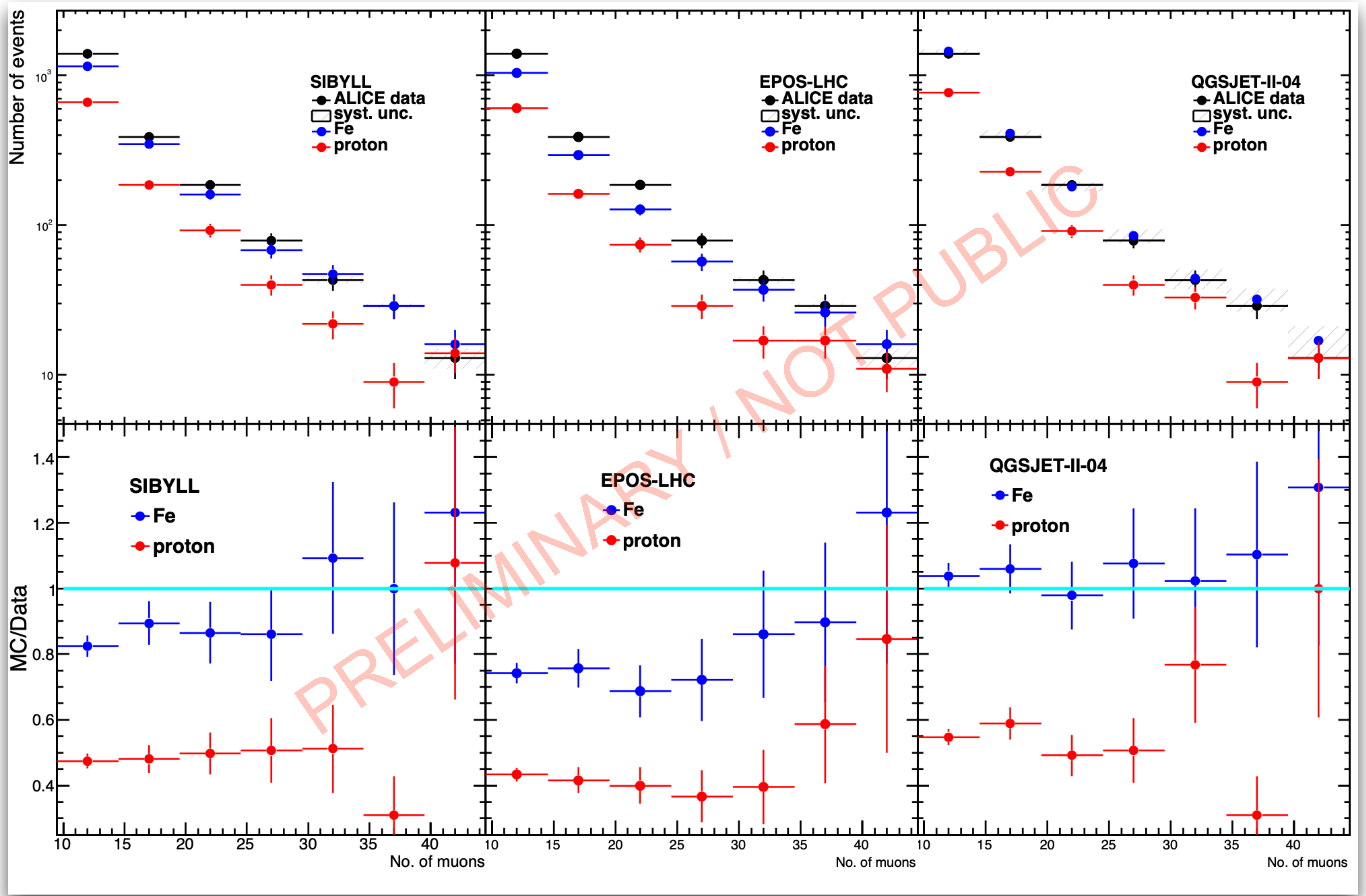
High multiplicity muon bundles from strange quark matter

From Maciej Rybczyński, ISMD 2017

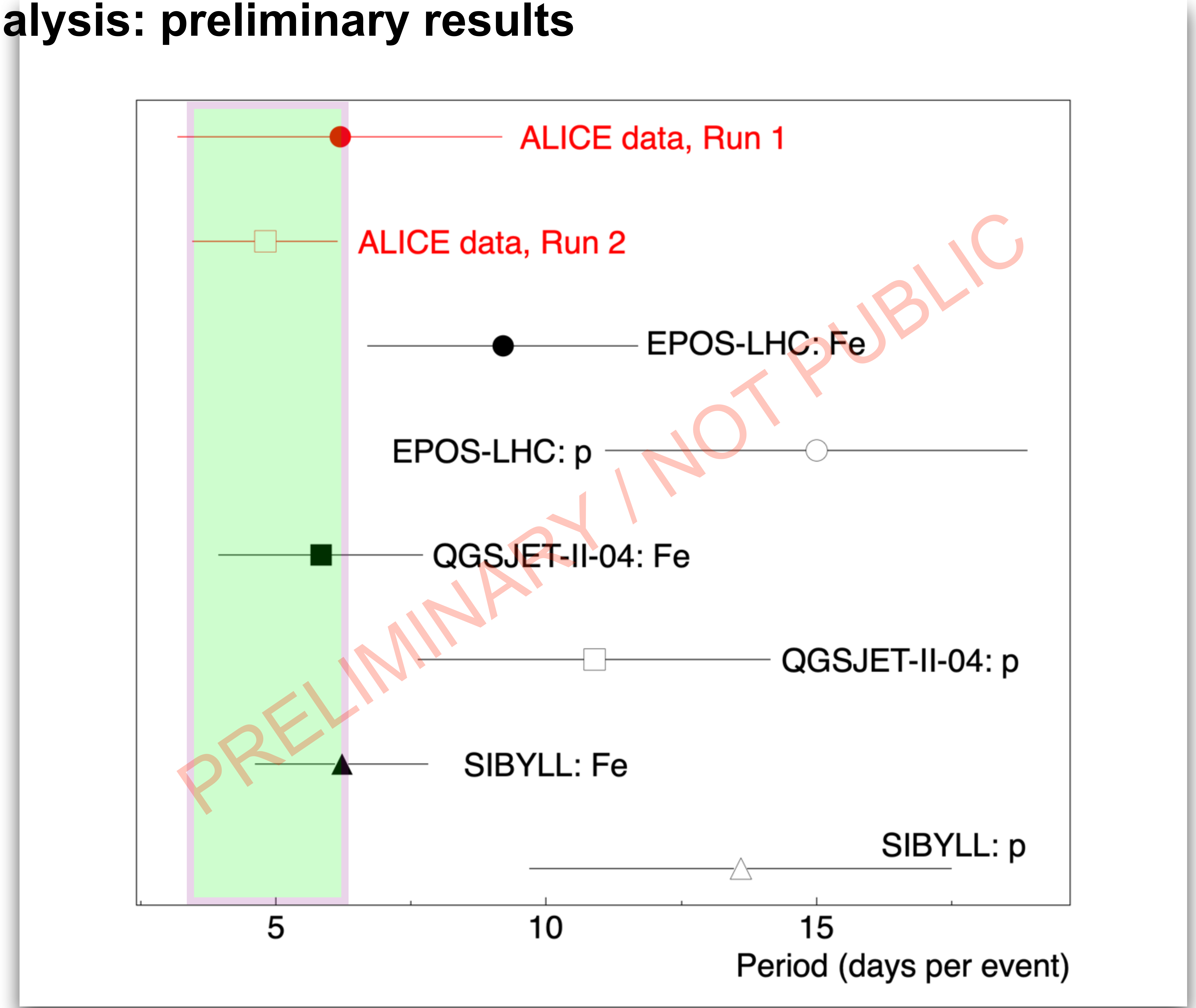


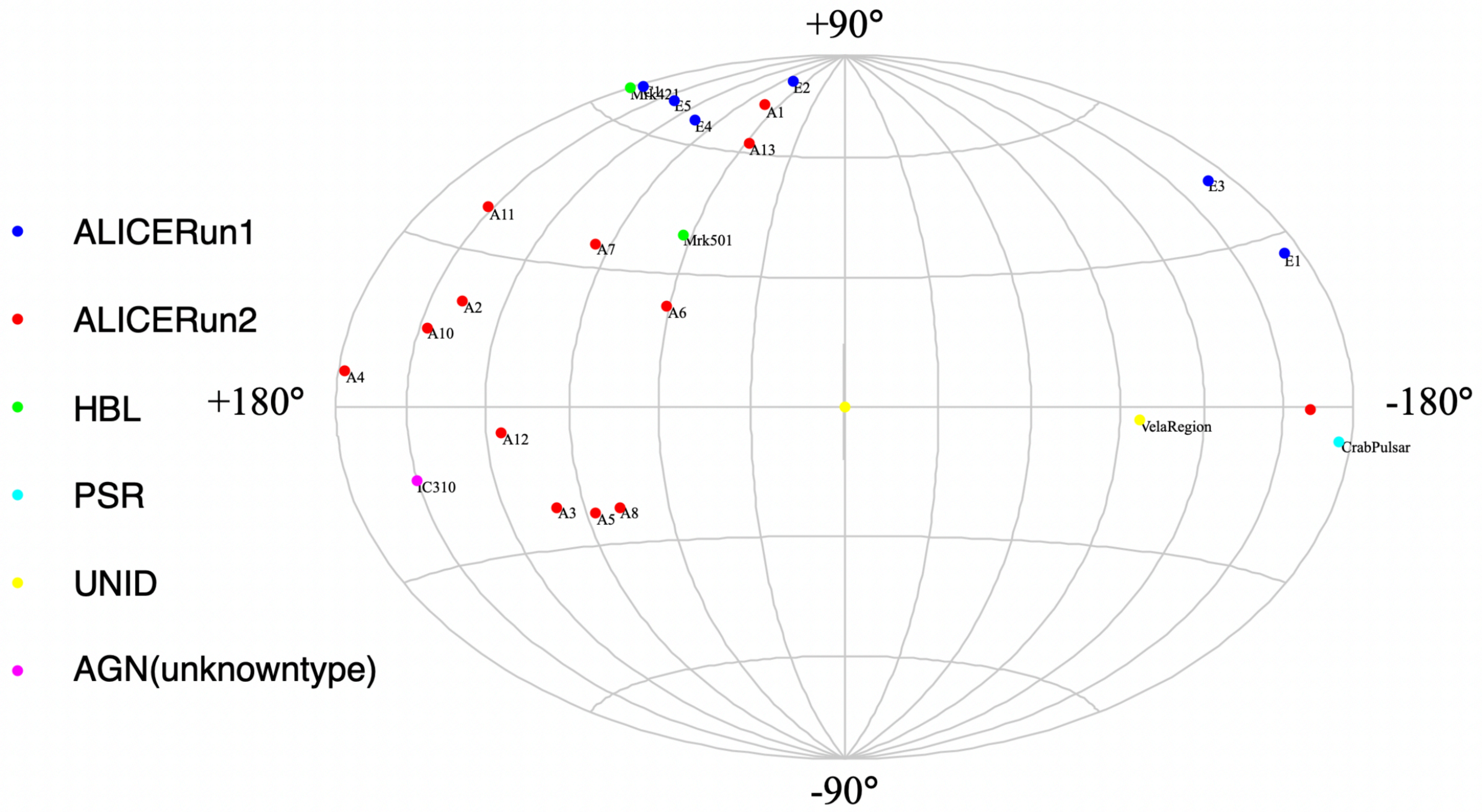
Integral multiplicity distribution of muons for the ALICE data (circles) published in JCAP 01 (2016) 032. Monte Carlo simulations for primary protons (dotted line); iron nuclei (dashed dot line) and primary strangelets with mass A taken from the $A^{-7.5}$ distribution (full line) with abundance of the order of $2 \cdot 10^{-5}$ of the total primary flux.

Run 2 data analysis: preliminary results

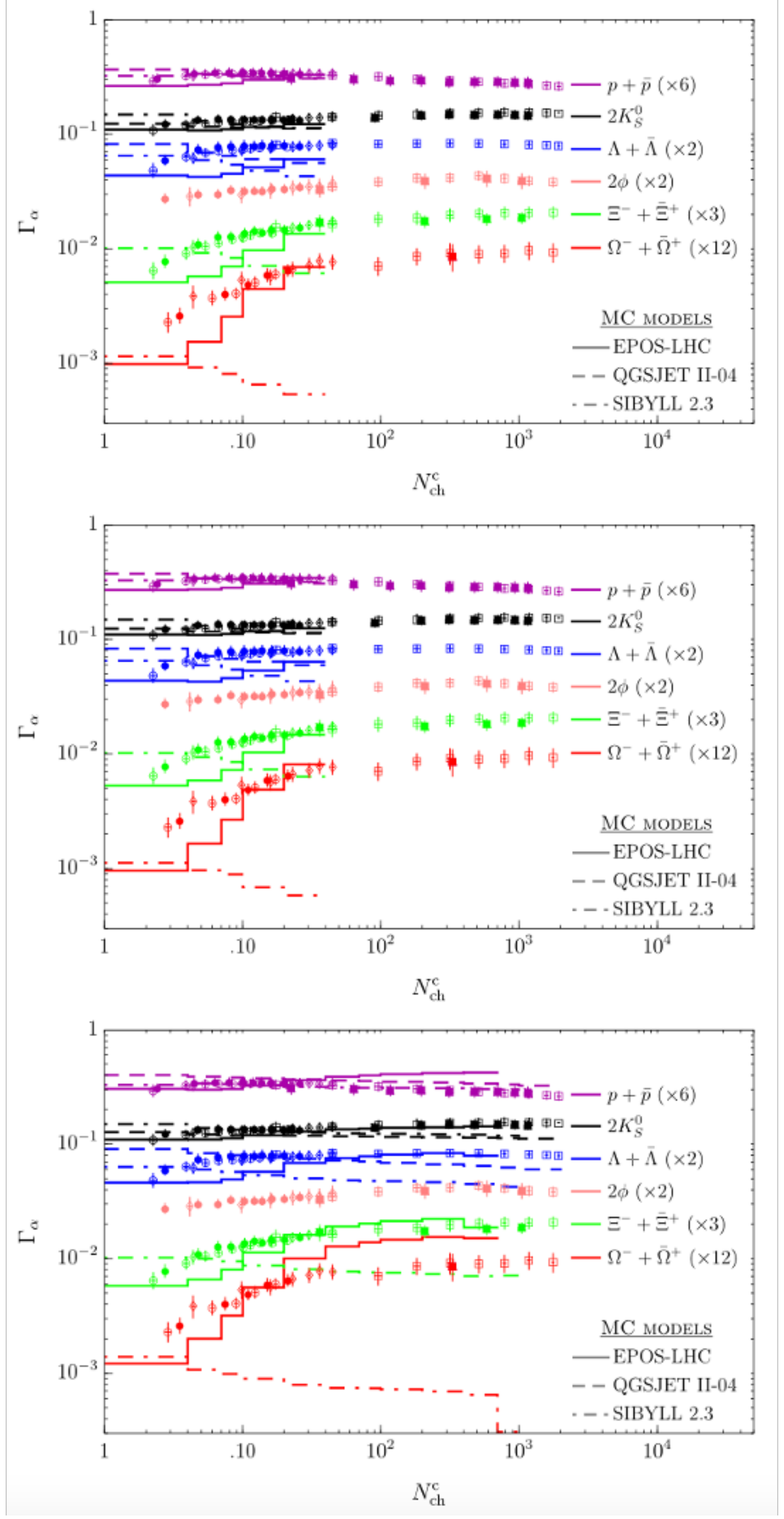


Run 2 data analysis: preliminary results




ALICERun1
ALICERun2
HBL
PSR
UNID
AGN(unknowntype)
+90°
-90°
+180°
-180°
Mrk421
E5
E2
A1
E4
A13
E3
A11
A7
Mrk501
E1
A2
A6
A10
A4
A12
VelaRegion
CrabPulsar
IC310
A3
A5
A8

Physics Letters B
Volume 810, 10 November 2020, 135837



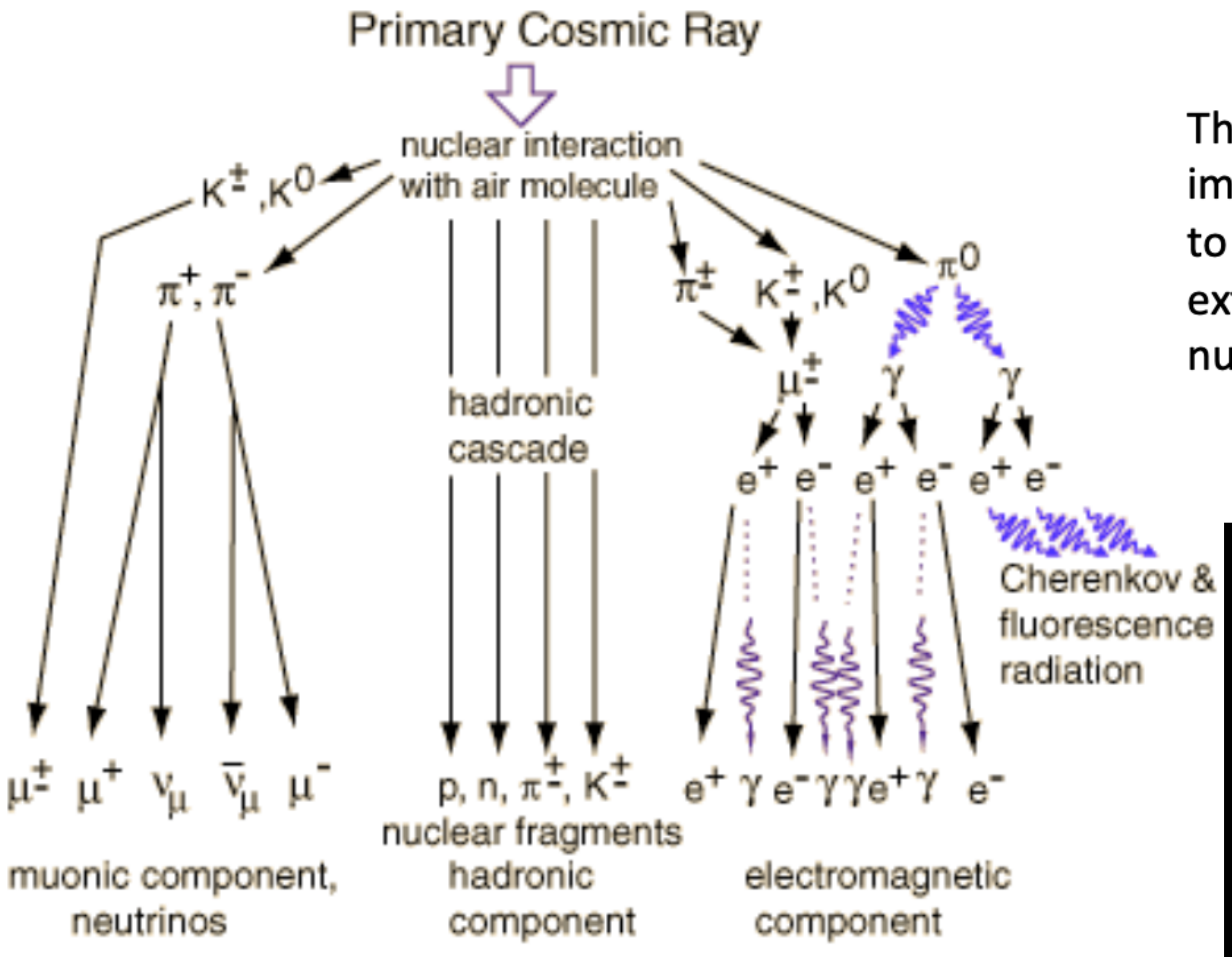
7 TeV,pp

13 TeV,pp

12 TeV,pp

ALICE Collaboration. Enhanced production of multi-strange hadrons in high-multiplicity proton–proton collisions. *Nature Phys* **13,** 535–539 (2017). https://doi.org/10.1038/nphys4111

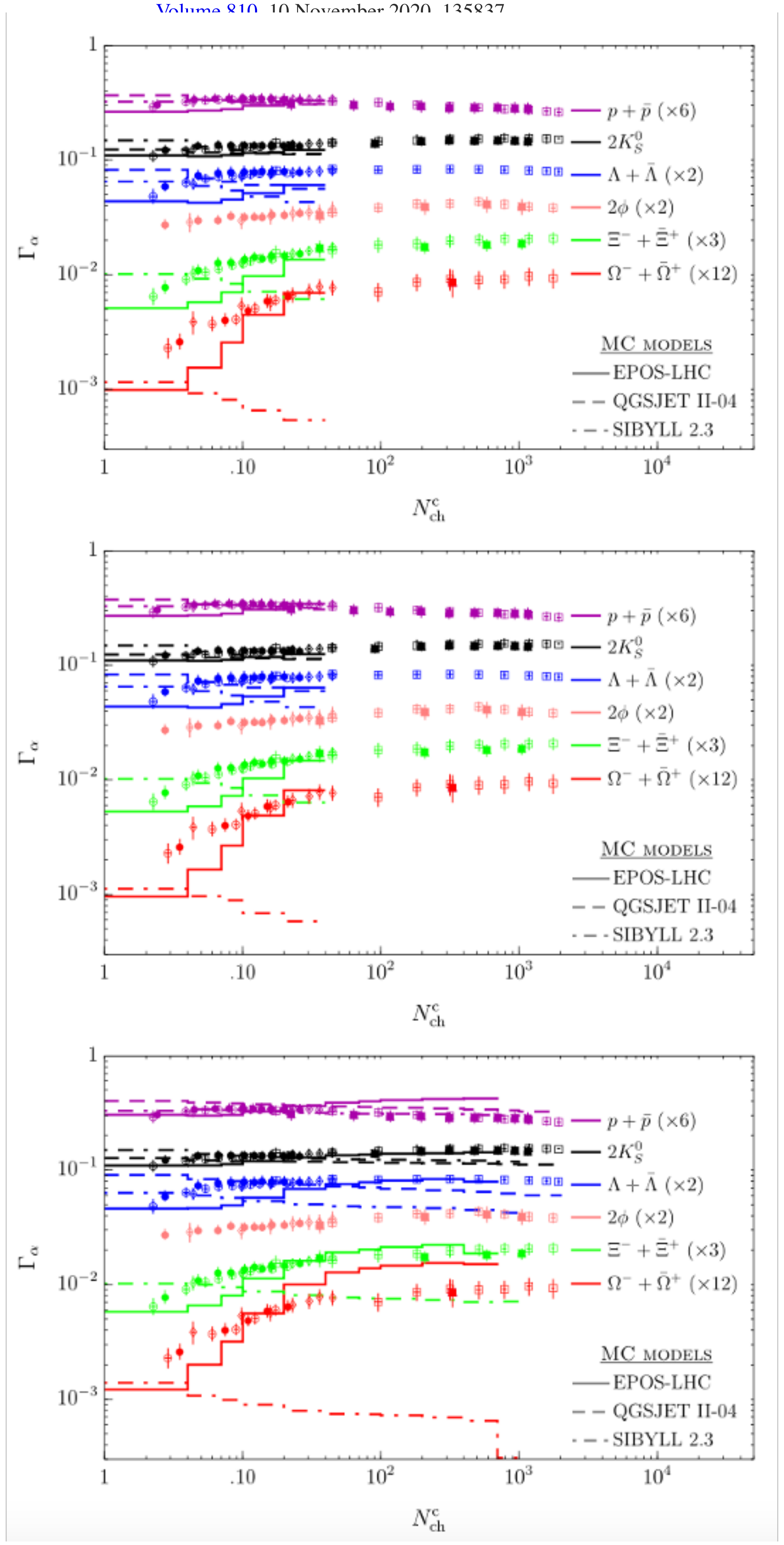
- the production rate of K^0_S, Λ, ϕ, Ξ, and Ω increases with multiplicity faster than that for charged particles;
- the higher the strangeness content of the hadron, the more pronounced is the increase;
- the ratios do not seem to depend on the system size or collision



The enhacement of strange hadrons may imply a suppresion of the transfered energy to the electromagnetic component of the extensive air shower → this will enhance the number of muons in extensive air showers.

If QGP is formed in heavy-ion collisions we would expect to be formed in scattering of ultra high energetic cosmic-rays in the upper atmosphere (at the core location of the collision).
With a large statistics we may be able to distinguish between the HHM events predicted by QGSJET and those from other source? i.e, QGP or strangelets. ?

Physics Letters B
Volume 810, 10 November 2020, 135837



7 TeV,pp

13 TeV,pp

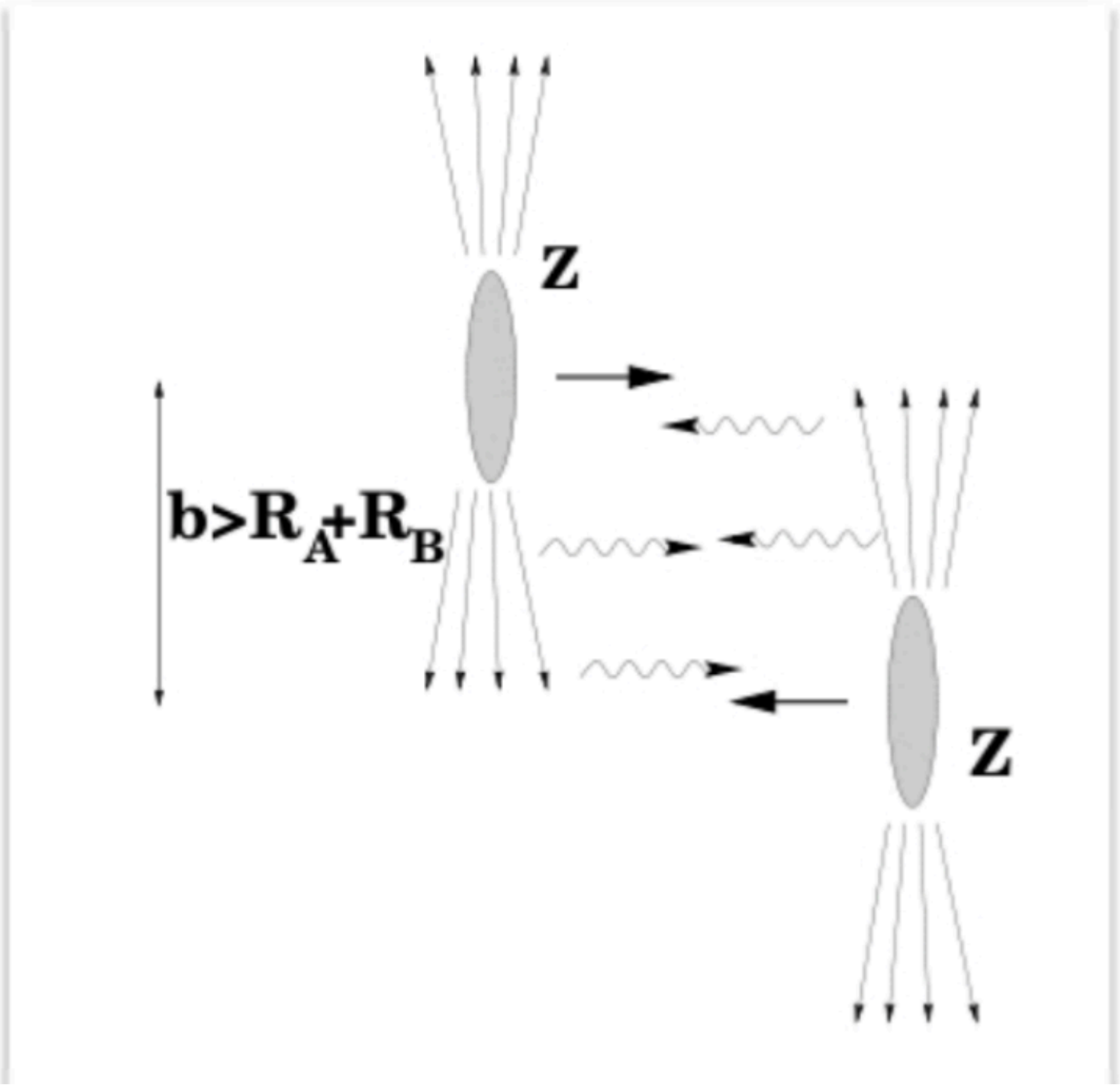
12 TeV,pp

The best description of the data is given by EPOS-LHC.
What about EPOS 3/4? This is a work in progress

The observed enhancement of strangeness in small systems and large colliding systems will suppress the fraction of energy transferred to the electromagnetic component of the extensive air shower -> this implies an enhancement of the muons at the surface level (muon puzzle). (Phys Lett. B 810 (2020) 135837) Is this effect connected, in some way, with some of the HMM events recorded by ALICE since 2008? A detailed study of HMM events is needed here.

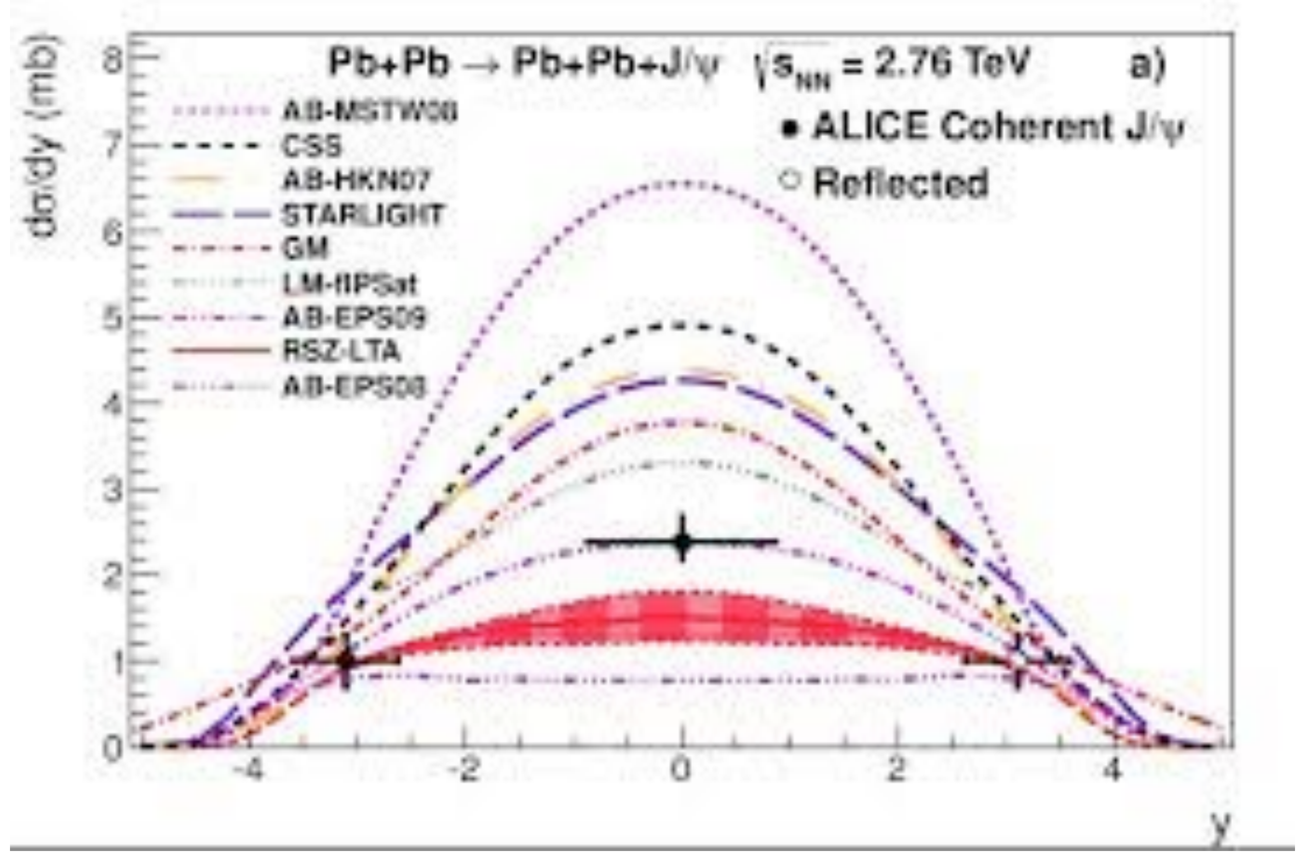
This kind of studies in pO and OO will enrich the modeling of hadron collisions at ultra high energies directly related with cosmic-ray physics.

UPC



- The photo production of vector mesons can be studied in ultra peripheral collisions (UPC) at LHC.
- UPC occurs if b > R_A+R_B —> the photons and nuclei can interact in several ways.
- Hadronic interactions are suppressed: only interactions mediated by the strong electromagnetic field behaving as a flux of virtual photons possible.
- LHC is used as a photon collider.

- Coherent process: photon interacts with the entire ion (all nucleons). In most of the cases there are not neutron emission (80%)
- Incoherent process: the photon interacts with single nucleon (most of the times the target nucleus dissociates)



BUAP contribution: invariant mass mu+mu- and luminosity determination

This is an old analysis, first results with run 1 data since Padova APW (2013)

Why to look for excited states of ρ^0 in photo-production with Pb+Pb and p+Pb data?

- ✧ Not clear how many excited states exist, or their possible quantum number (see special PDG review)
- ✧ STAR already published a paper on four-pion production in UPC
- ✧ No HERA papers on the photo-production of a ρ^0 excited state

Introduction

http://pdg.lbl.gov/2012/reviews/rpp2012-rev-rho1450-rh

THE $\rho(1450)$ AND THE $\rho(1700)$

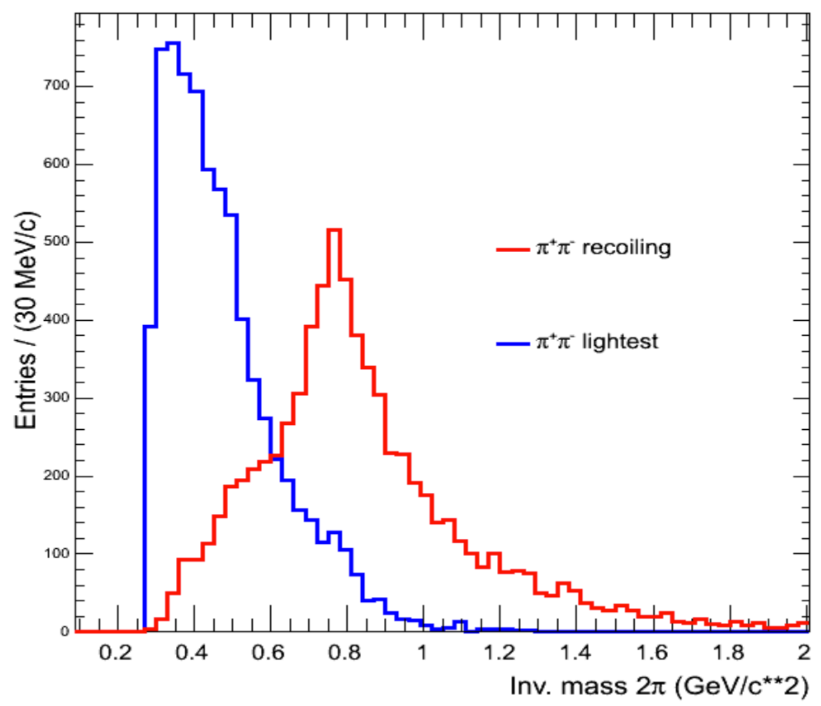
Updated May 2010 by S. Eidelman (Novosibirsk) and G. Venanzoni (Frascati).

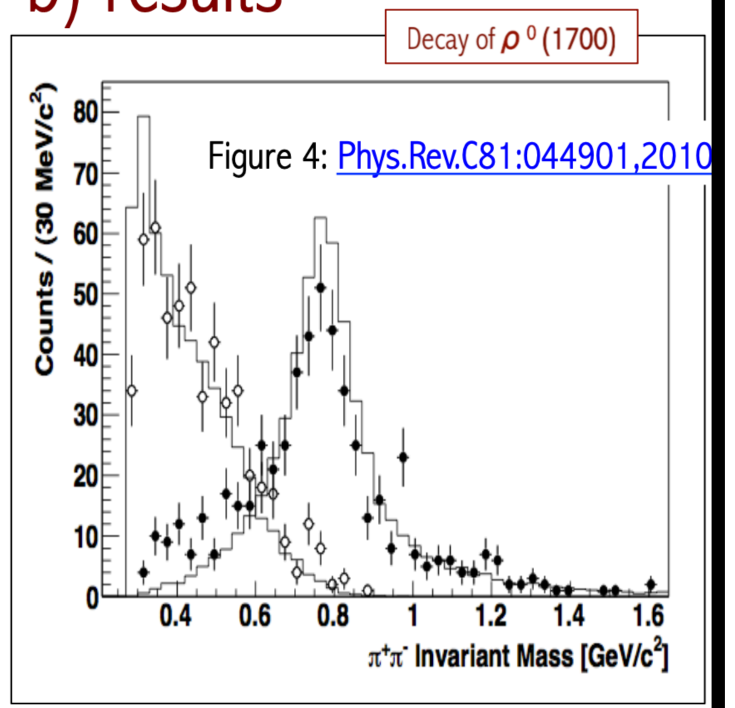
In our 1988 edition, we replaced the $\rho(1600)$ entry with two new ones, the $\rho(1450)$ and the $\rho(1700)$, because there was emerging evidence that the 1600-MeV region actually contains two ρ-like resonances. Erkal [1] had pointed out this possibility

Decisive evidence for the $\pi\pi$ decay mode of both $\rho(1450)$ and $\rho(1700)$ comes from $\bar{p}p$ annihilation at rest [11]. It has been shown that these resonances also possess a $K\overline{K}$ decay mode [12–14]. High-statistics studies of the decays $\tau \to \pi\pi\nu_\tau$ [15,16], and $\tau \to 4\pi\nu_\tau$ [17] also require the $\rho(1450)$, but are not sensitive to the $\rho(1700)$, because it is too close to the τ mass. A recent very-high-statistics study of the $\tau \to \pi\pi\nu_\tau$ decay performed at Belle [18] reports the first observation of both $\rho(1450)$ and $\rho(1700)$ in τ decays.

The structure of these ρ states is not yet completely clear.

Four-pion system: 2011(Pb+Pb) results



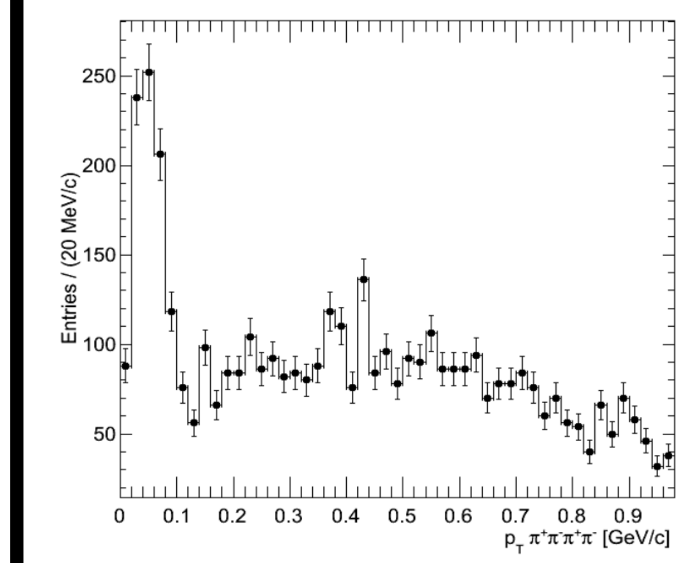


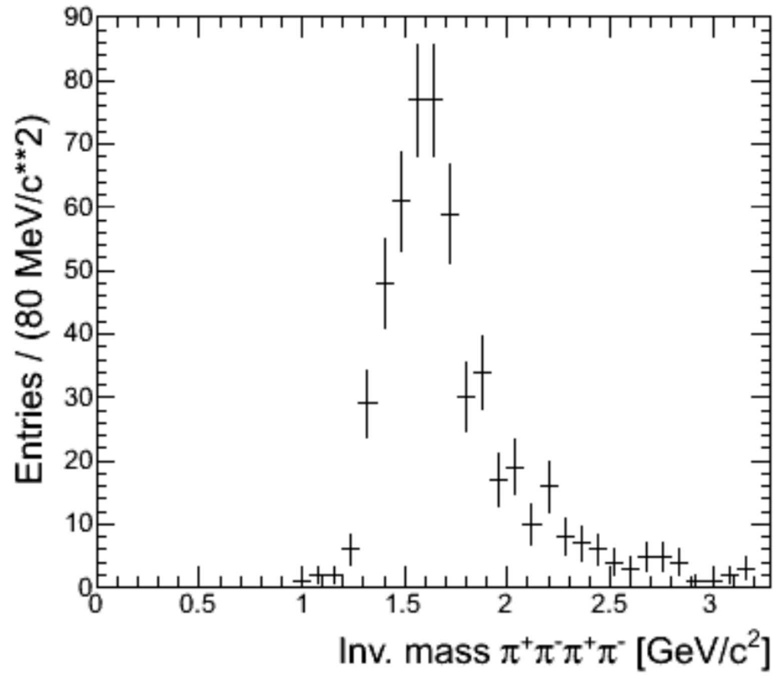
Remember slide # 4

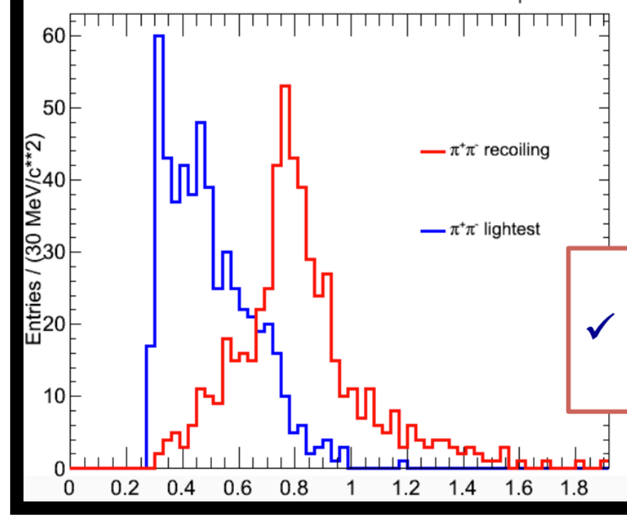
✓ # of Four-pion events with p_T < 0.15 GeV/c (coherent events): 7,332

✓ 10 times more events than used by STAR in their paper

Four-pion system: 2010 (Pb+Pb) results







Remember slide # 4

✓ # of Four-pion events with p_T < 0.15 GeV/c (coherent events): 537

✓ More or less the same number of events reported by STAR

ALICE's Physics Week – Padova, Italia

8

UPC triggers

Triggers determines which events to collect

A group of fast detector signals (1.2μs) compose a Trigger class.

CUP29:

- No signal in V0A(C)
- No signal in ADA(C)
- SPD topological trigger

CUP30

- CUP29 +At least 2 TOF pads activated

CUP31

- CUP21+ Between 2 and 6 TOF pads activated

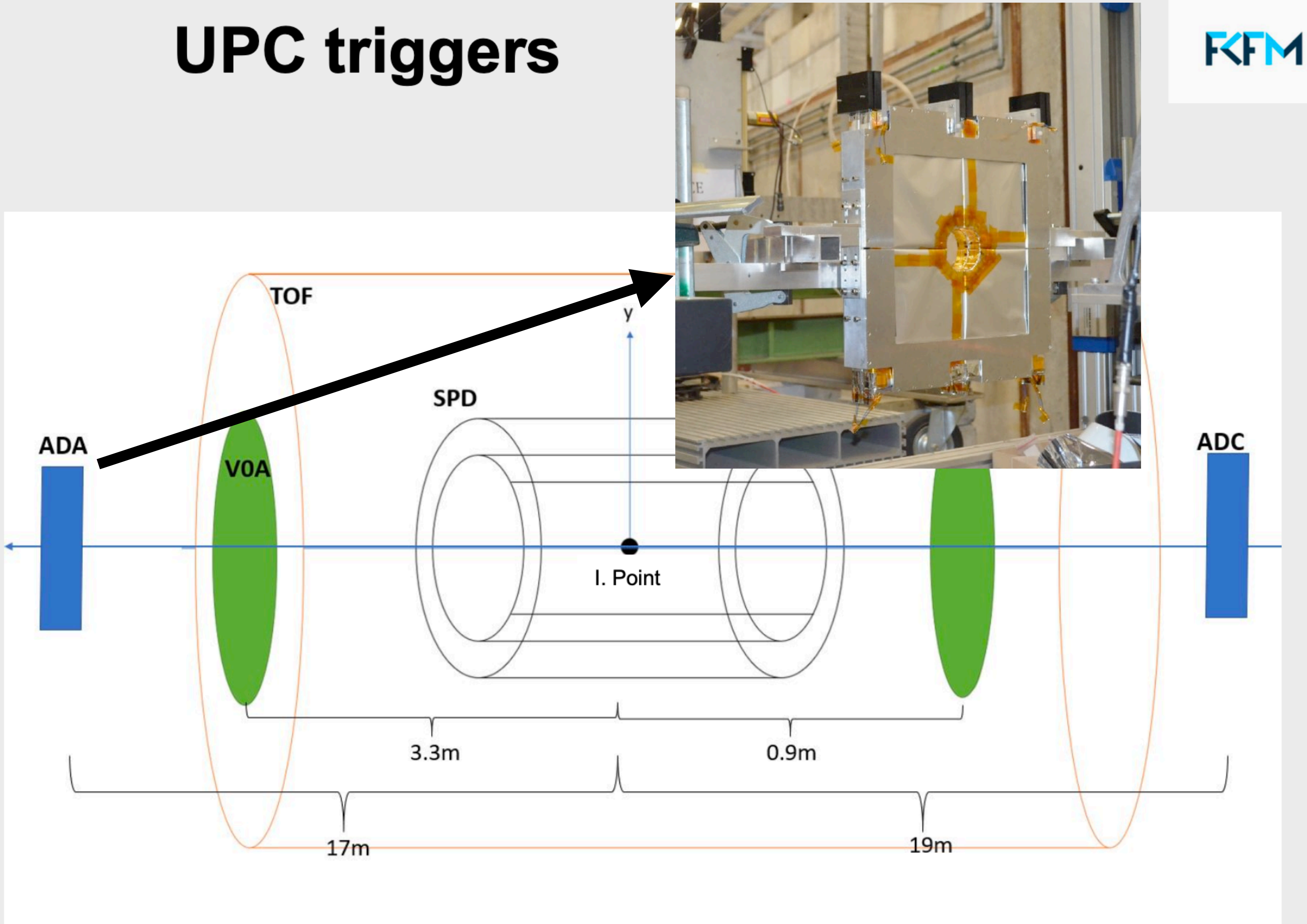


***Figure**: Detectors that conform the trigger CUP31*

Event-track selection

Track selection:

- ITS and TPC refit
- TPCNcls>50
- TPCchi2/TPCNcls < 4
- 2 hits in SPD(inner and outer layer)
- Primary Vertex related
- DCAz,xy< 2cm, 0.0182 + 0.035/$p_T^{1.01}$ cm
- Particle identification (pions)
- |rapidity(2-tracks) |< 0.9
- Pt<0.15GeV/c(Coherent production)

Event selection

- Events with any of the UPC triggers
- Primary vertex events
- |Zvertex |<10cm
- Net charge equal to zero
- V0 and AD offline decisions = Empty
- Exactly 2 (4) good tracks

Standard event and track selection

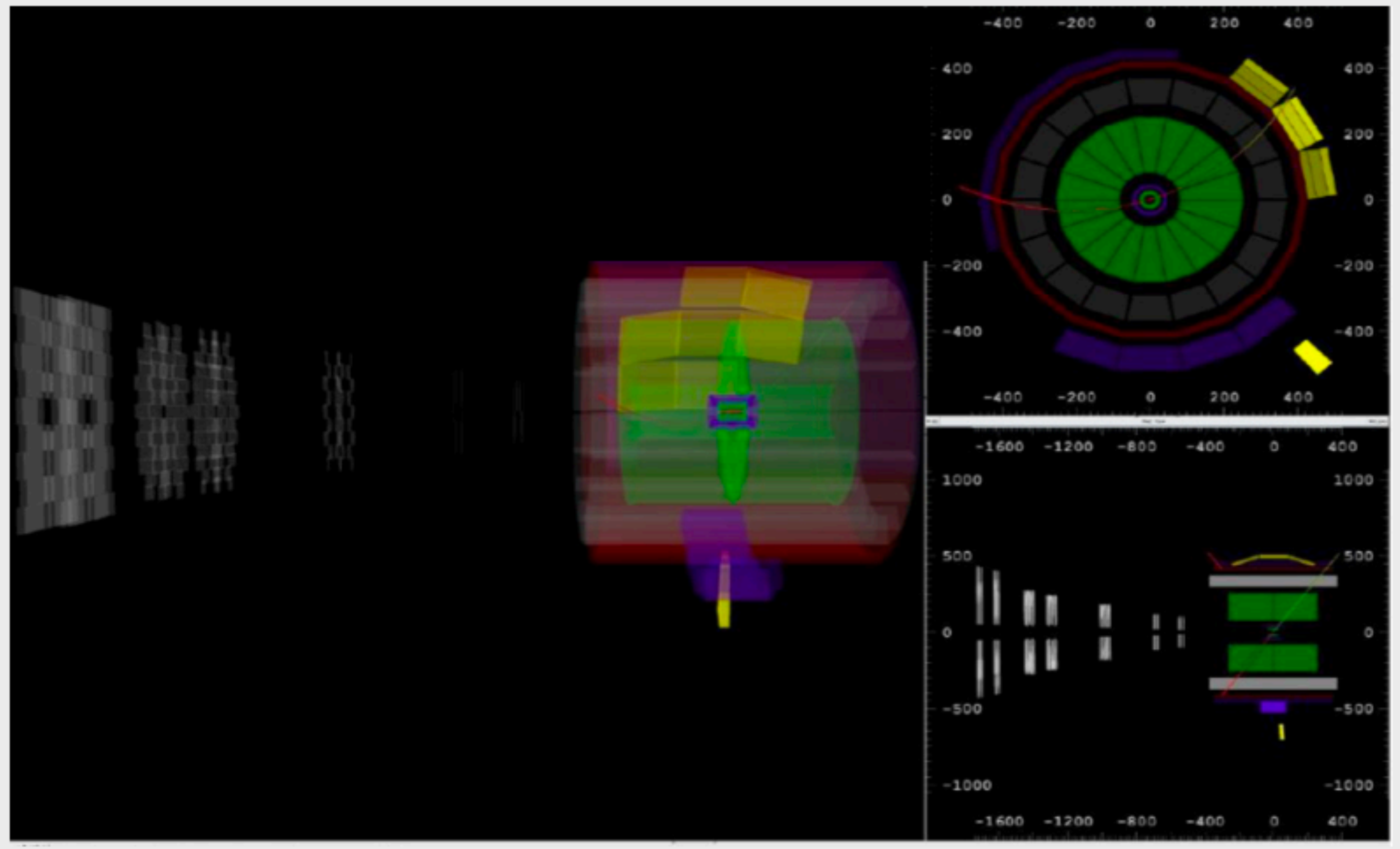


Figure: *2-pions event display*

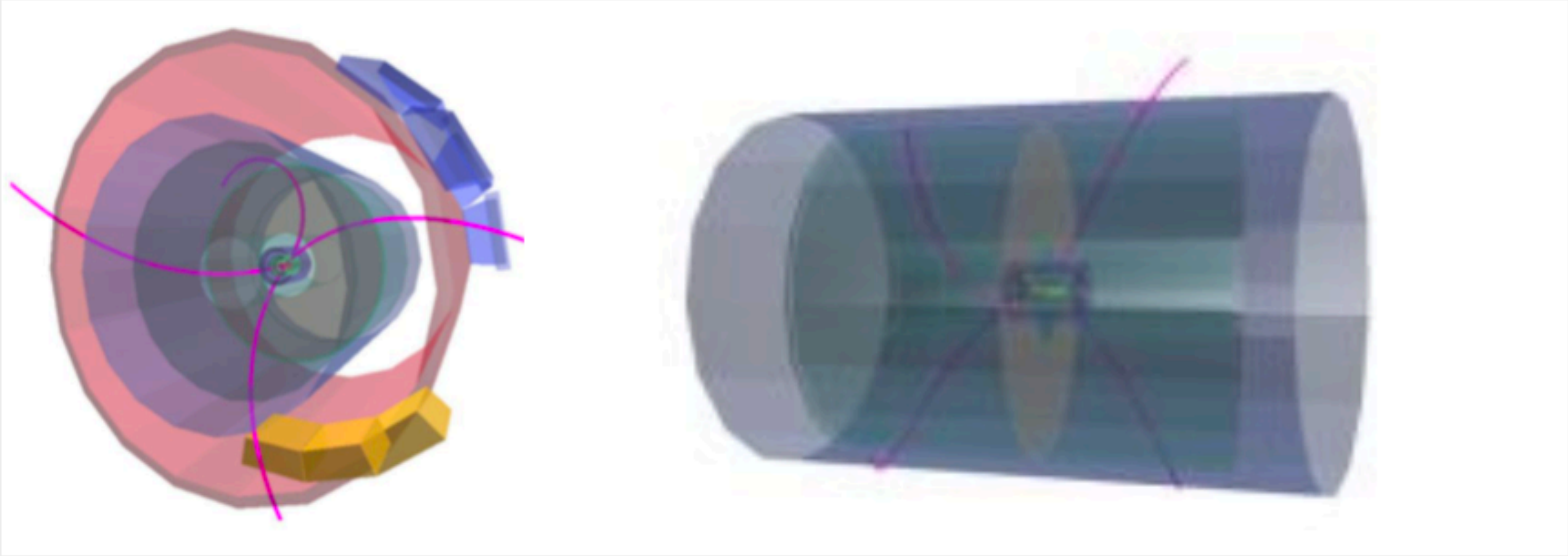
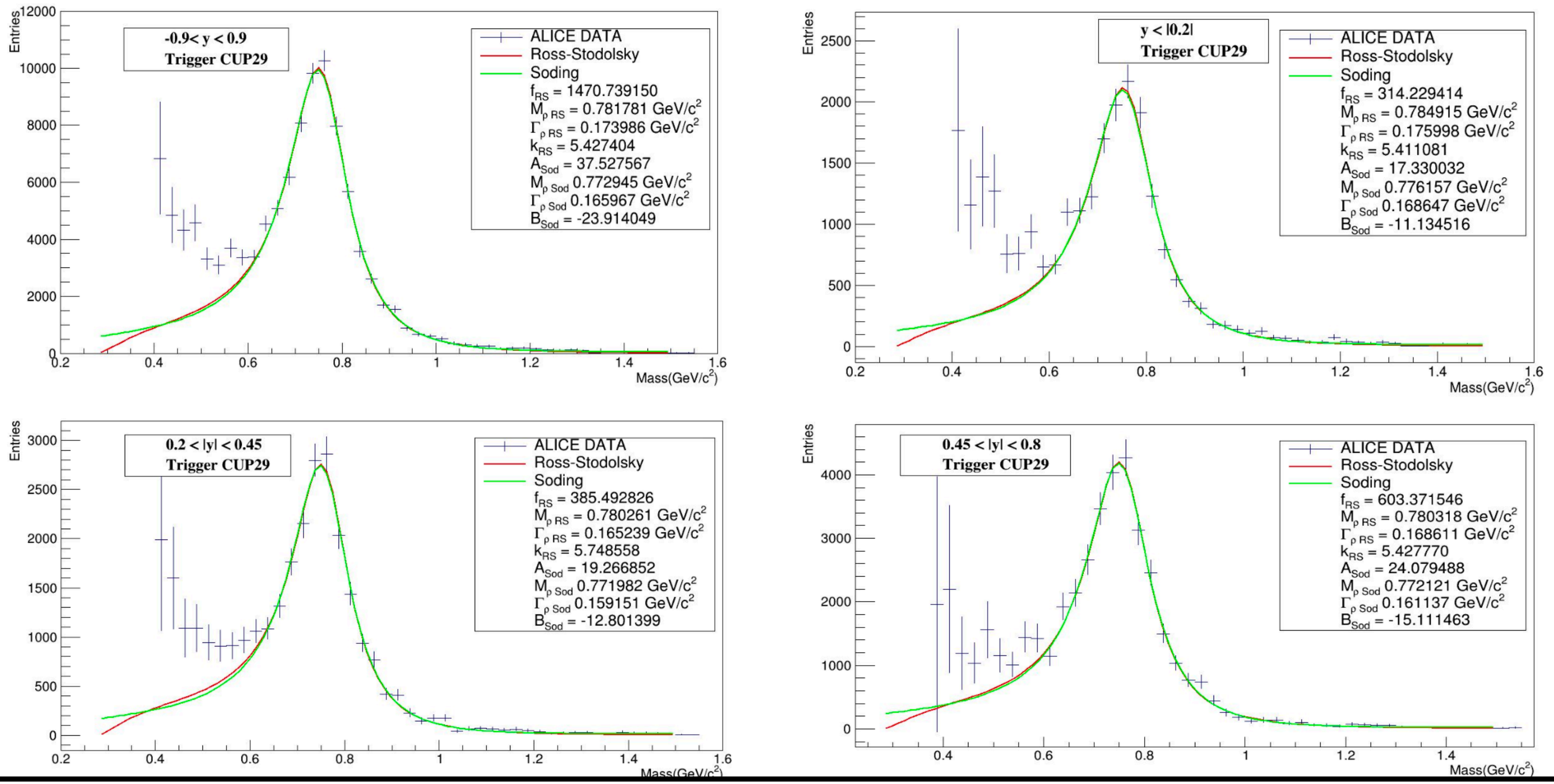


Figure: *4-pions event display*

Invariant mass distributions for 2 pions



22

2 pions 2018

Trigger CUP29 THIS ANALYSIS

Rapidity region	Ross-Stodolsky cand	Soding cand	Soding(resonant only) cand	CS estimation [mb]
|y|<0.9	90473.5	91707	83359	500.80
|y|<0.2	19318.3	19628	17733	479.41
0.2<|y|<0.45	24546	22072	24659	533.32
0.45<|y|<0.8	37097	37596	34432	531.92

Cross section (mb)
537.0
538.6
547.0

ALICE published paper (JHEP06 (2020) 35)

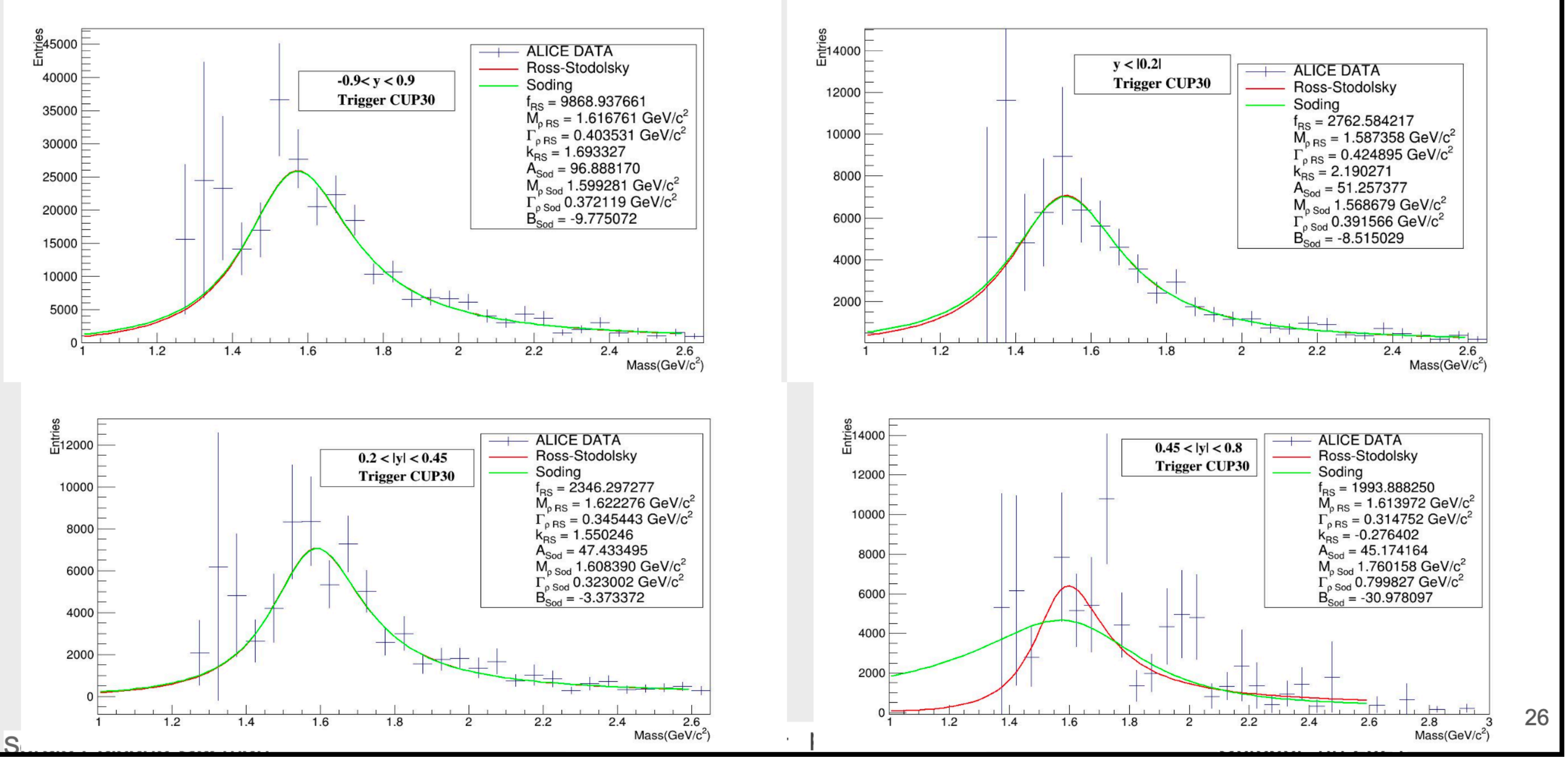
Trigger CUP30

Rapidity region	Ross-Stodolsky cand	Soding cand	Soding(resonant only) cand	CS estimation [mb]
|y|<0.9	2.93433e+06	3.01587e+06	2.89645e+06	556.87
|y|<0.2	599256	599966	603178	521.85
0.2<|y|<0.45	792354	825701	769362	532.5
0.45<|y|<0.8	1.4405e+06	1.38909e+06	1.24836e+06	617.23

Sergio Paisano Guzman π+π- and π+π-π+π- photoproduction October 4th 2021 24

Invariant mass distributions for 4 pions

THIS ANALYSIS



THIS ANALYSIS

4 pions 2018

CUP29

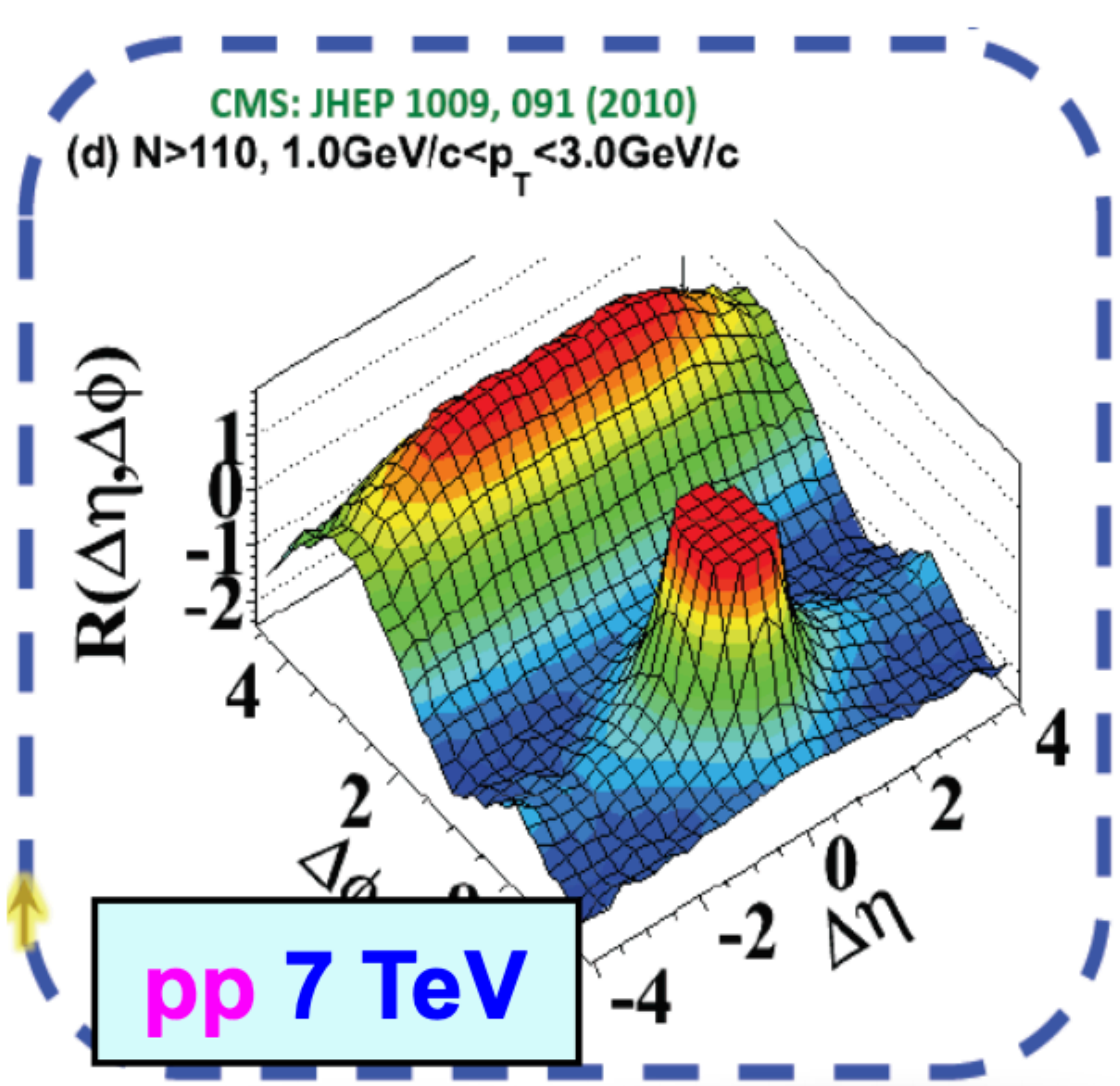
rapidity region	Ross-Stodolsky cand	Soding cand	CS estimation [mb]
|y|<0.9	8418.24	8456.53	50.68

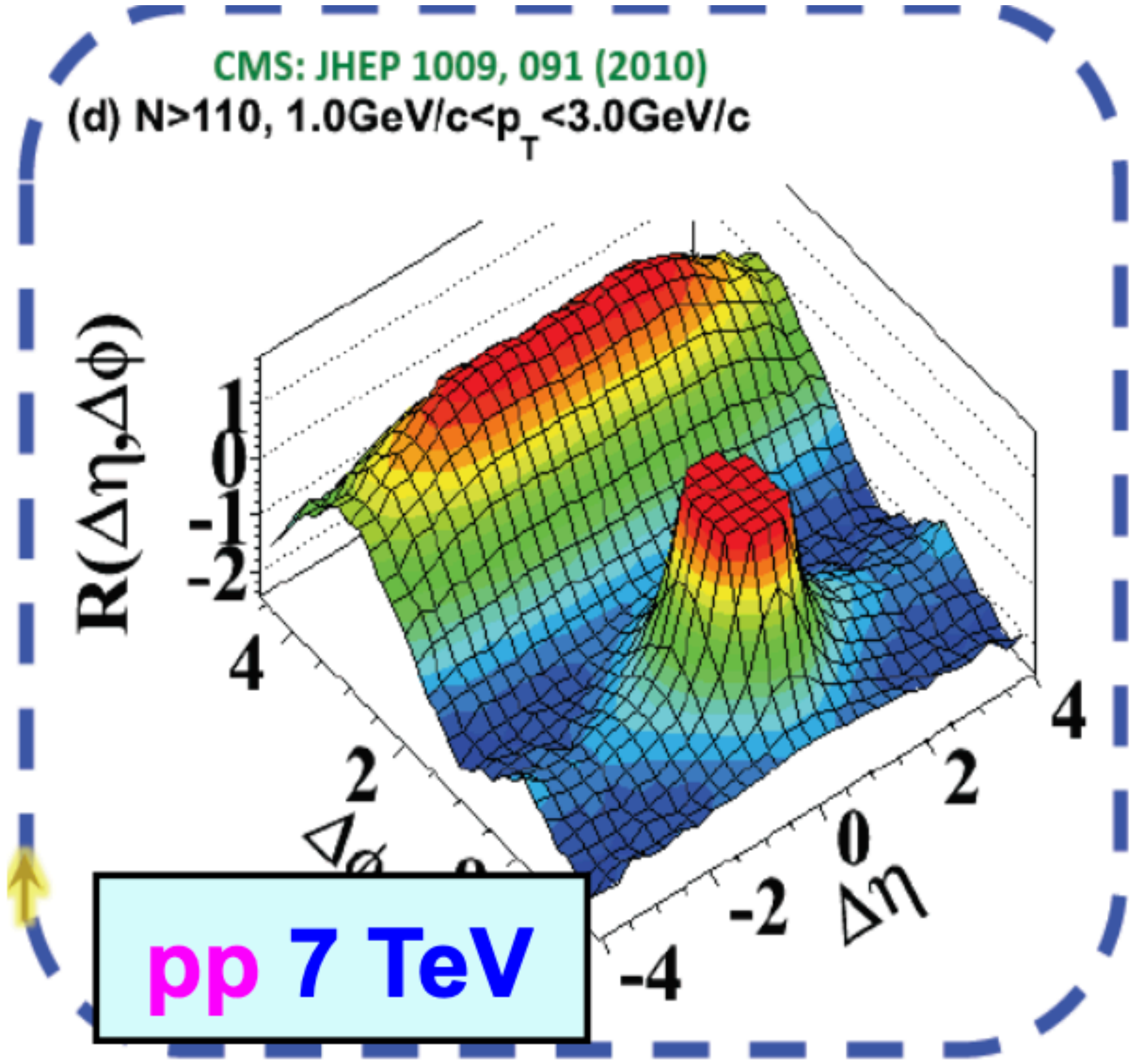
CUP30

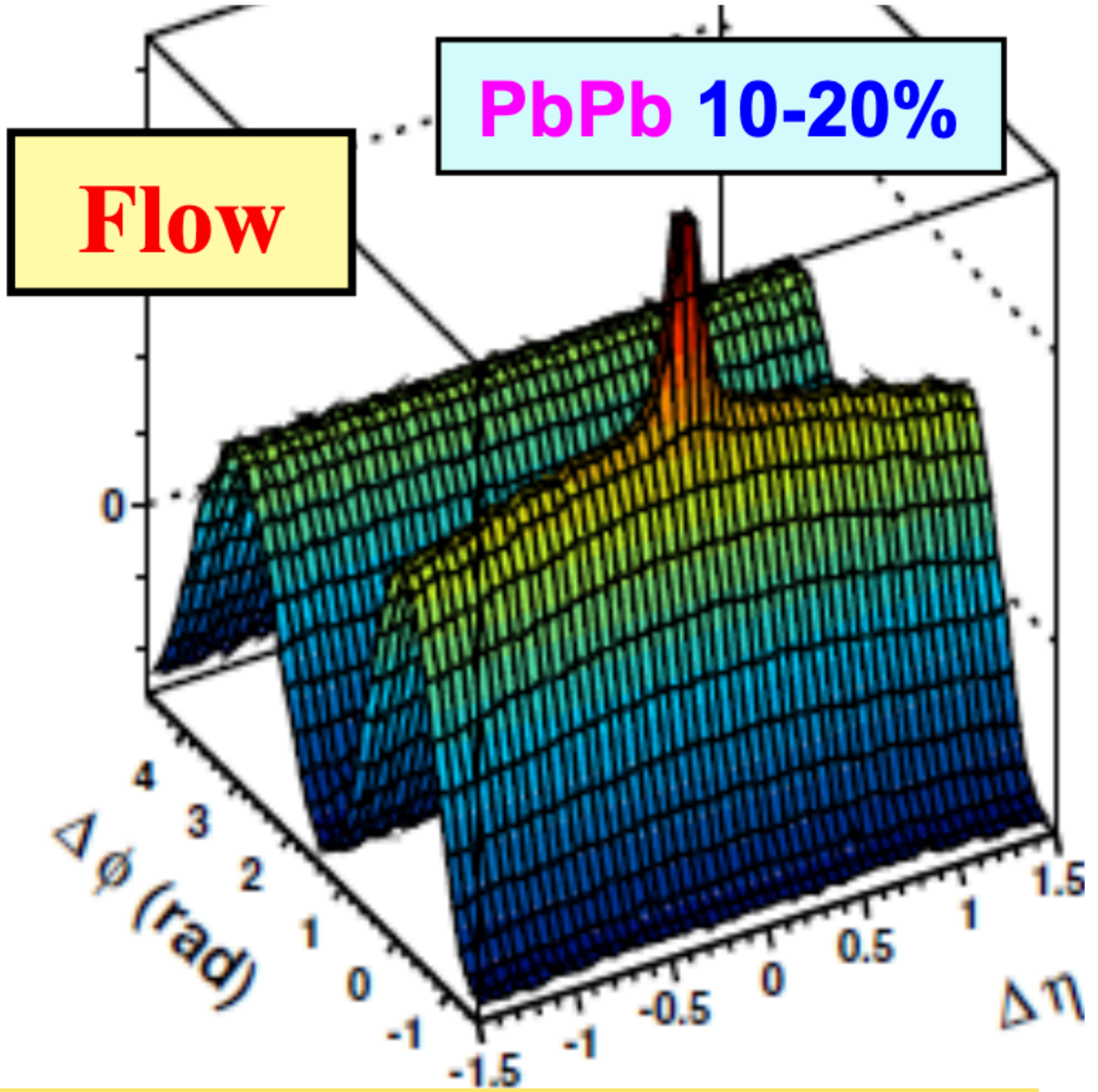
rapidity region	Ross-Stodolsky cand	Soding cand	CS estimation [mb]
|y|<0.9	247788	250263	47.87
|y|<0.2	67924.6	69140.2	59.29
0.2<|y|<0.45	61335.5	61644.3	42.55
0.45<|y|<0.8	57645.4	74072.2	32.6

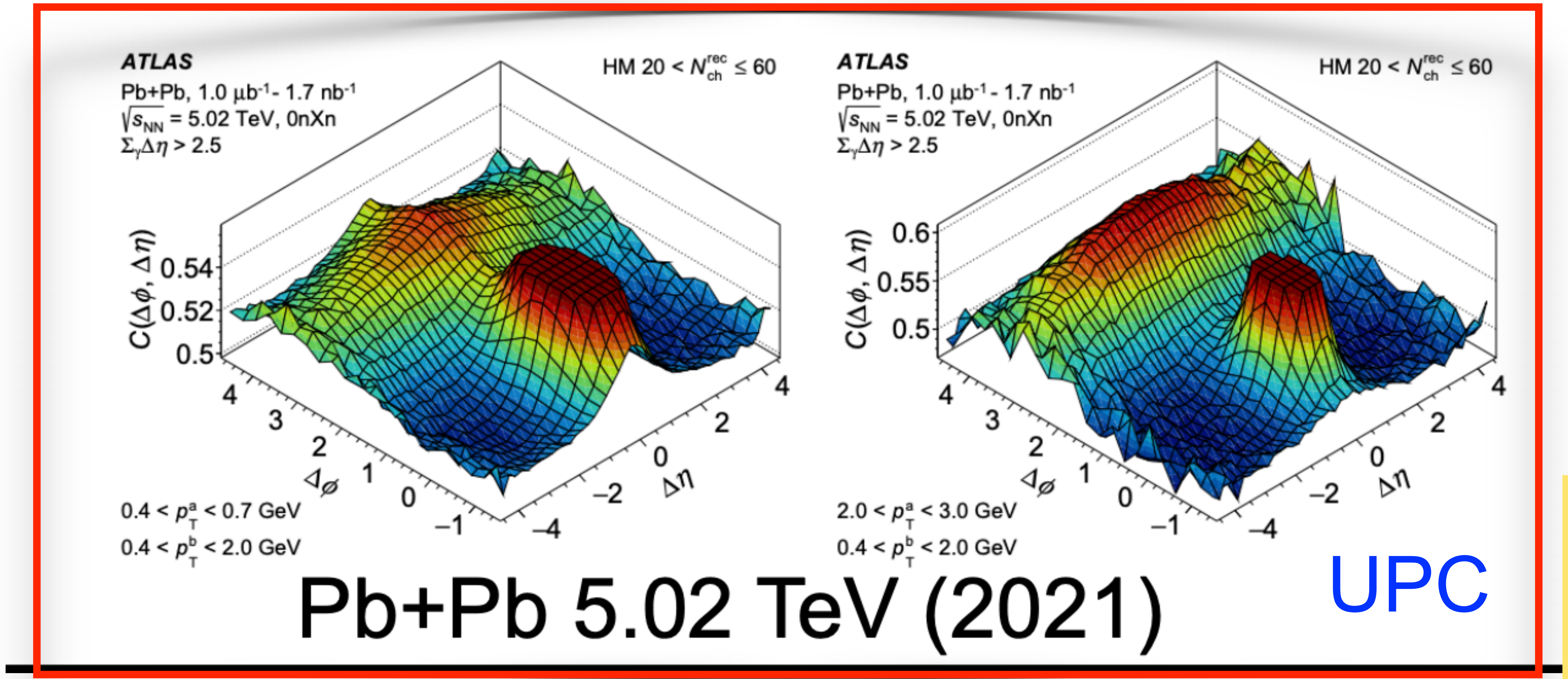
To do list:

- systematic uncertainties estimation
- background studies (Monte Carlo)
- model comparison.
- first version of the analysis note almost ready

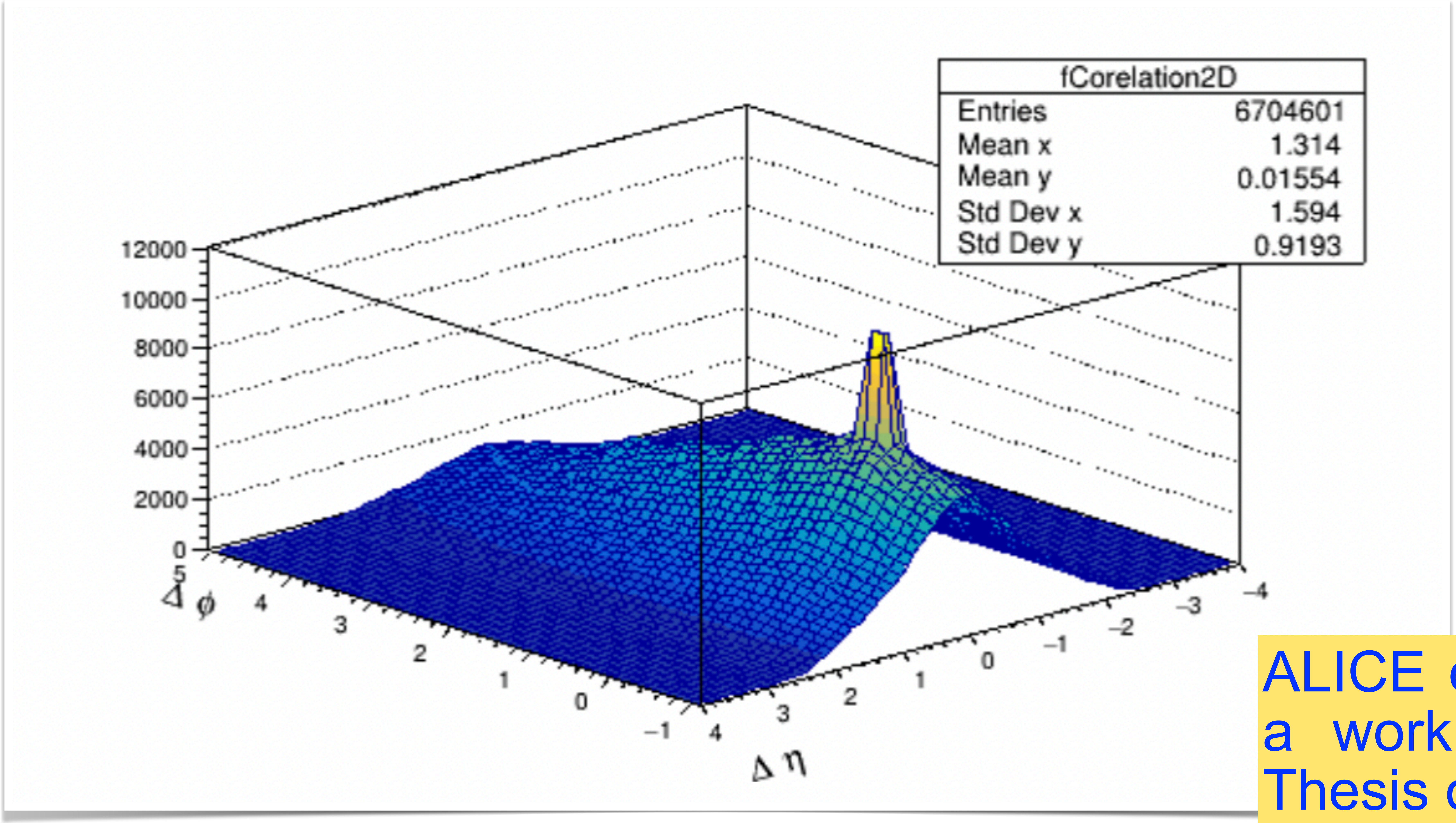






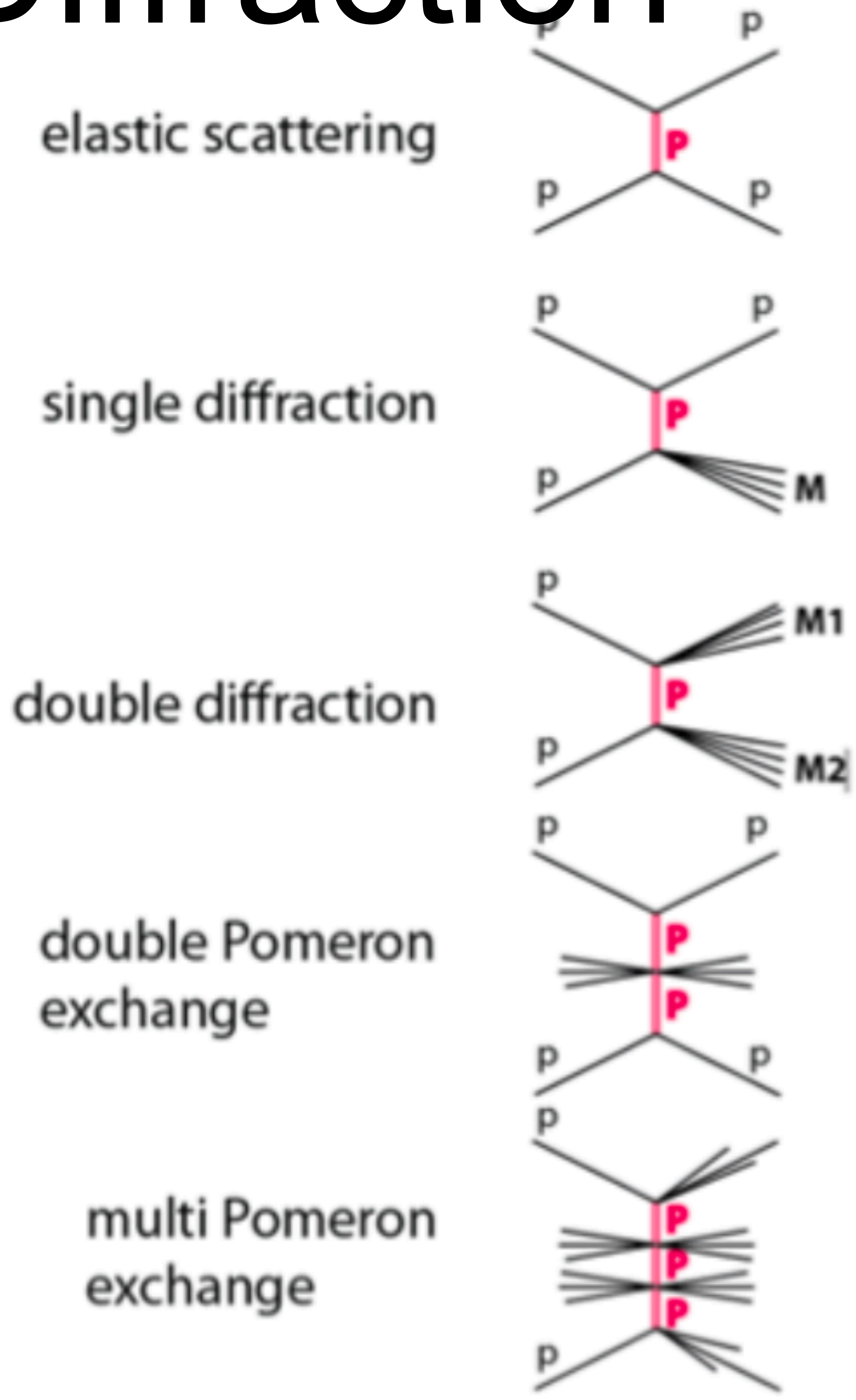


We may have a look to our UPC data and make an estimation for Run 3 data



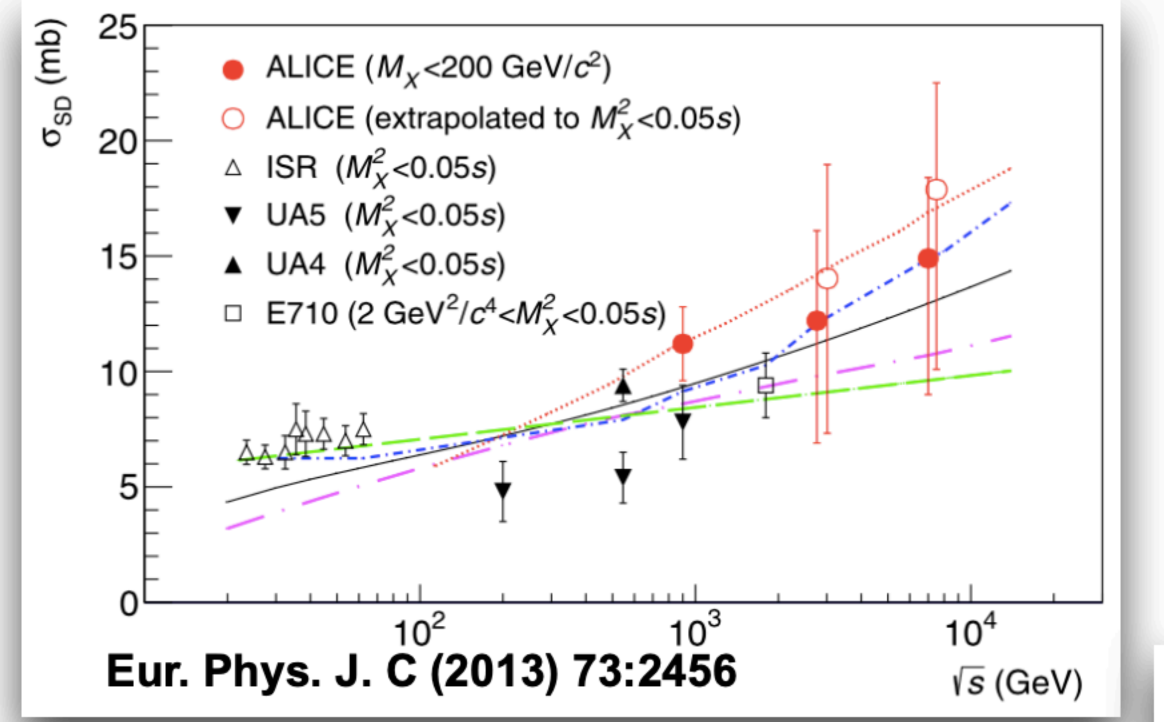
ALICE data, few runs. This is a work in progress (Master Thesis of Josué Martínez)

Diffraction



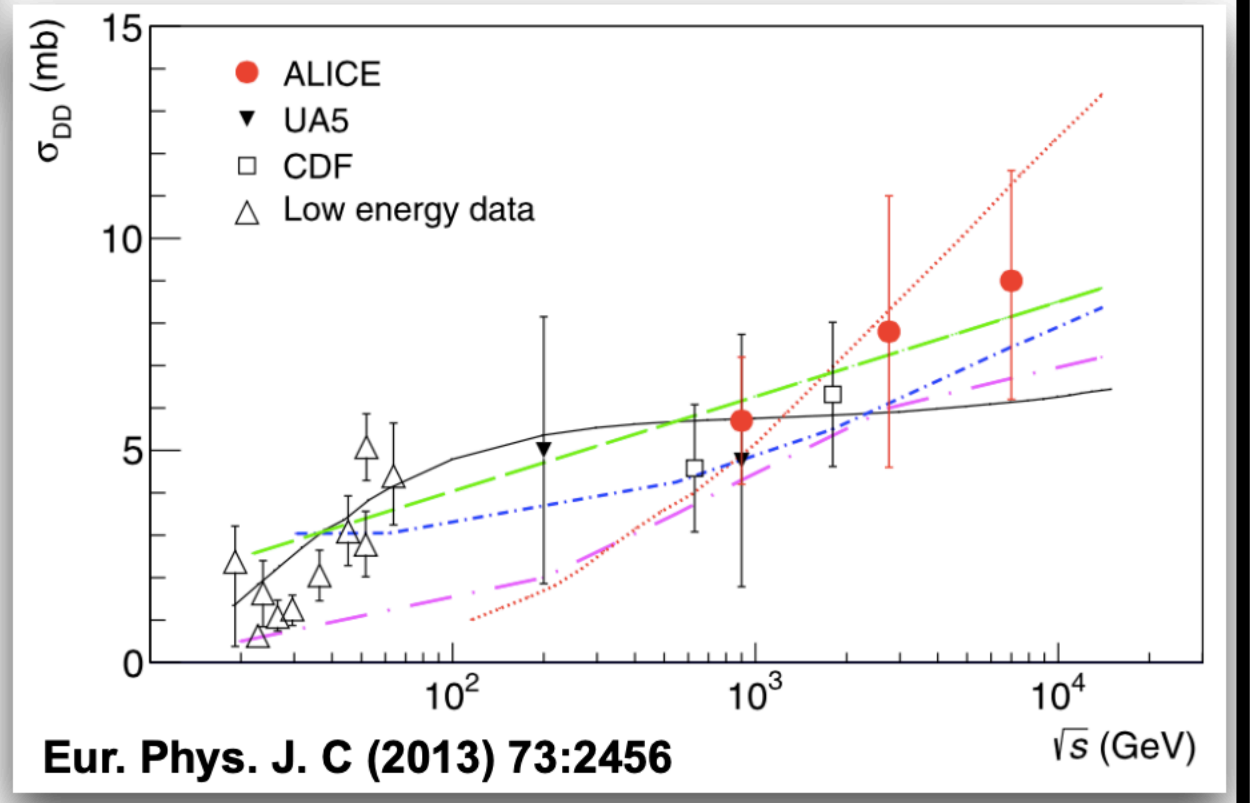
- In a diffraction reaction, no quantum number are exchanged between the particles colliding at high energies.
- Diffraction is elastic (or quasi elastic) scattering caused by the absorption of components of the wave function of the incoming particles: *p-p->p-p*, *p-p->pX* (single proton dissociation, Single Diffractive), *p-p->XX* (both protons dissociate, Double Diffractive).
- A diffractive process is characterized by a large rapidity gap (LRG).
- Needed so as to understand the structure of high energy cosmic ray phenomena.

Unfortunately we don't have a diffractive cross section with ALICE Run 2 data. With the FDD we can try to get the diffractive cross sections.

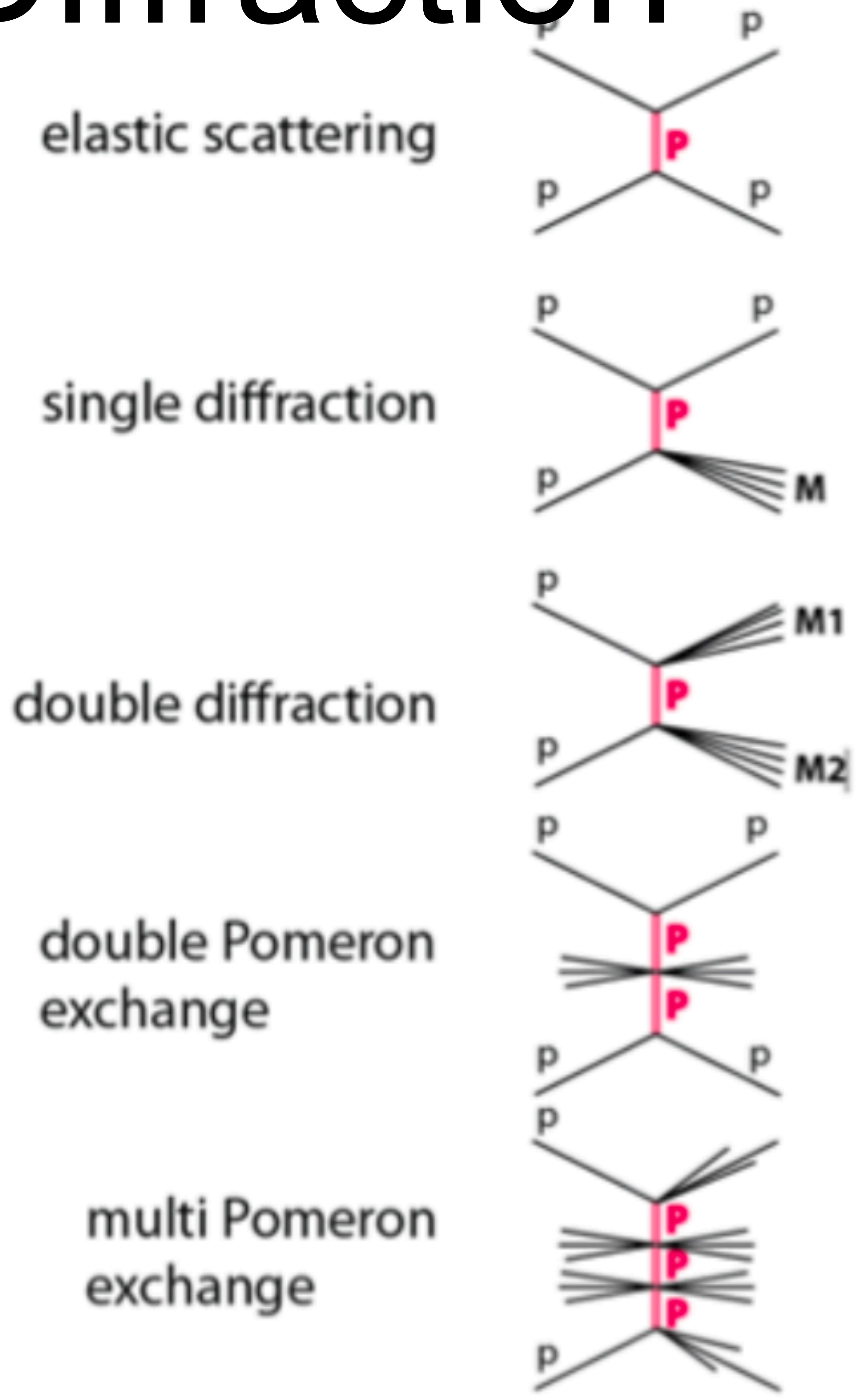


Within large uncertainties, ALICE measurements are in agreement with the data from UA5, UA4 and CDF.

With the inclusion during LS1 of the Alice Diffractive Detector (**AD**), ALICE could extend its studies on diffractive events at higher energies.



Diffraction



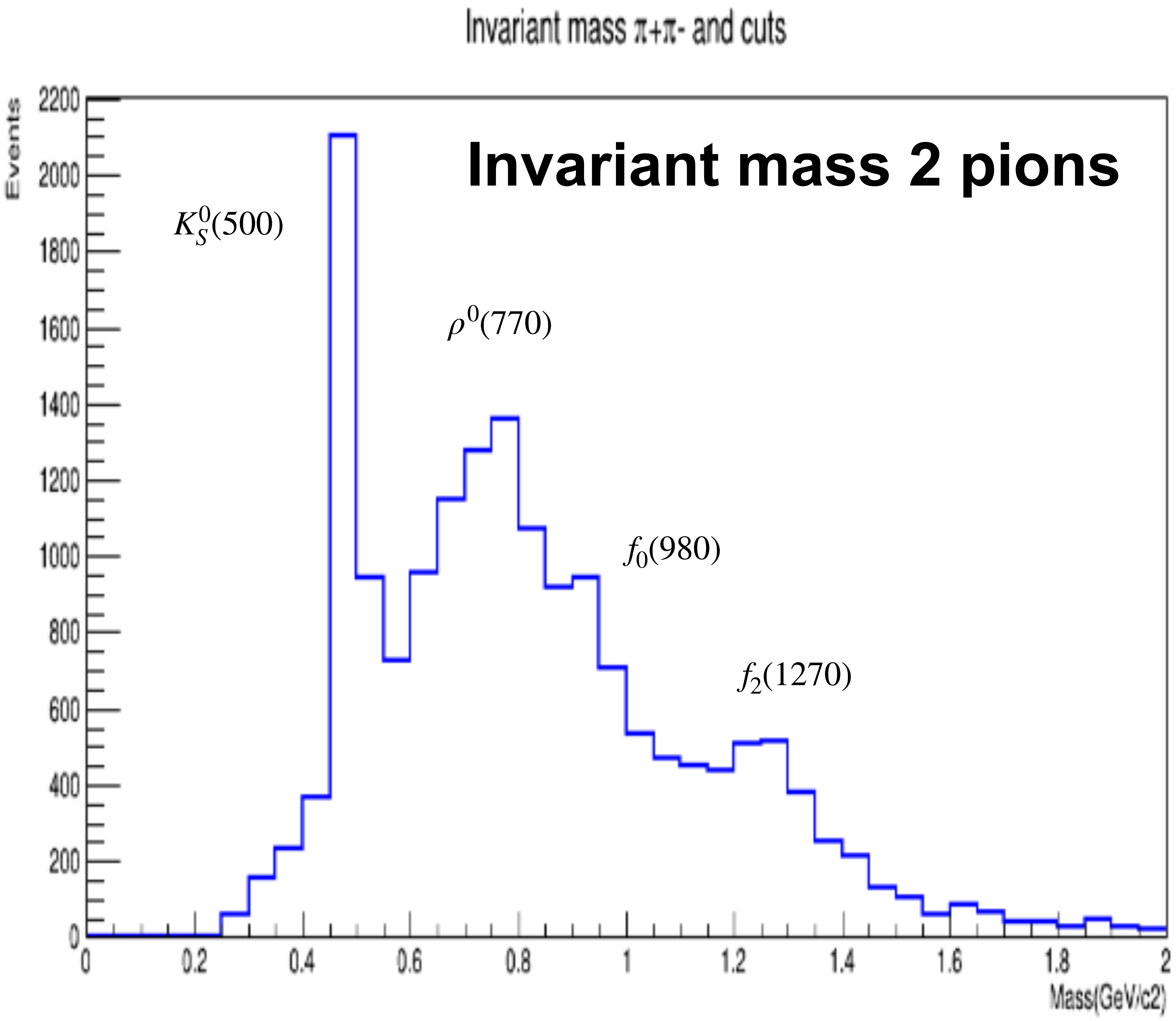
Detection of bound states of gluons: glueballs predicted by QCD

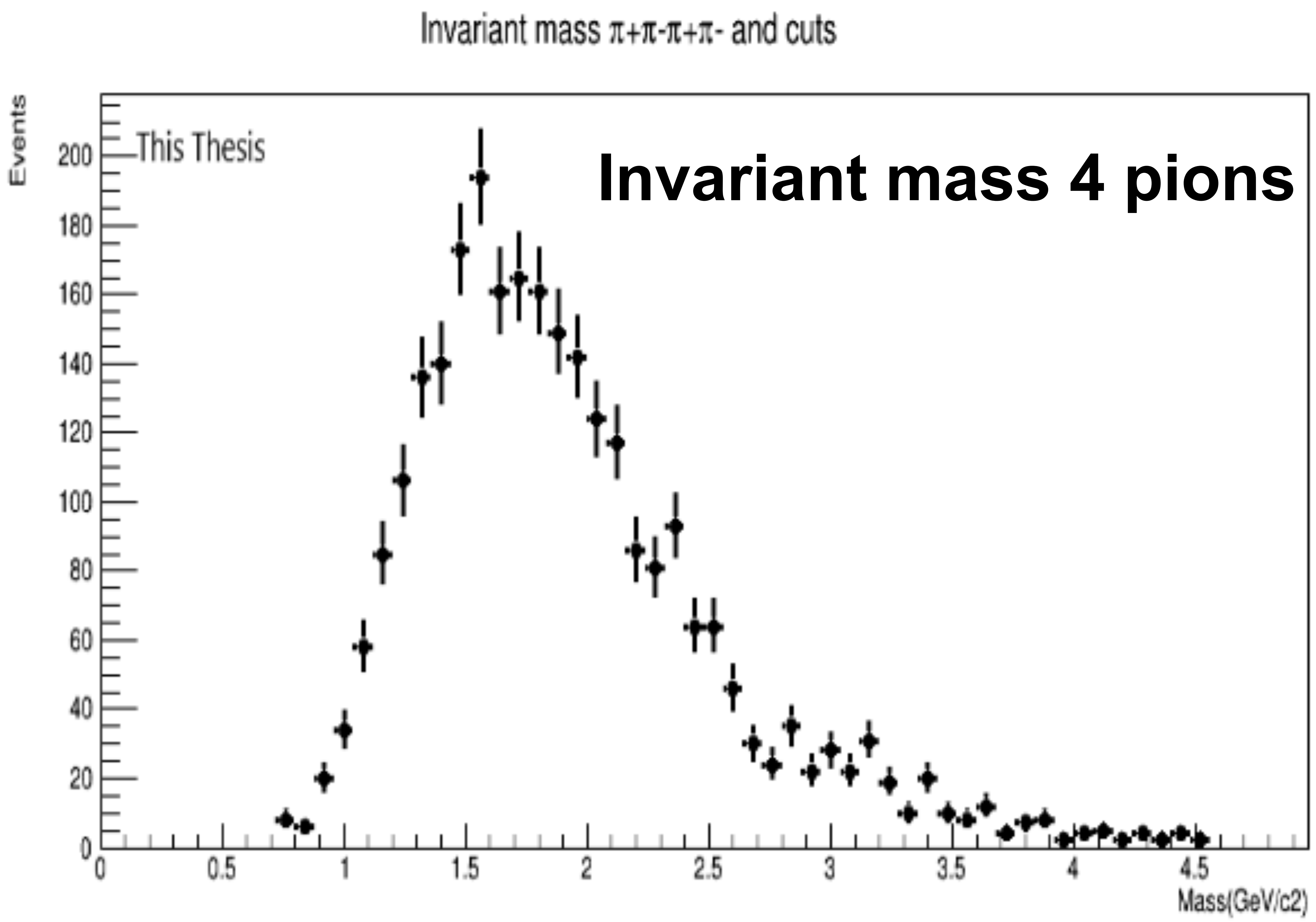
Candidates

Mesons f0(500), f0(980), f0(1370), f0(1500) f0(1710), f0(1810), f2(2340) -> some of this resonances could be the ground state of the glue ball (lattice QCD)

In practice we may pay attention to central production of 2/4 pions/kaons.

Data sample: 2017-2018, p+p 13 TeV / double gap trigger





PWA analysis is a work in progress for 2 pions systems

Data sample: 2017-2018, p+p 13 TeV / double gap trigger

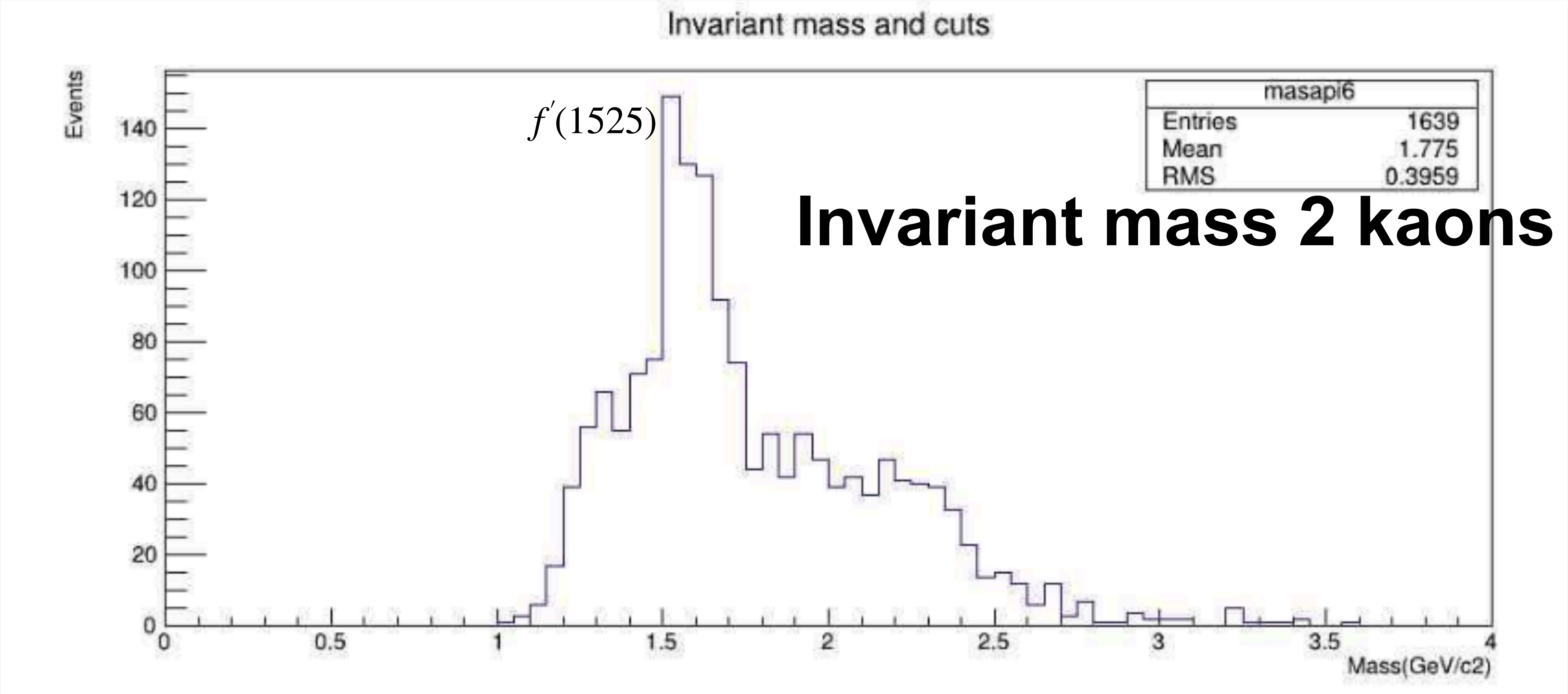


Figure 1.15 This figure shows the Invariant Mass vs phi with the IM+PID+Pt+!V0 +!AD+Vtx+VtxChi2 cut

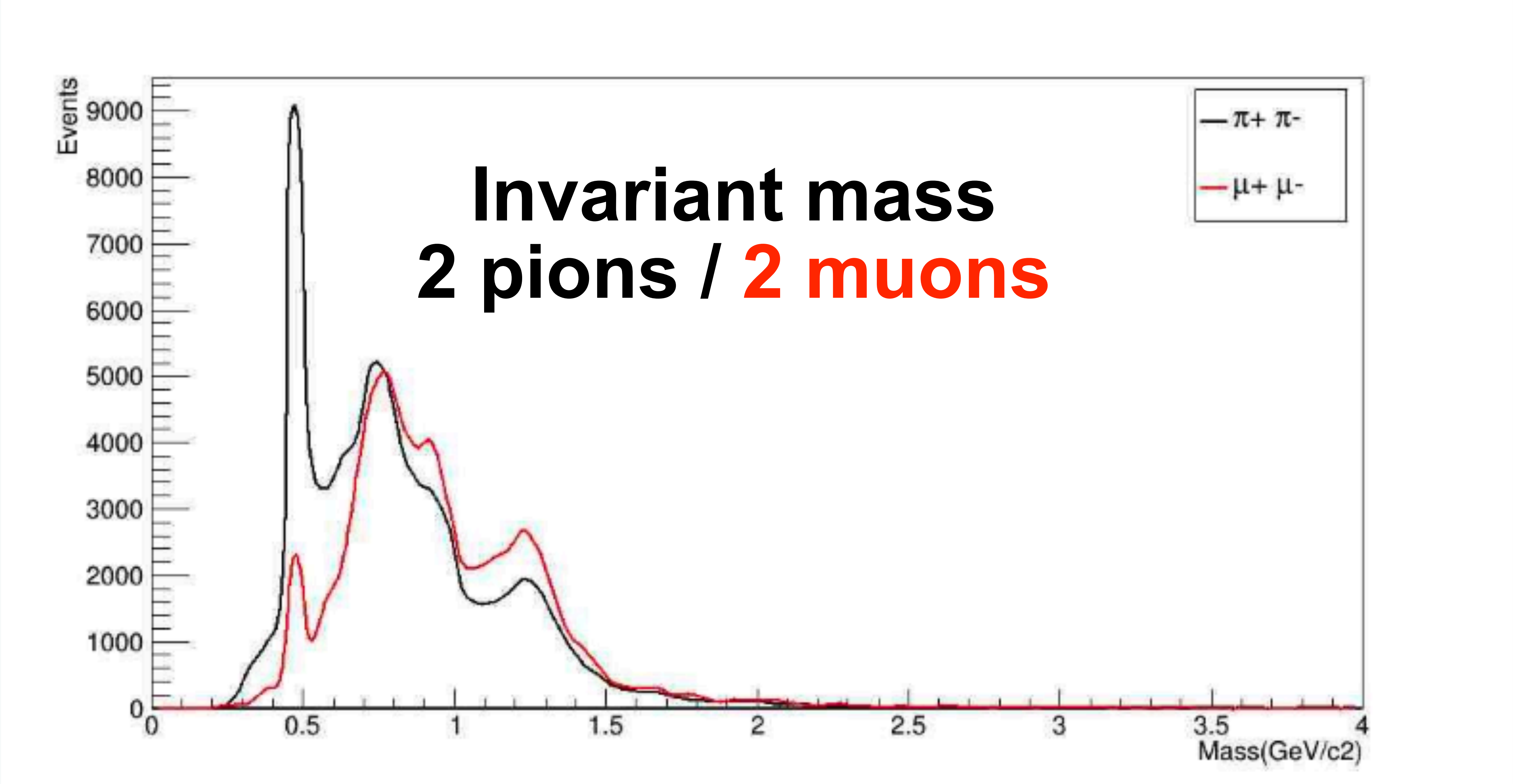


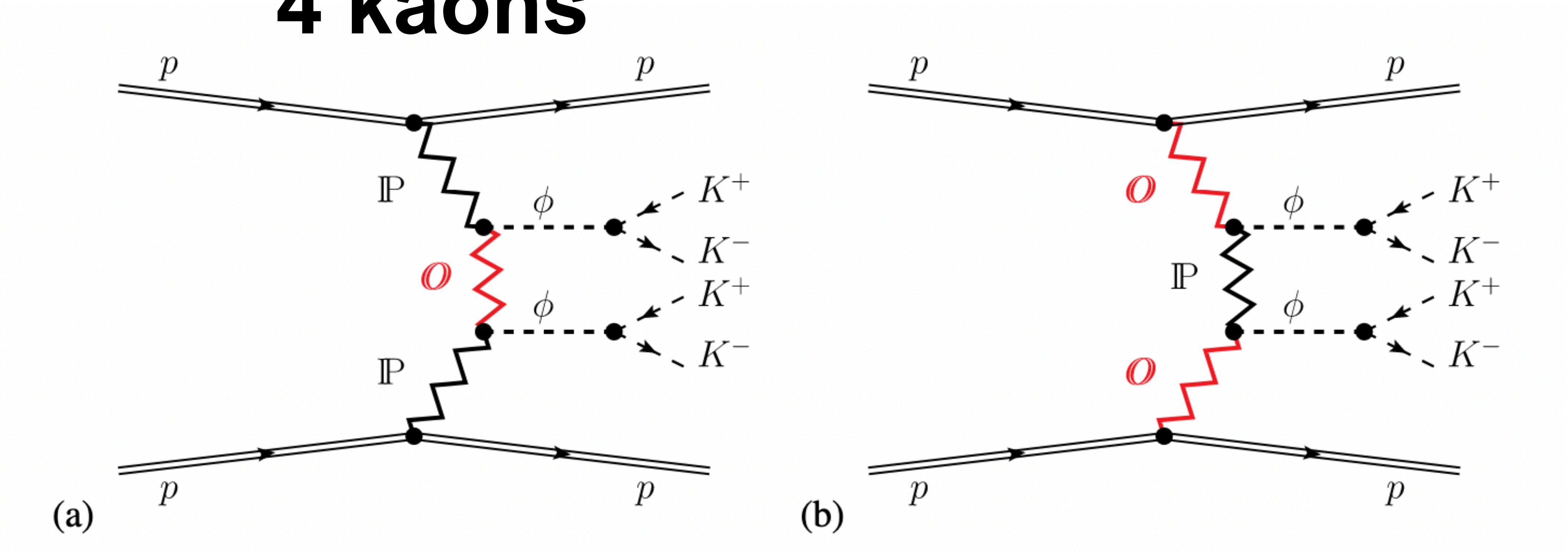
Figure 1.28 This figure shows the Invariant Mass with the IM+PID+Pt+!V0 +!AD+Vtx+VtxChi2 cut

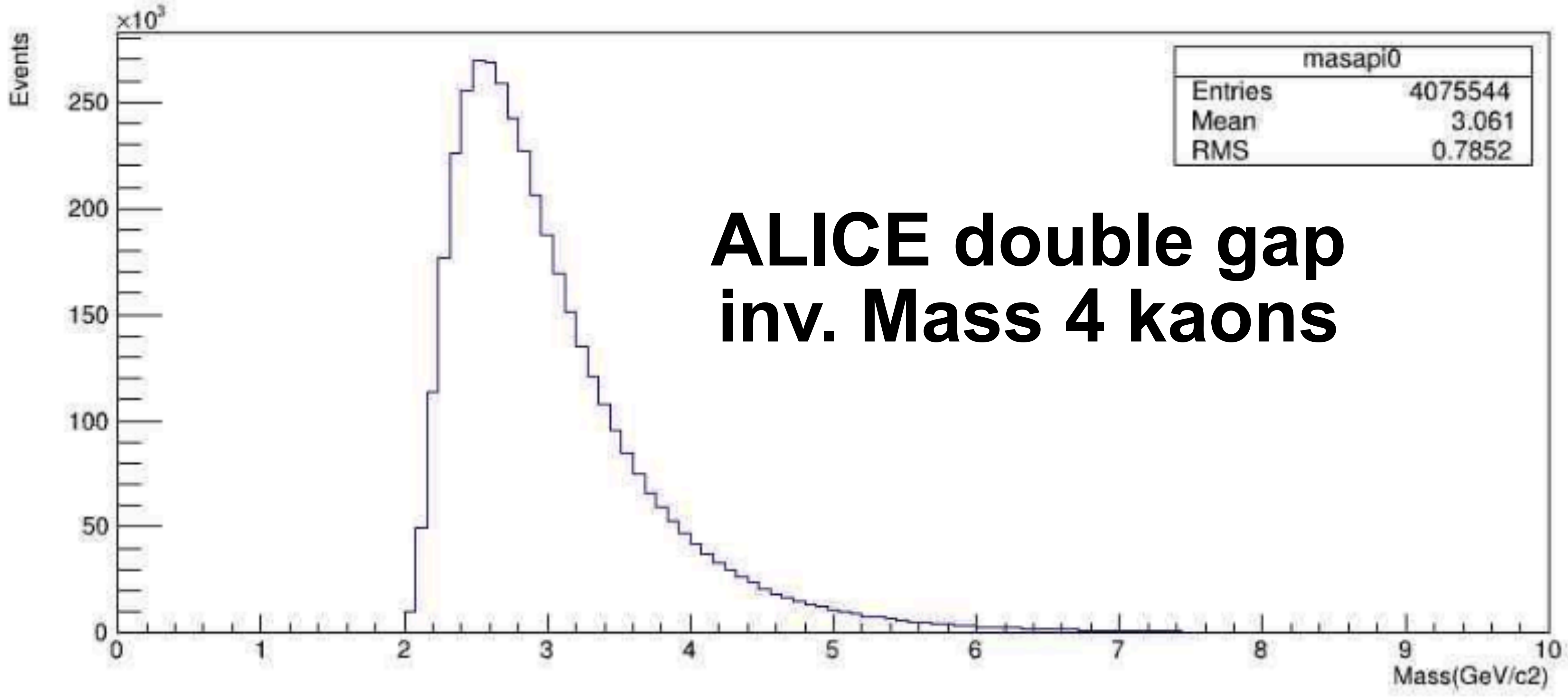
Muon misidentification?

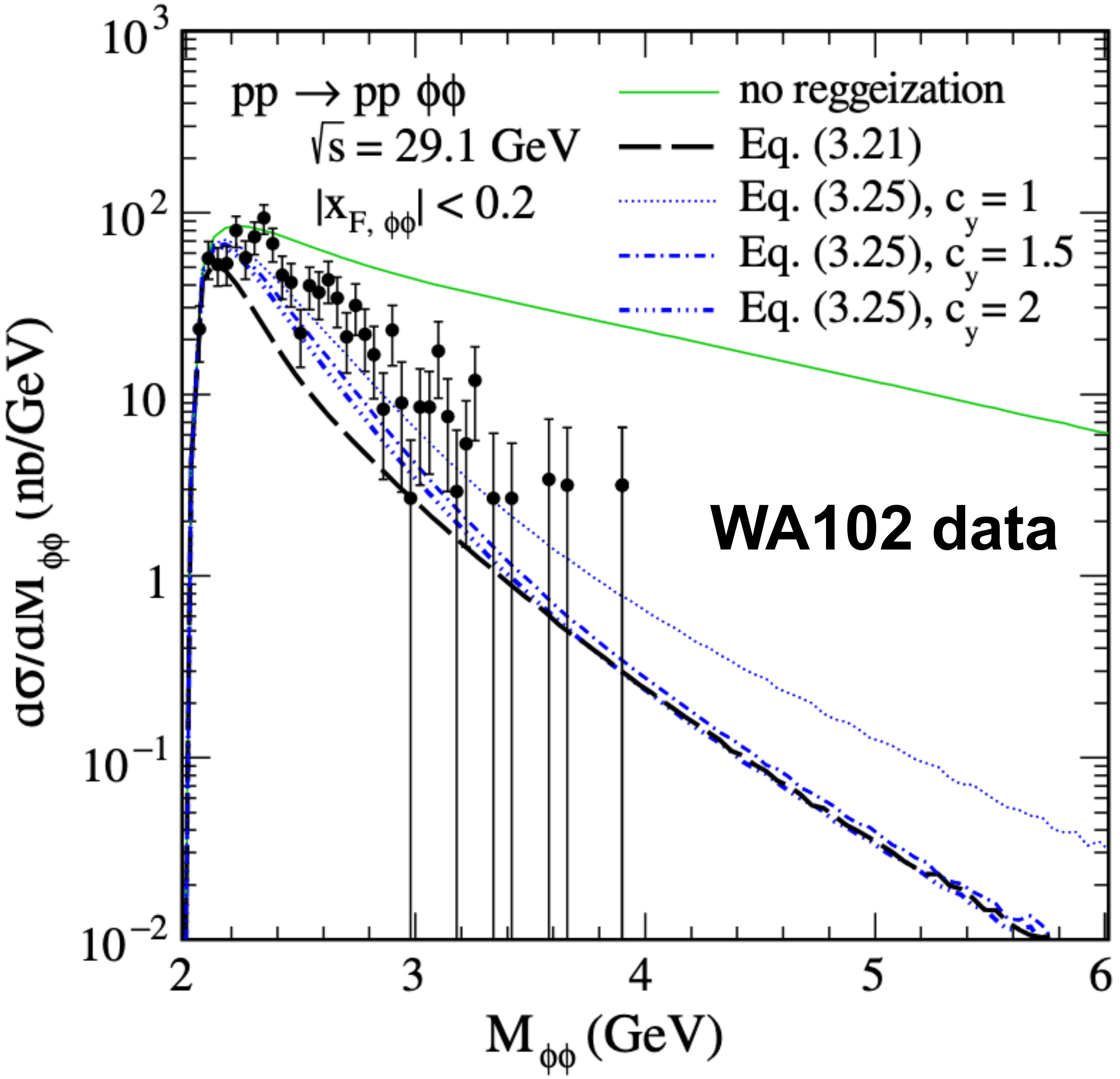
Data sample: 2017-2018, p+p 13 TeV / double gap trigger

PRD 99, 094034 (2019)

4 kaons





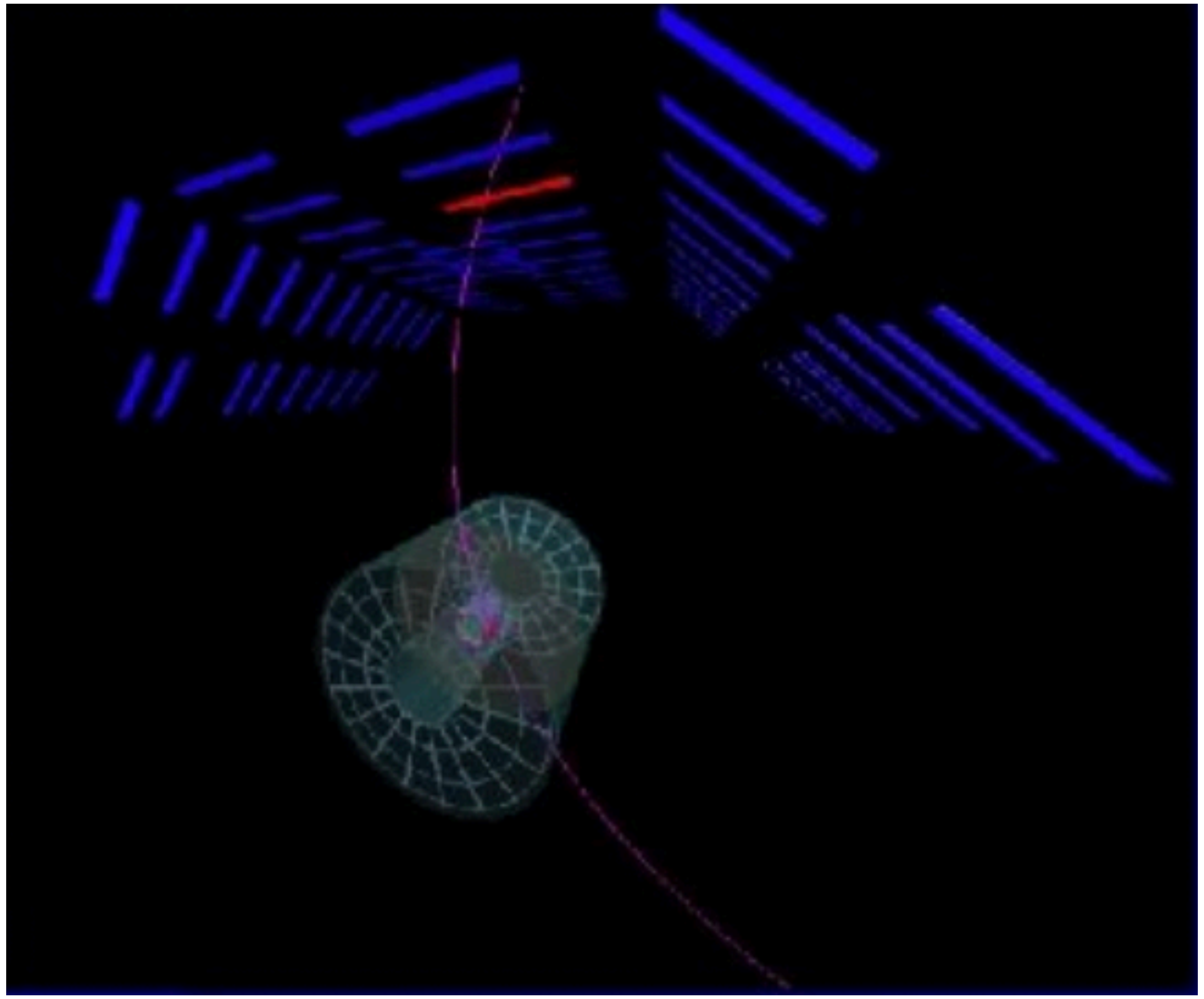


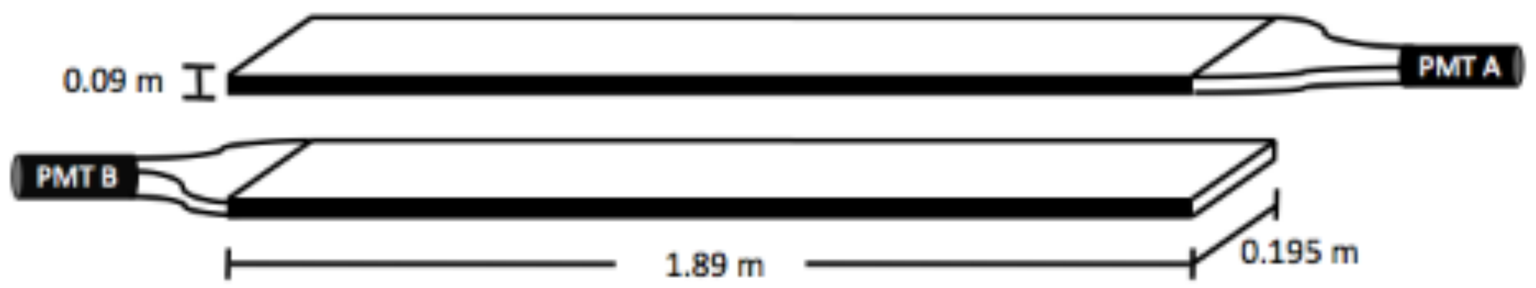
PRD 99, 094034 (2019)

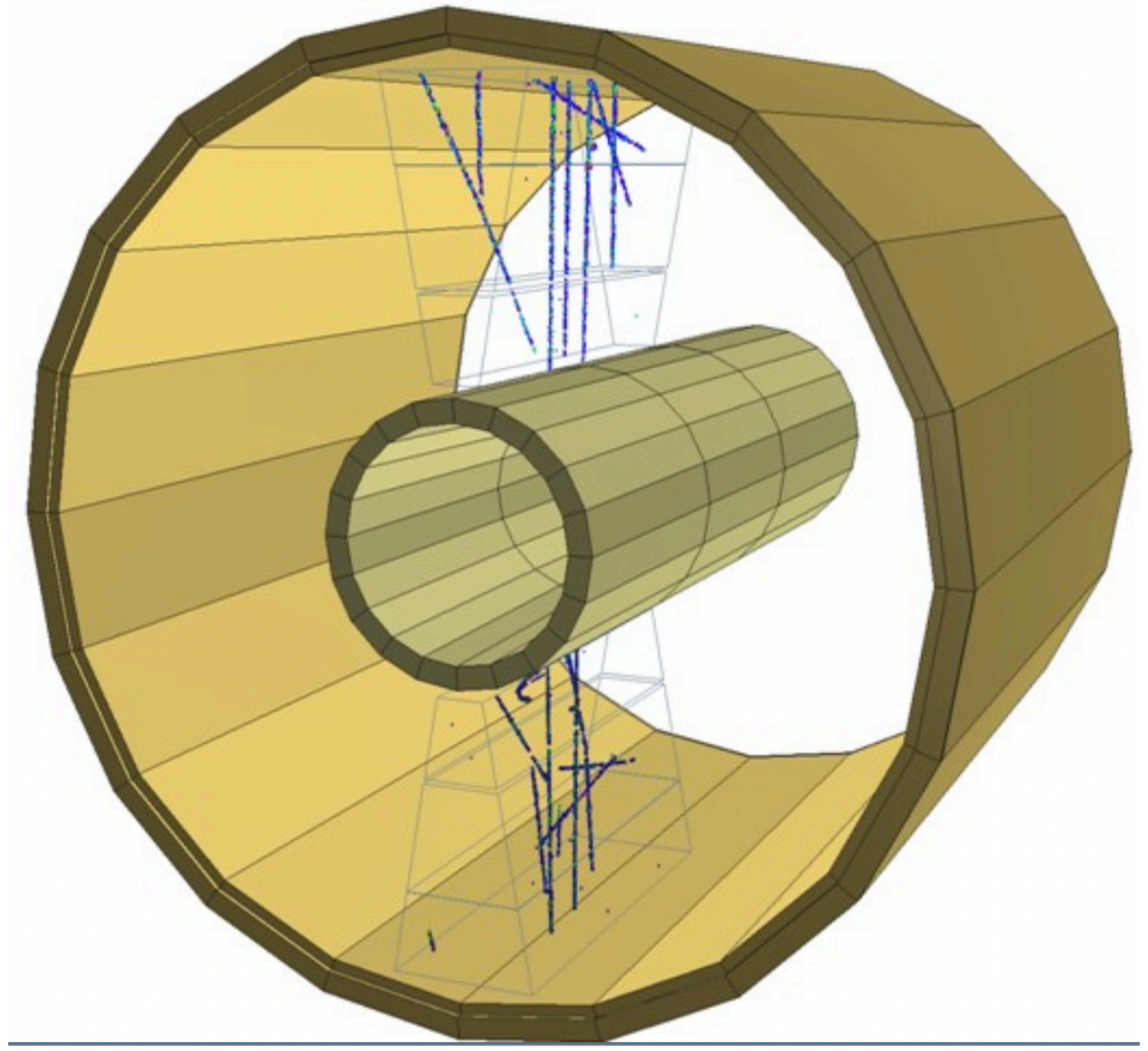
Meson	$I^G J^{PC}$	m (MeV)	Γ (MeV)	$\phi\phi$	$K^{*0}\bar{K}^{*0}$	$\rho^0\rho^0$	$\omega\omega$
• $f_1(1285)$	0^+1^{++}	1281.9 ± 0.5	22.7 ± 1.1			Seen	
• $f_0(1370)$	0^+0^{++}	1200–1500	200–500			Dominant	Not seen
• $f_0(1500)$	0^+0^{++}	1504 ± 6	109 ± 7			Seen	
$f_2(1565)$	0^+2^{++}	1562 ± 13	134 ± 8			Seen	Seen
$f_2(1640)$	0^+2^{++}	1639 ± 6	99^{+60}_{-40}				Seen
• $f_0(1710)$	0^+0^{++}	1723^{+6}_{-5}	139 ± 8				Seen
$\eta(1760)$	0^+0^{-+}	1751 ± 15	240 ± 30			Seen	Seen
$f_2(1910)$	0^+2^{++}	1903 ± 9	196 ± 31			Seen	Seen
• $f_2(1950)$	0^+2^{++}	1944 ± 12	472 ± 18		Seen		
• $f_2(2010)$	0^+2^{++}	2011^{+60}_{-80}	202 ± 60	Seen			
$f_0(2020)$	0^+0^{++}	1992 ± 16	442 ± 60			Seen	Seen
$f_0(2100)$	0^+0^{++}	2101 ± 7	224^{+23}_{-21}	Seen (?)			
$\eta(2100)$	0^+0^{-+}	2050^{+30+75}_{-24-26} [43]	$250^{+36+181}_{-30-164}$ [43]	Seen (?)			
• $f_4(2050)$	0^+4^{++}	2018 ± 11	237 ± 18				Seen
$f_J(2220)$	$0^+(2^{++}$ or $4^{++})$	2231.1 ± 3.5	23^{+8}_{-7}	Not seen			
$\eta(2225)$	0^+0^{-+}	2221^{+13}_{-10}	185^{+40}_{-20}	Seen (?)			
• $f_2(2300)$	0^+2^{++}	2297 ± 28	149 ± 40	Seen			
$f_4(2300)$	0^+4^{++}	2320 ± 60	250 ± 80			Seen	Seen
• $f_2(2340)$	0^+2^{++}	2345^{+50}_{-40}	322^{+70}_{-60}	Seen			
$X(2500)$	0^+0^{-+}	$2470^{+15+101}_{-19-23}$ [43]	230^{+64+56}_{-35-33} [43]	Seen (?)			

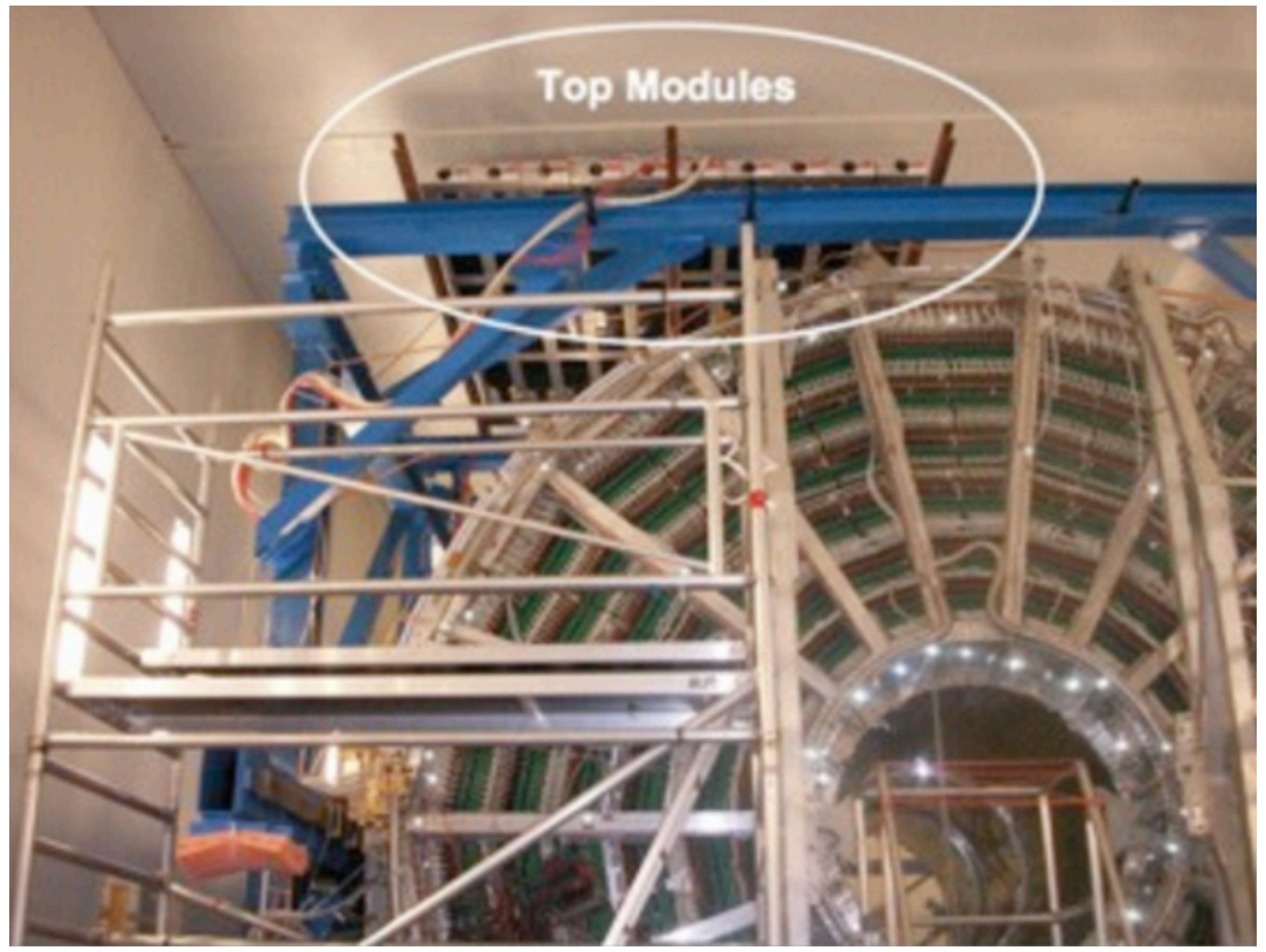
BUAP

Detector development







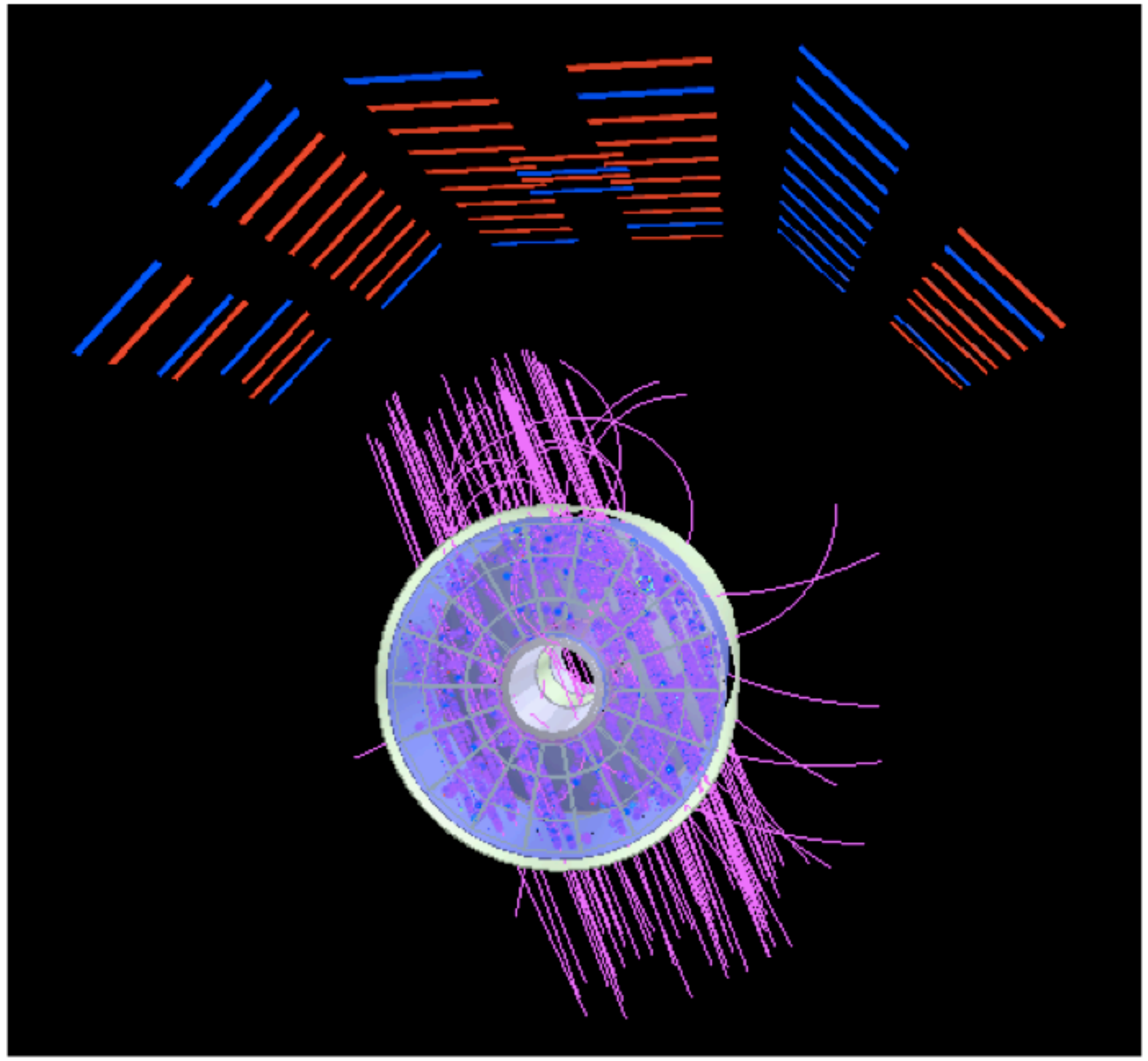


Event triggered by ACORDE on Thursday 9th. October 2008

- **Run # 62107, Chunk 460, # of Event: 8560**
- **Acorde multiplicity: 35**
- **Number of ESD tracks: 148**

R&D, installation, commissioning, operation, offline, DCS, electronics, data analysis

TPC Calibration 2006-2007



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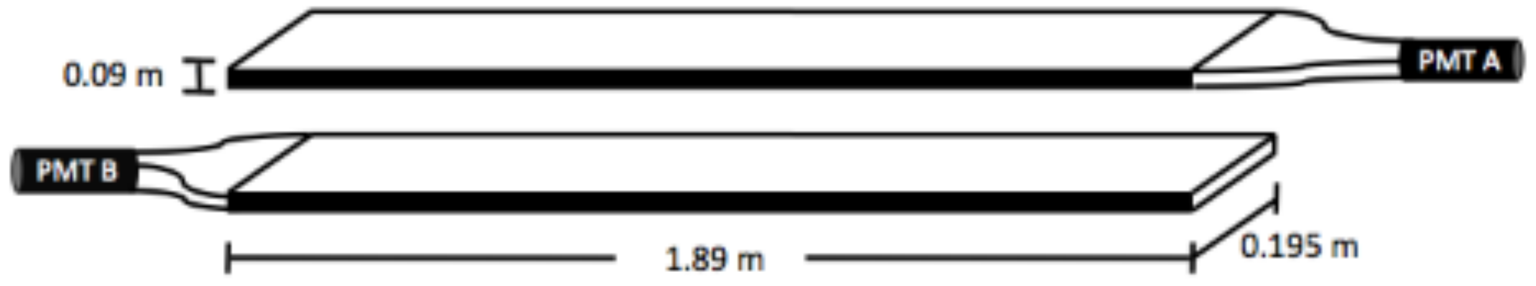
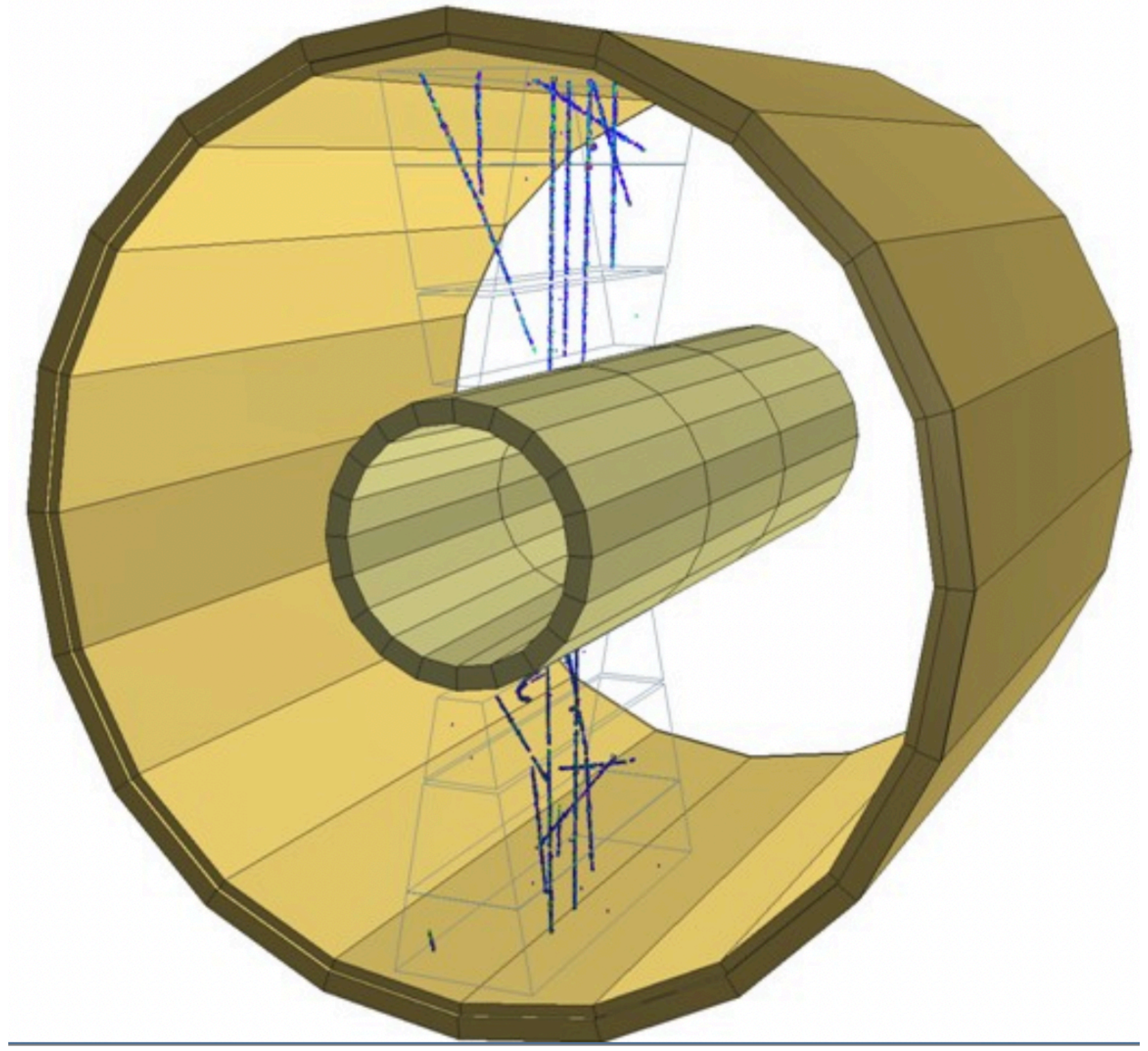
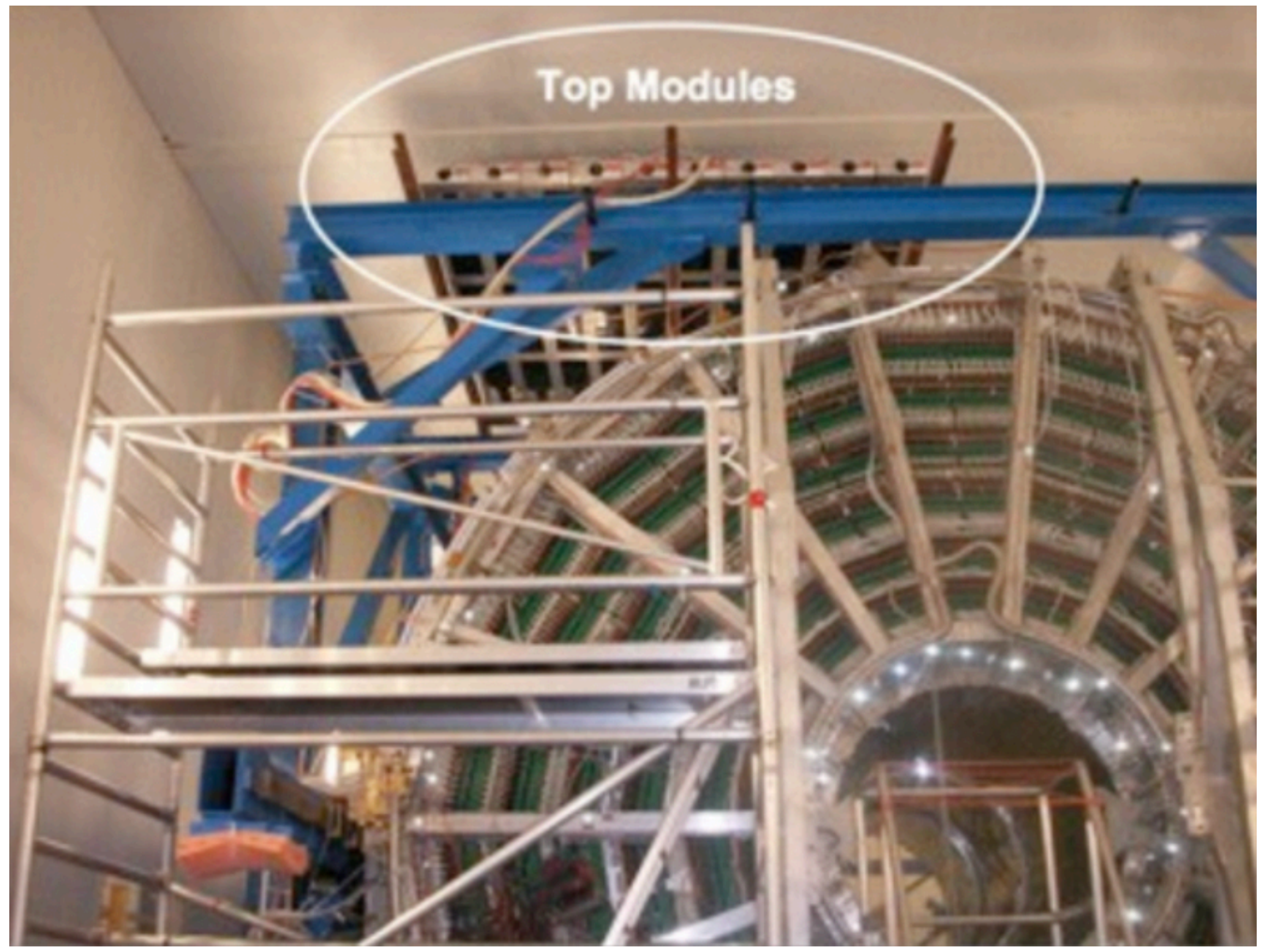
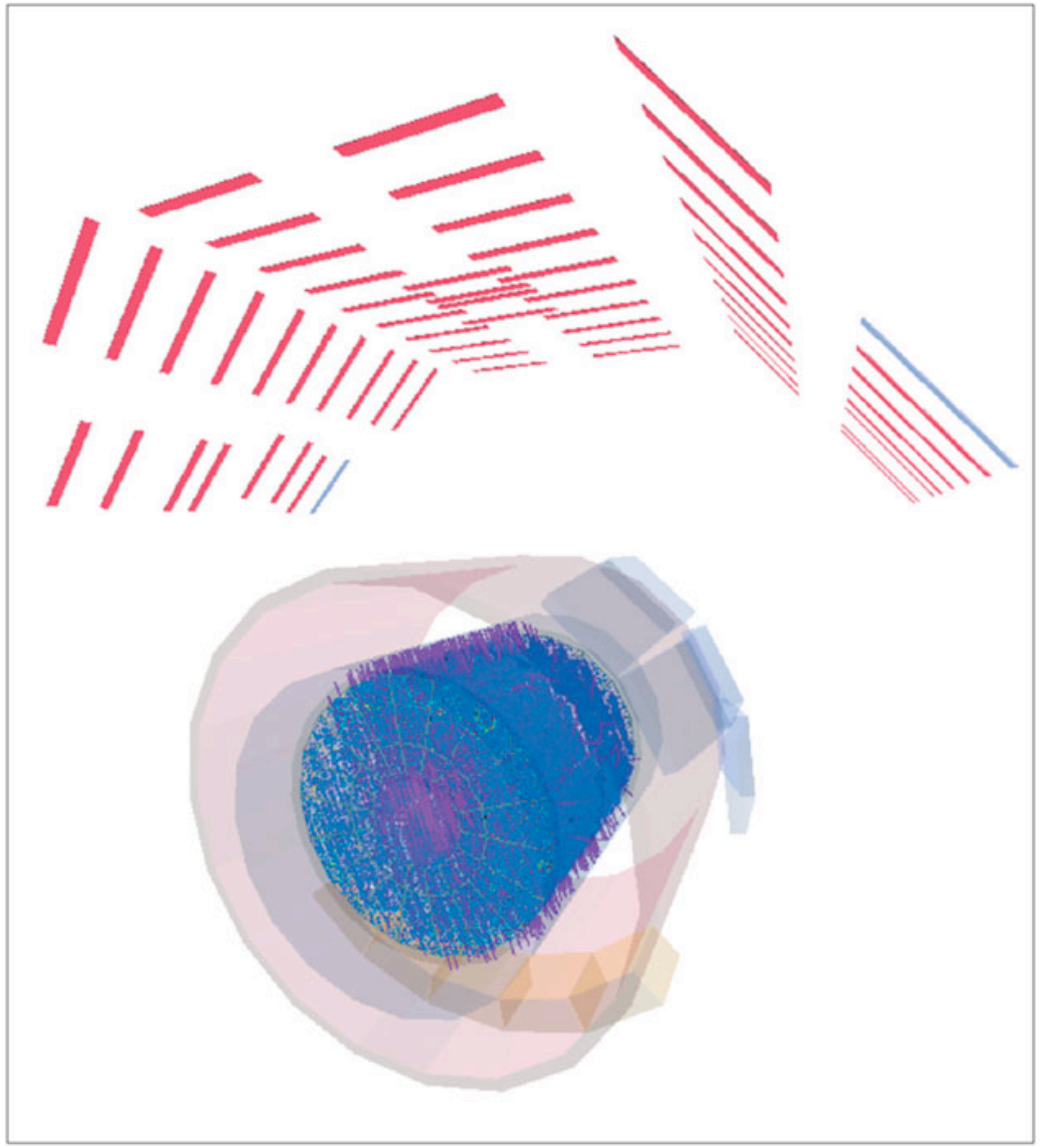
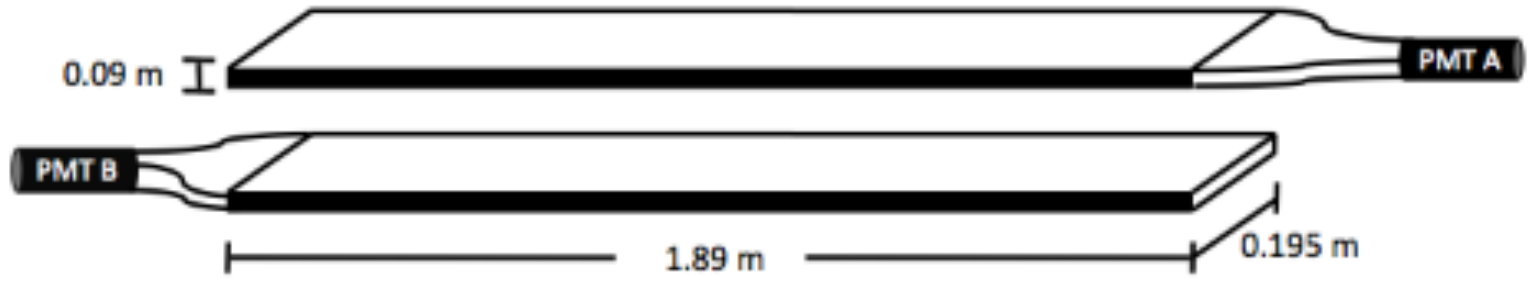


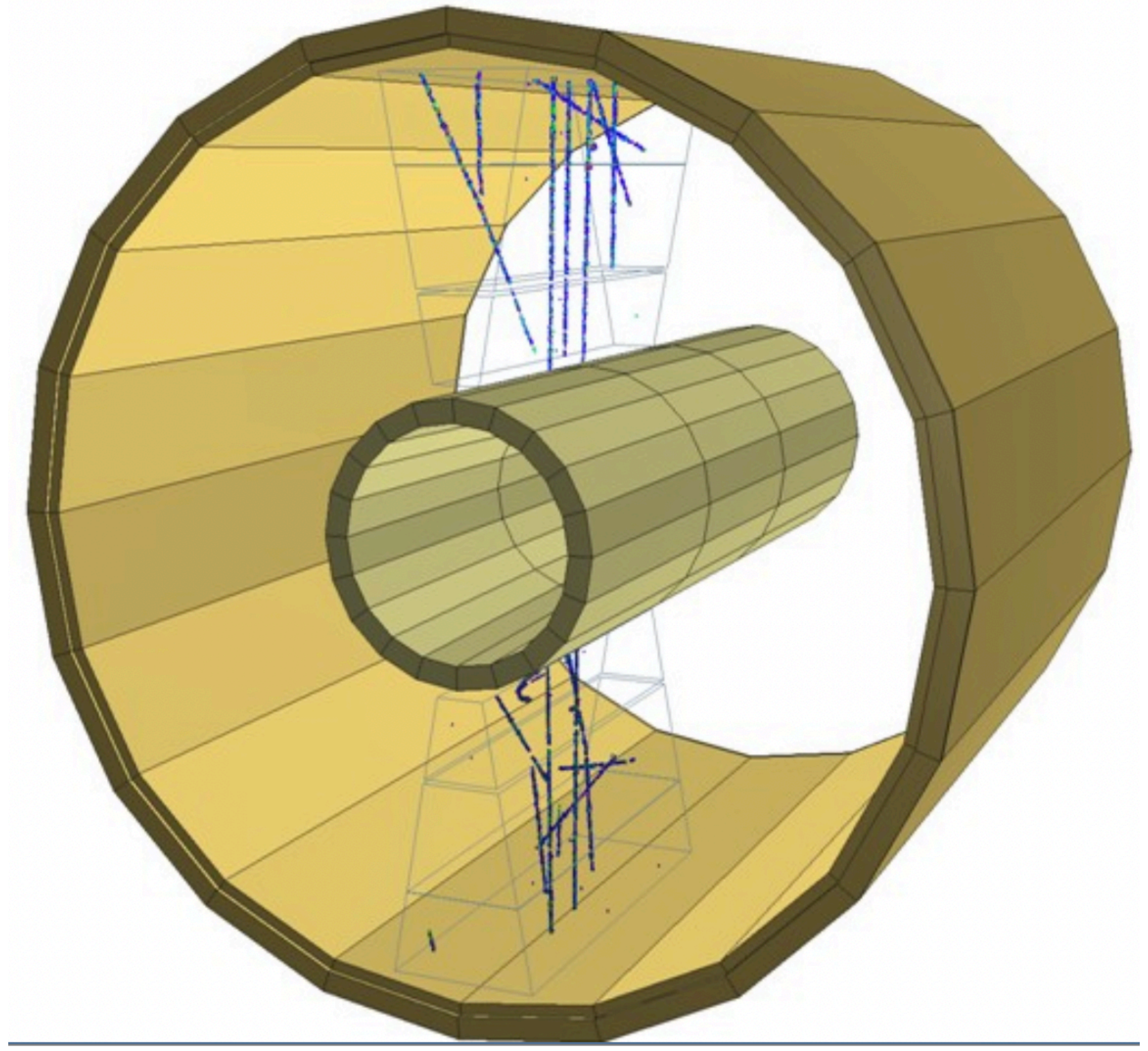


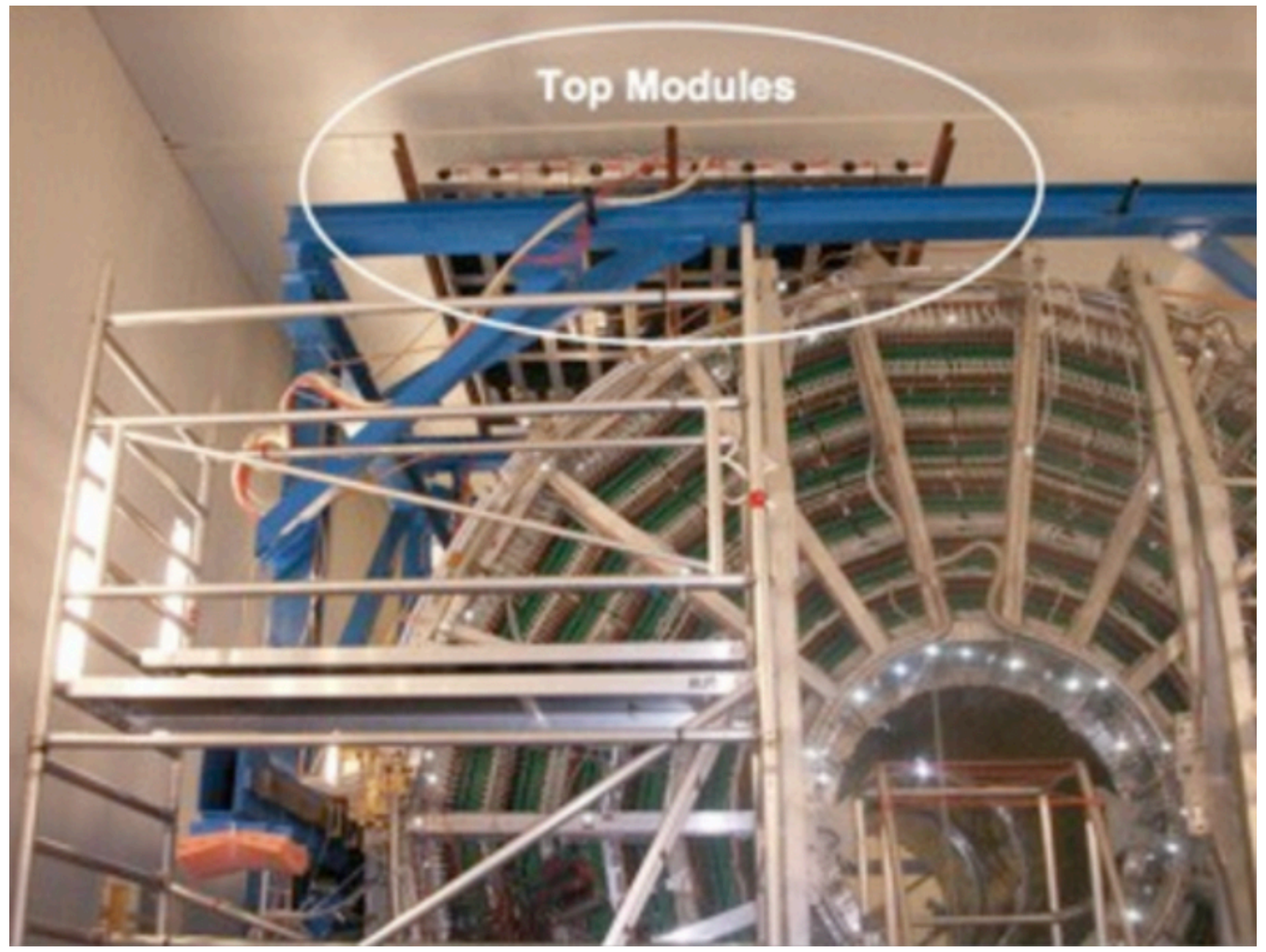
TPC Calibration 2006-2007











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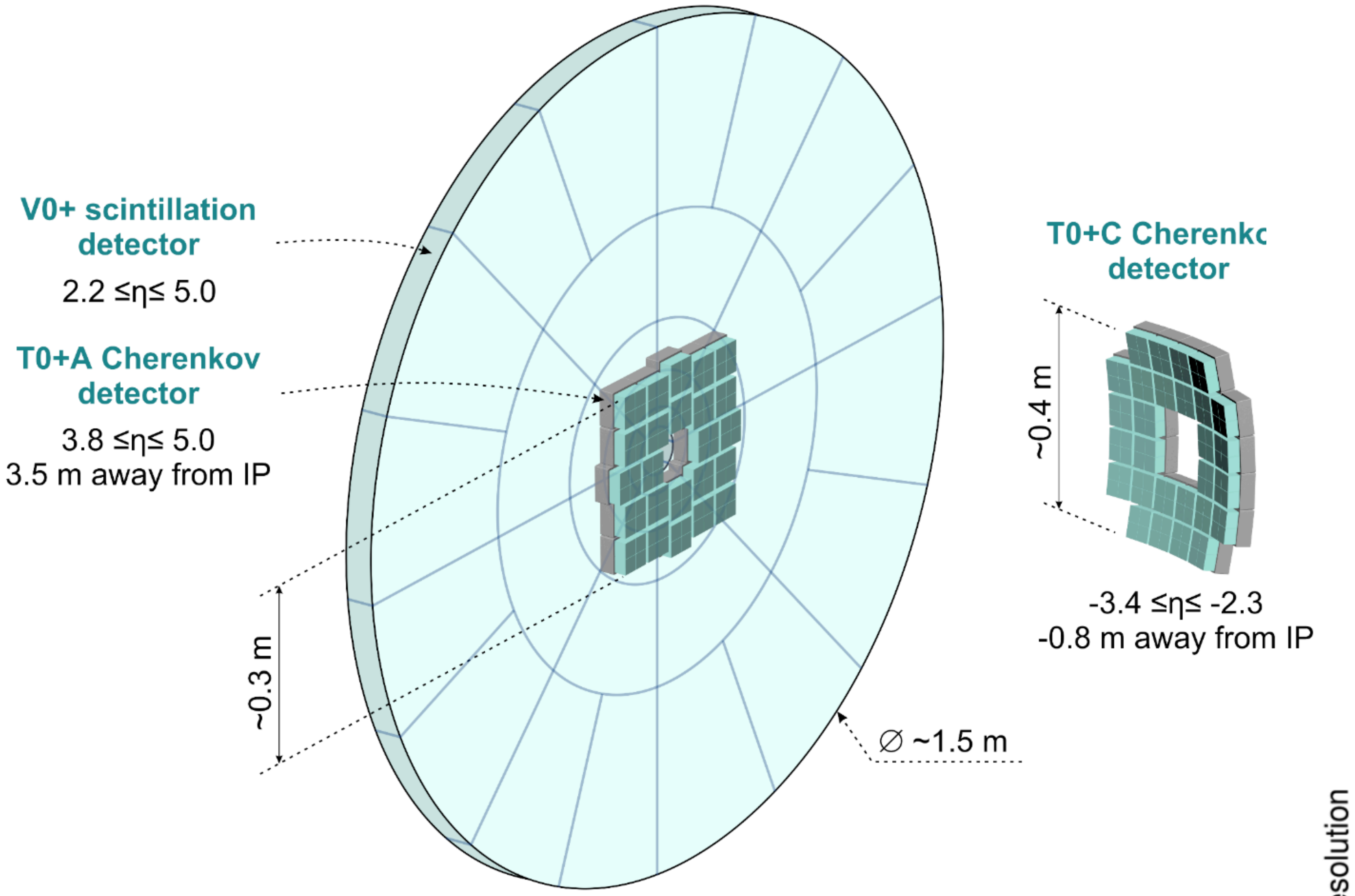
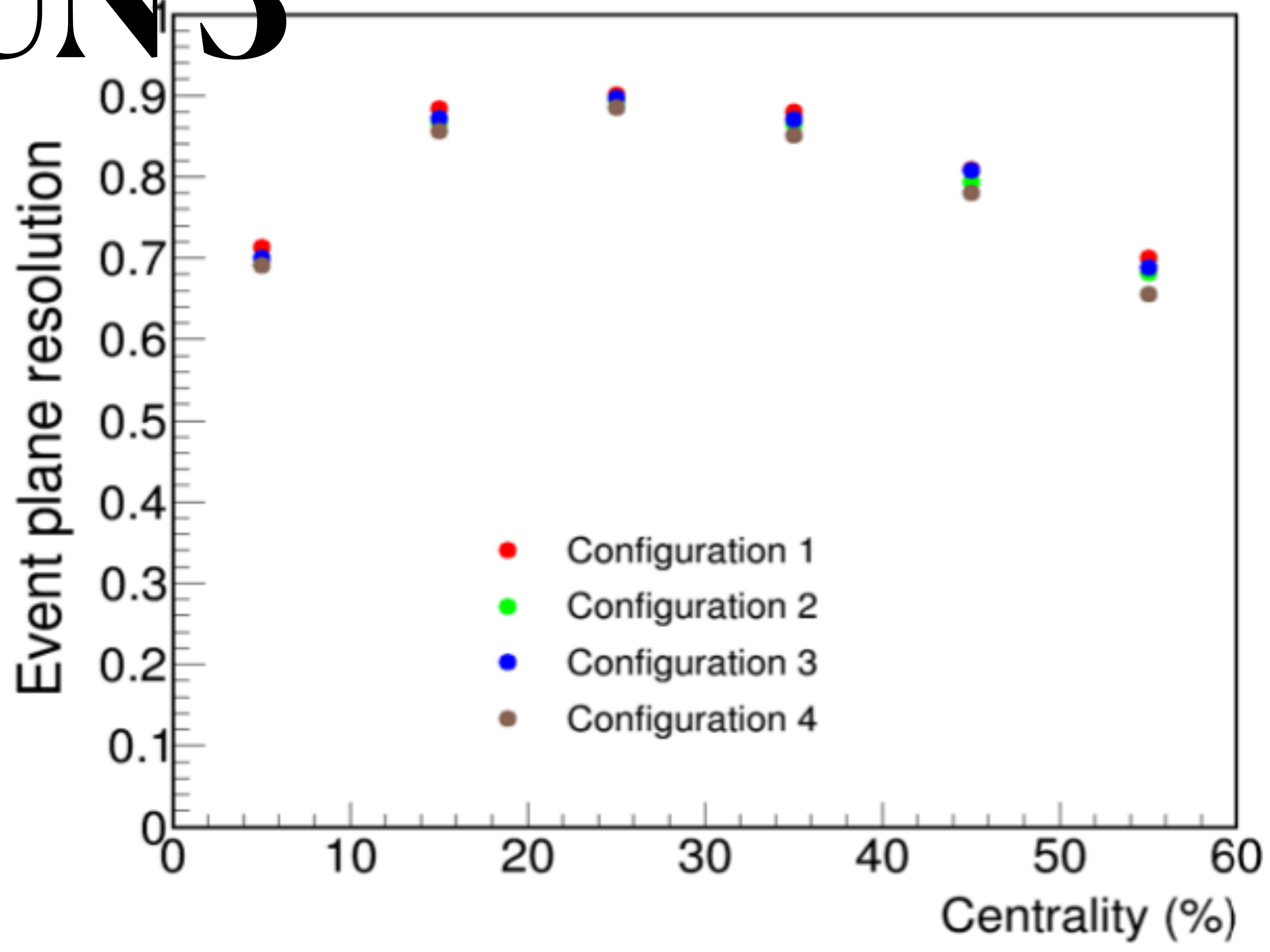
TPC Calibration 2006-2007

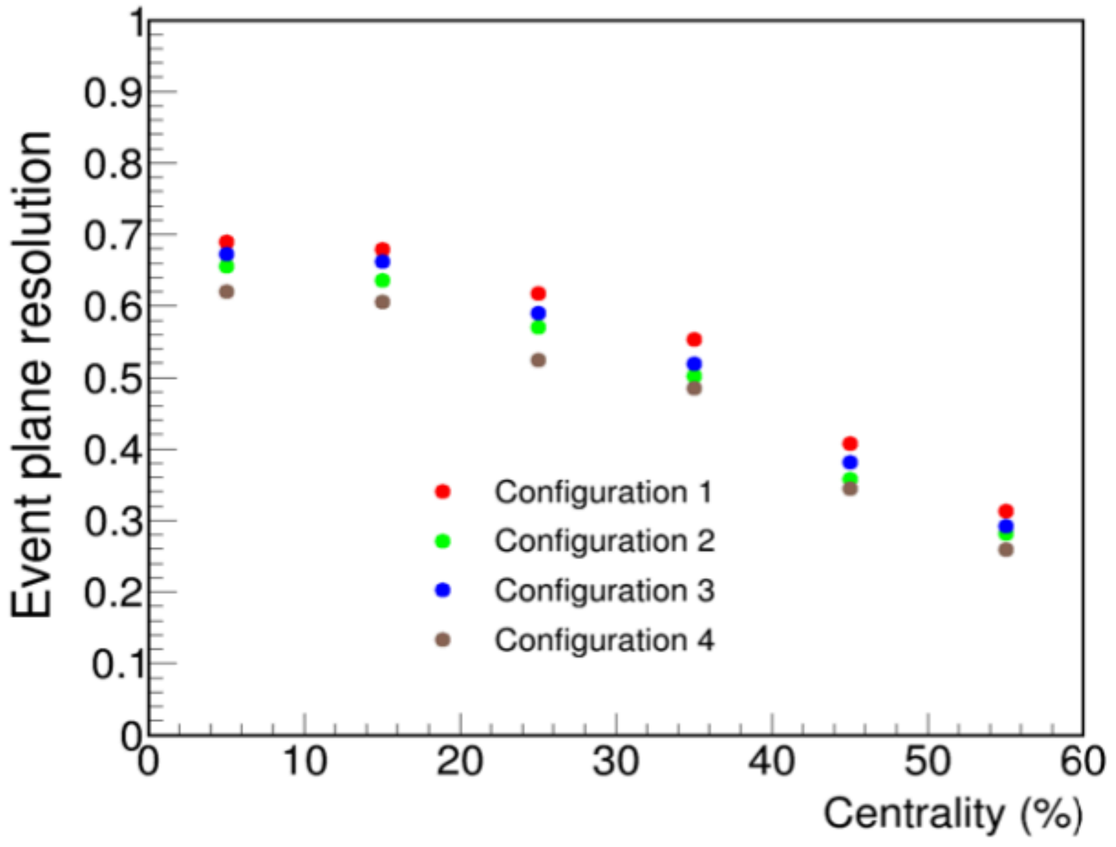
FIT DETECTOR FOR RUN 3

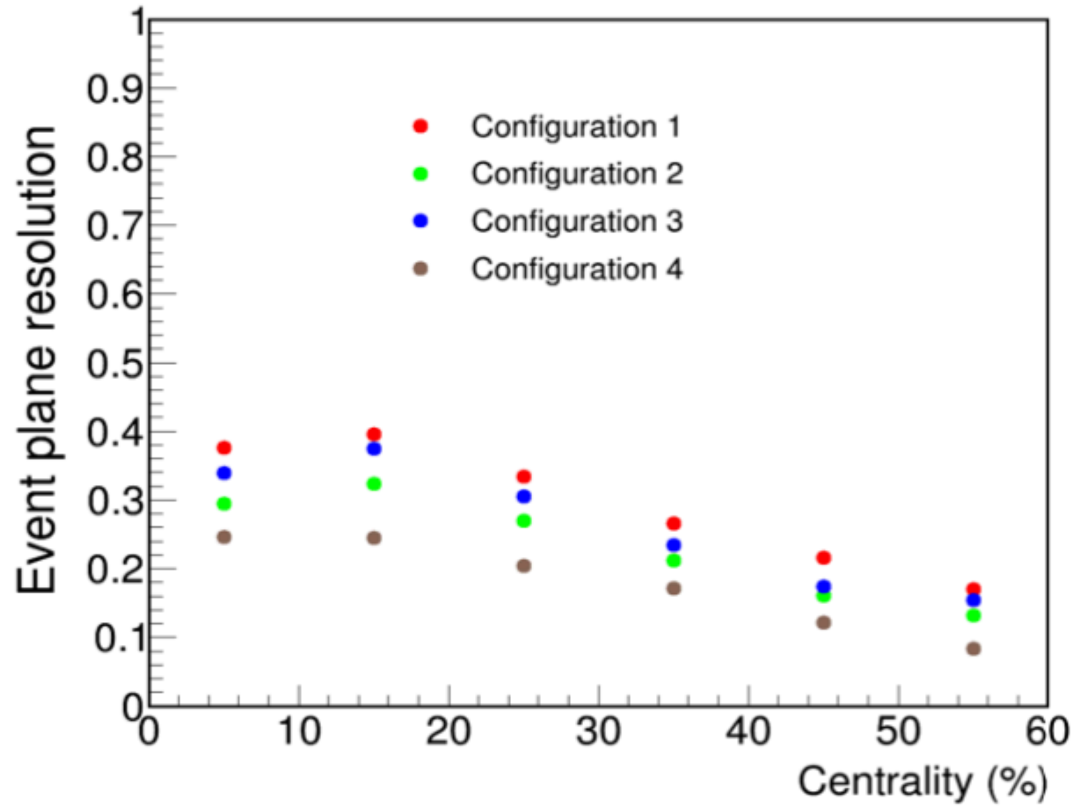
Also DCS contribution focused in FDD





BUAP Contribution: physics performance (event plane)





- Configuration 1. This is the original AliFITv6 and has 5 rings, with 16 cells per ring.
- Configuration 2. Rings 1 to 4 have 8 cells each one and ring 5 has 16 cells.
- Configuration 3. It has rings 1 to 3 with 8 cells per ring and rings 4 and 5 with 16 cells each one.
- Configuration 4. This is the original AliFITv5 and has 5 rings, with 8 cells per ring.

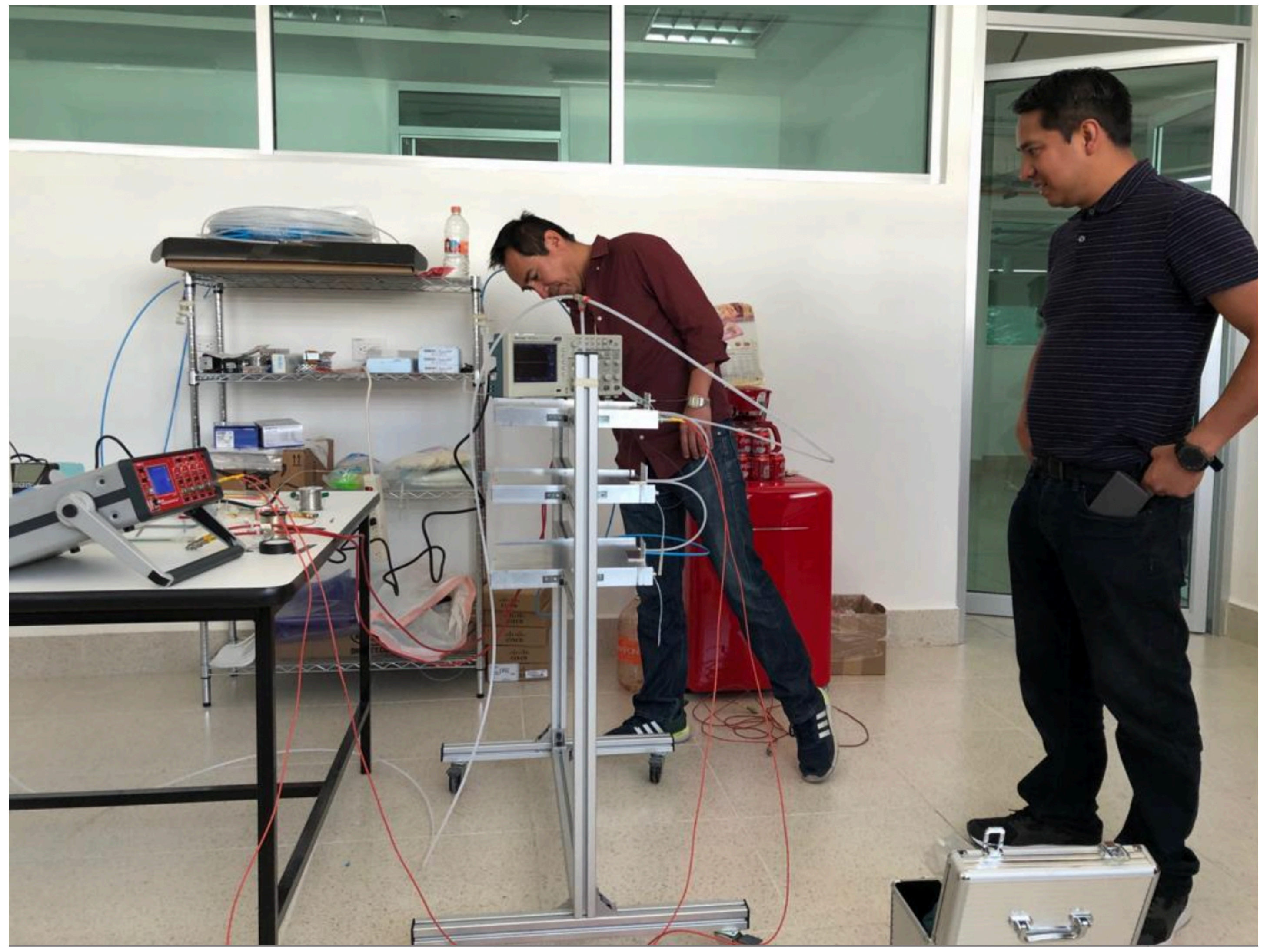
IN COLLABORATION WITH LIZARDO VALENCIA (UNISON, CMS)

ALICE 3

BUAP (Puebla) group is interested in muon chamber detector. We have experience in plastic scintillator and RPC detectors. We can discuss some ideas like an hybrid geometry (simulation studies are needed here). BUAP has a dedicated laboratory for particle detector development.

Concrete tasks: DCS and detector development.

We are willing to join to ALICE 3 project.

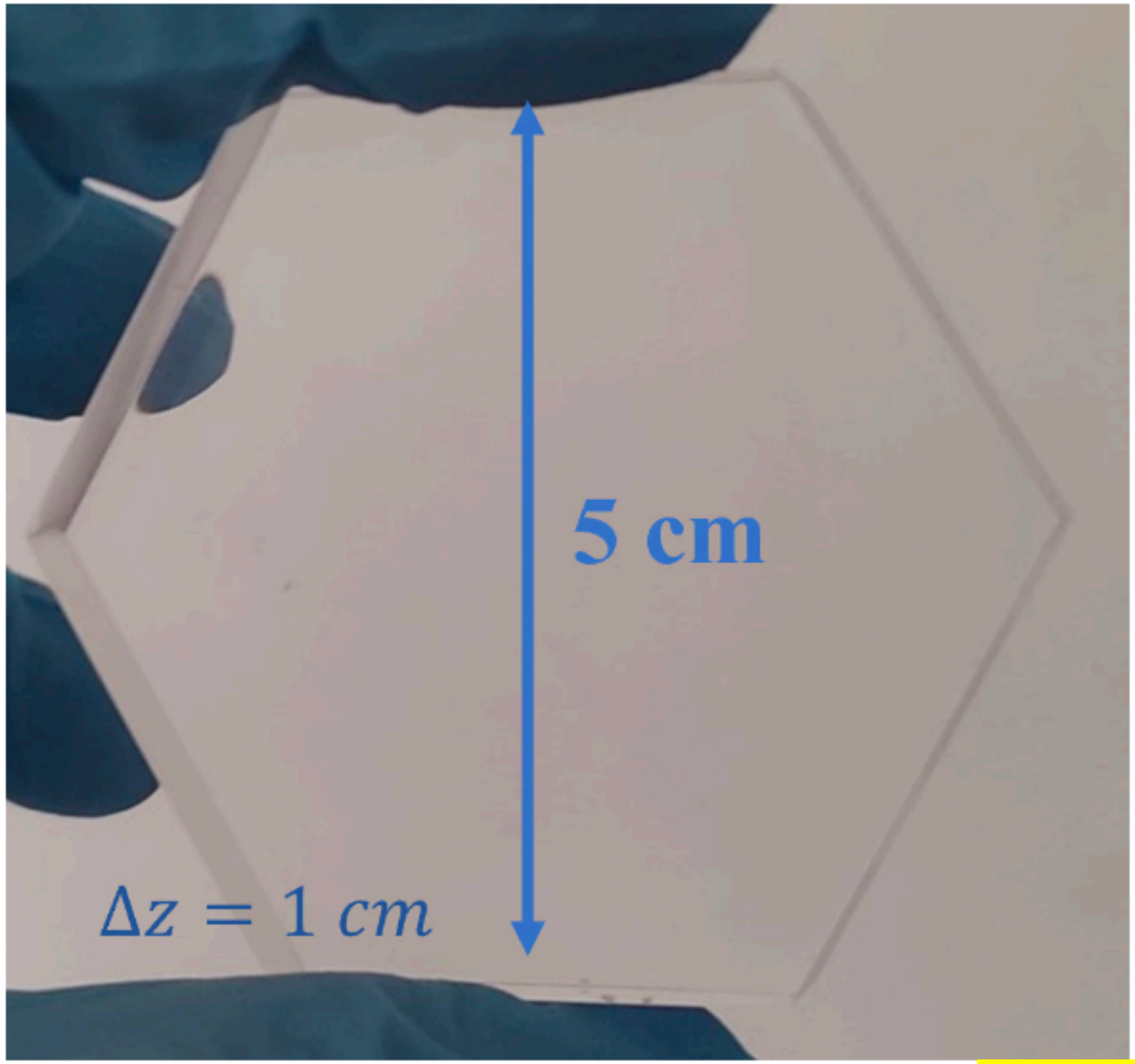


In future meetings we will show the performance of BUAP RPC's

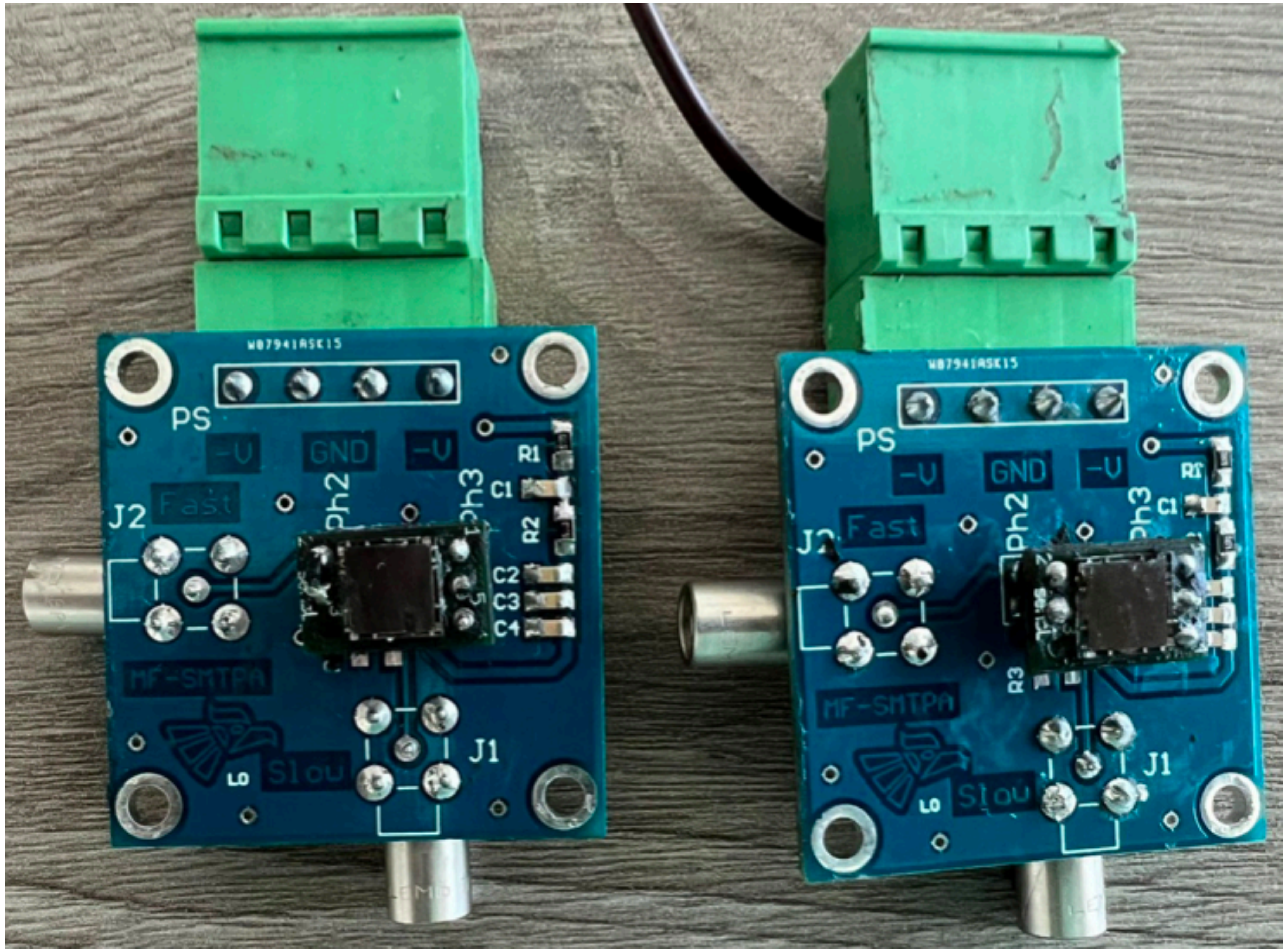
BUAP

COSMICS

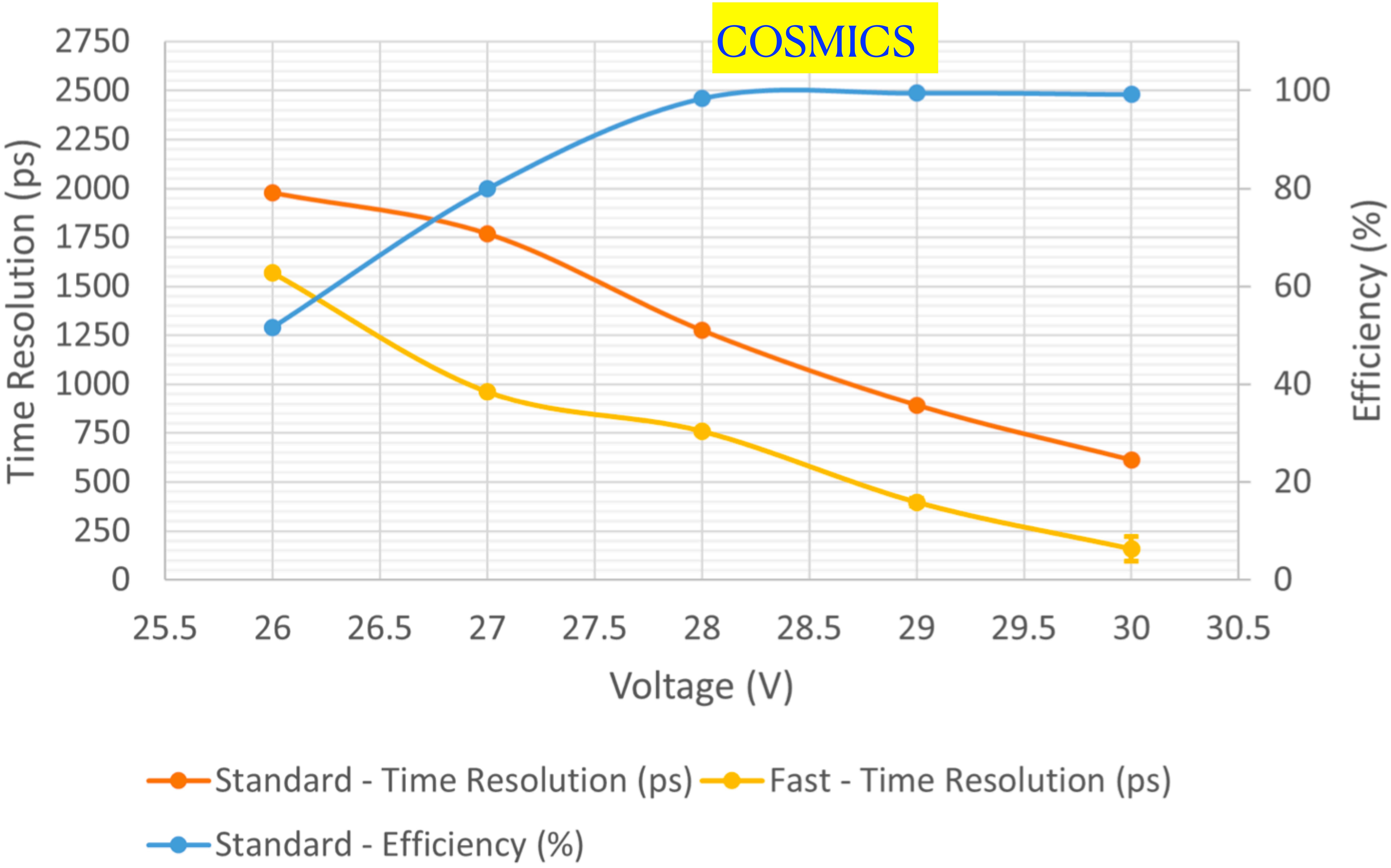
Plastic scintillator



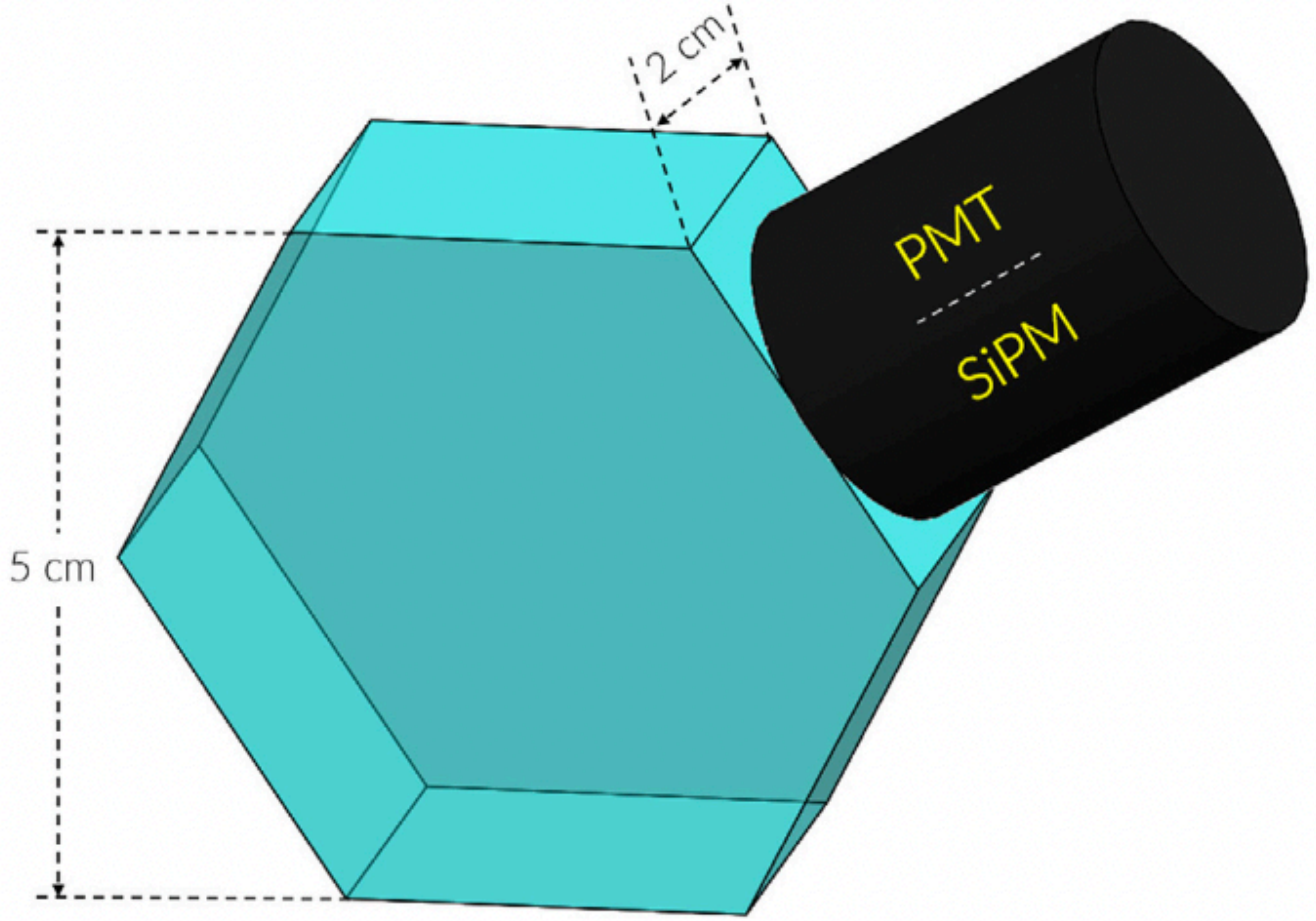
Simple FEE

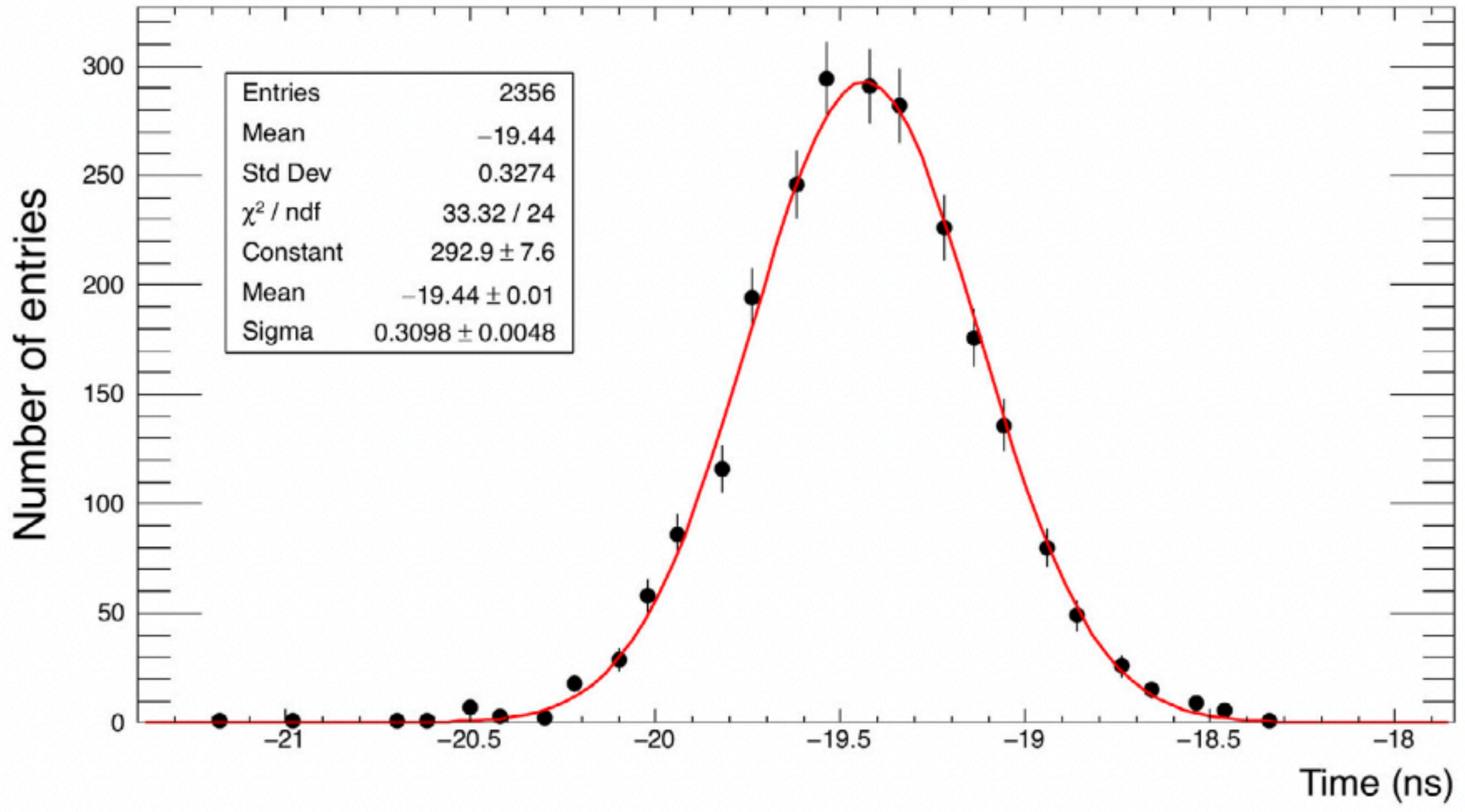


6 mm x 6 mm SENZ-L SiPM: fast and slow outputs


COSMICS
Time Resolution (ps)
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
Efficiency (%)
100
80
60
40
20
0
25.5
26
26.5
27
27.5
28
28.5
29
29.5
30
30.5
Voltage (V)
Standard - Time Resolution (ps)
Fast - Time Resolution (ps)
Standard - Efficiency (%)

Beam test at T10/CERN

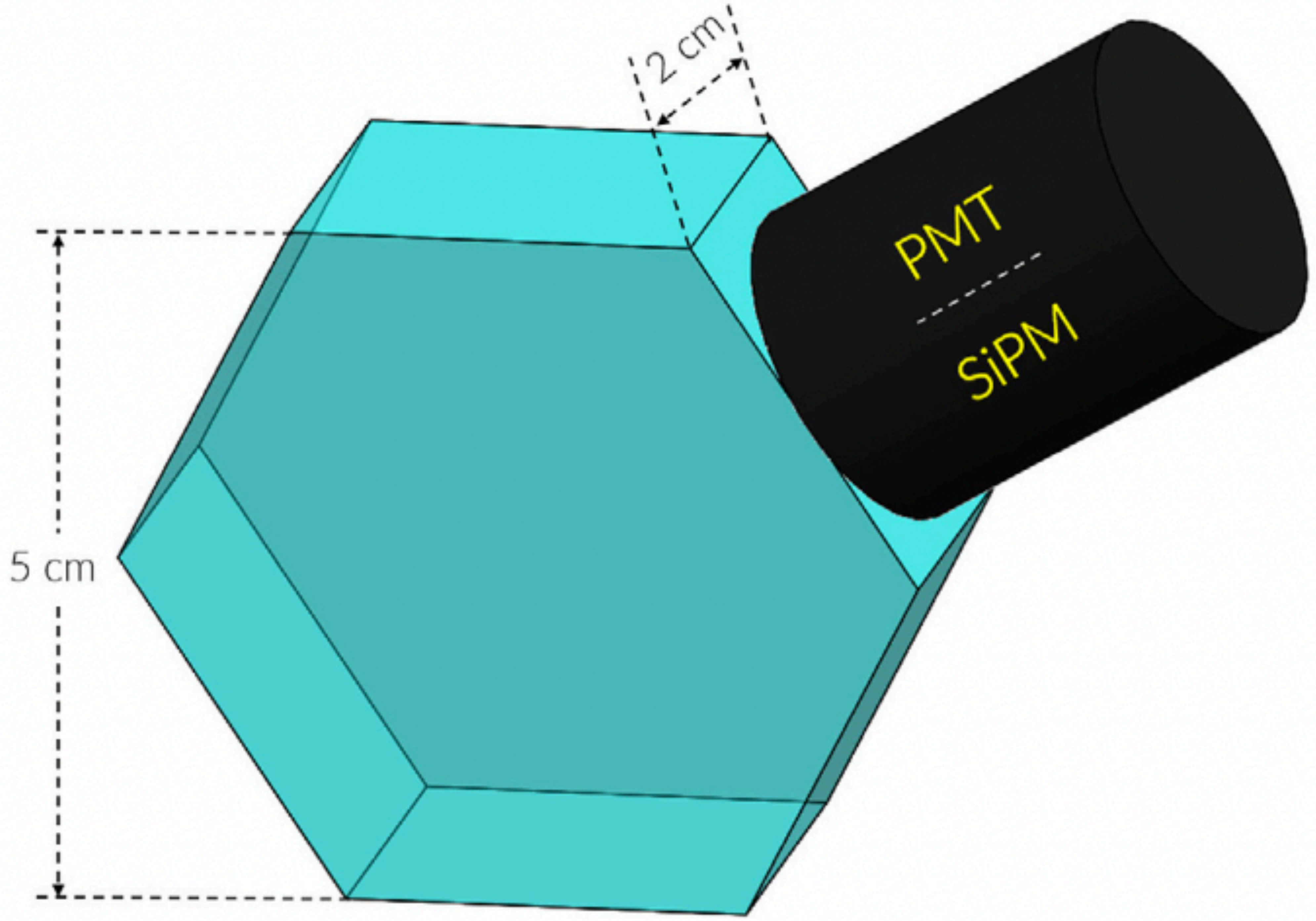


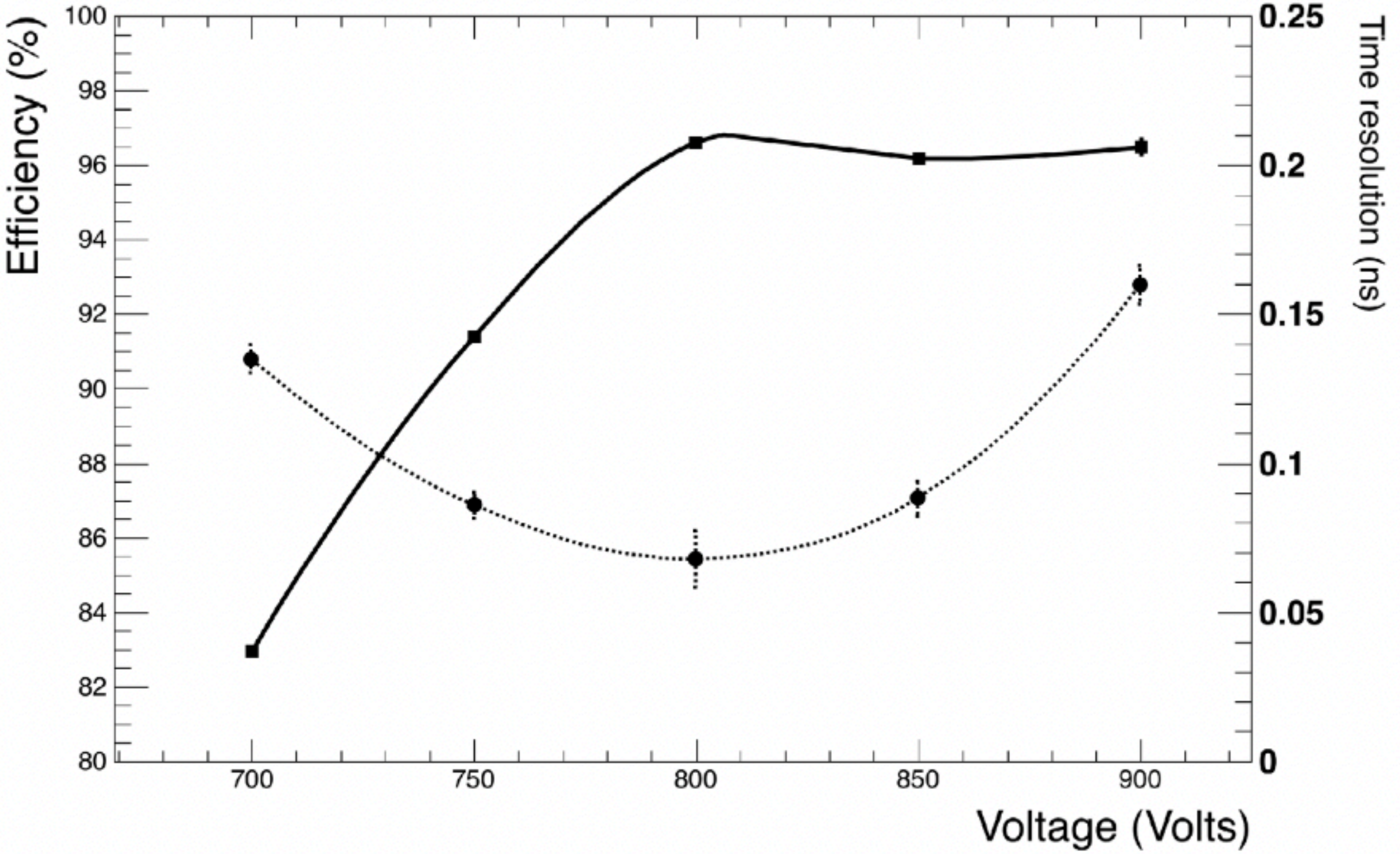


NIMA A 953 (2020) 163150, https://doi.org/10.1016/j.nima.2019.163150

Beam test at T10/CERN

PMT

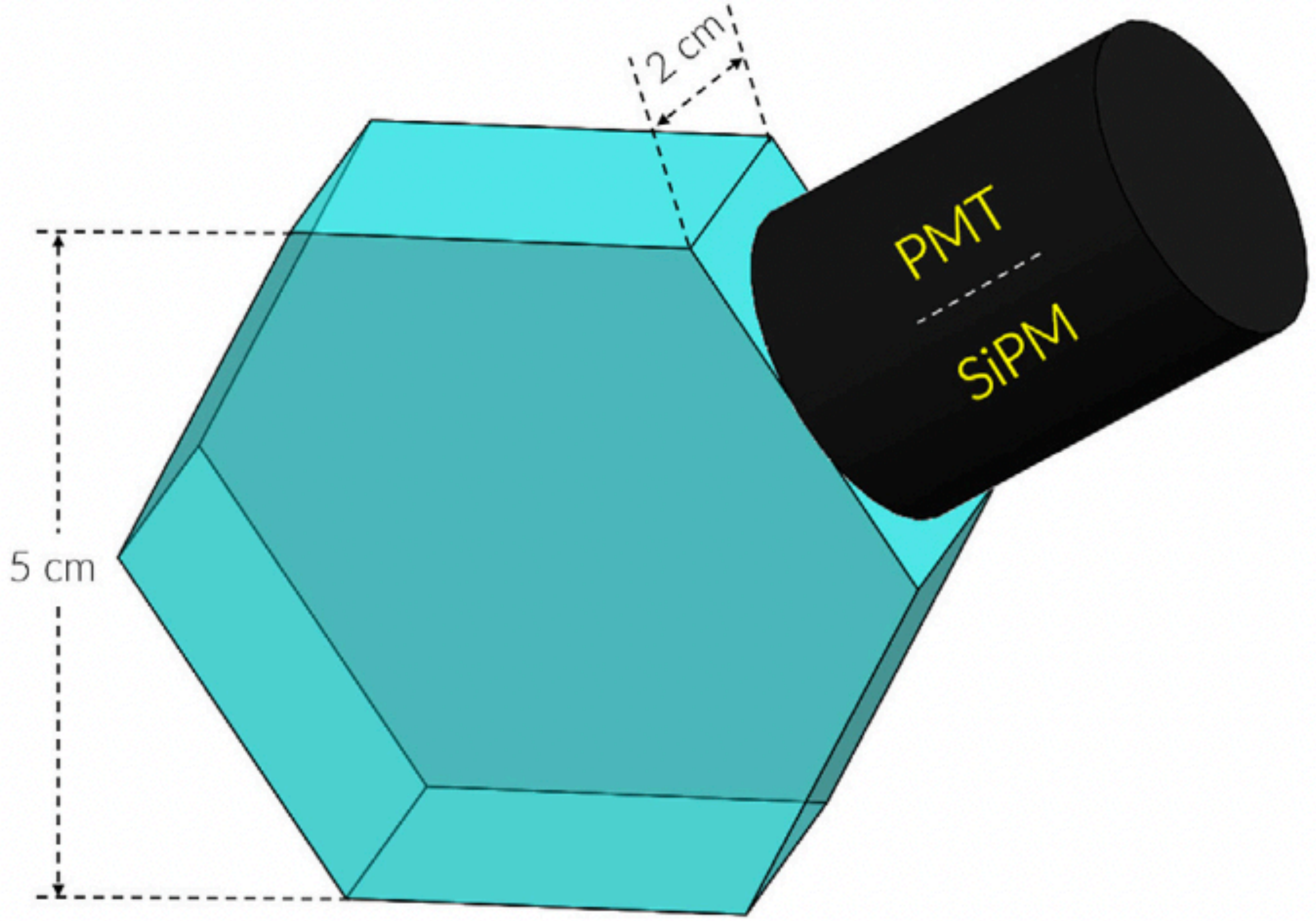


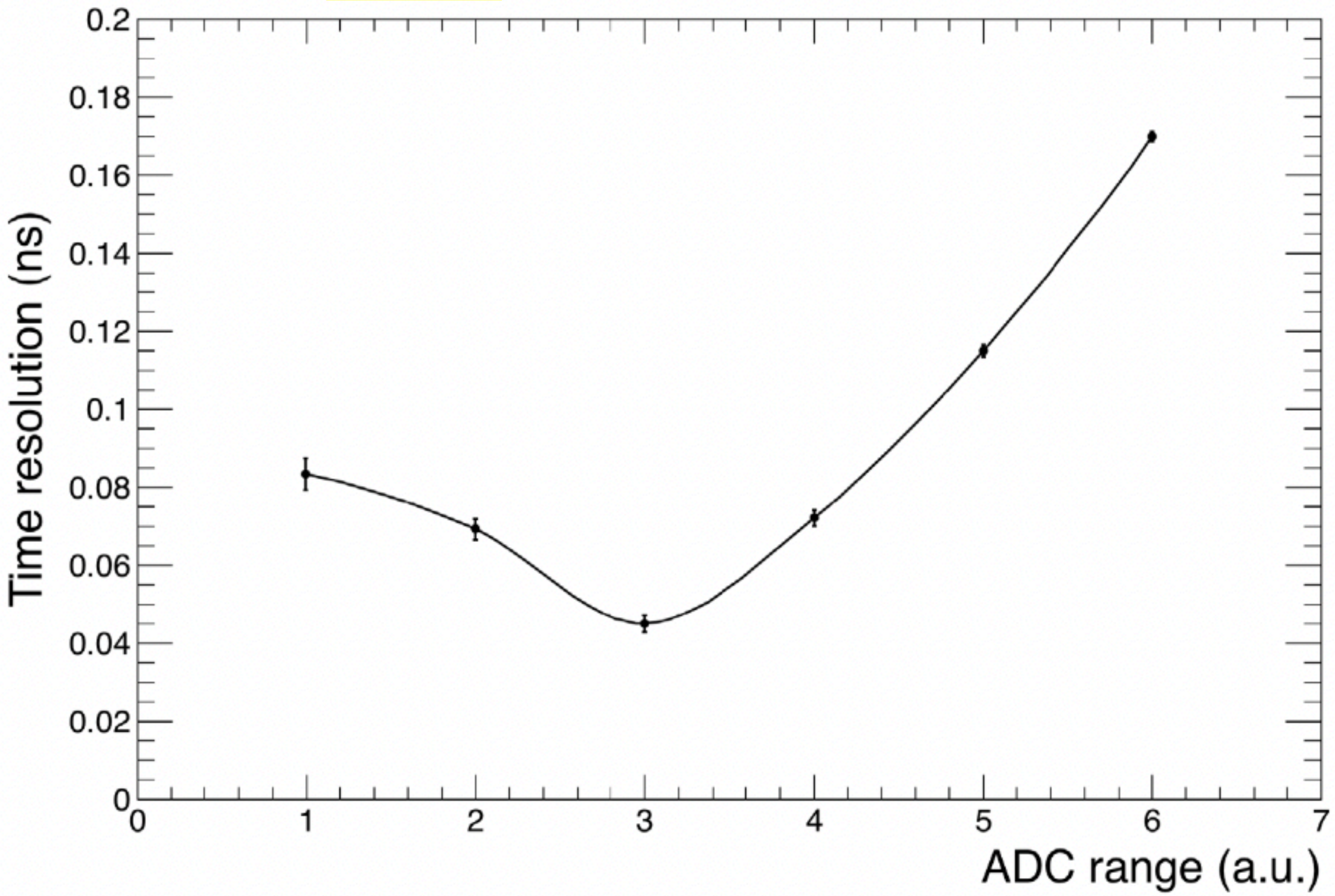


NIMA A 953 (2020) 163150, https://doi.org/10.1016/j.nima.2019.163150

Beam test at T10/CERN

SiPM

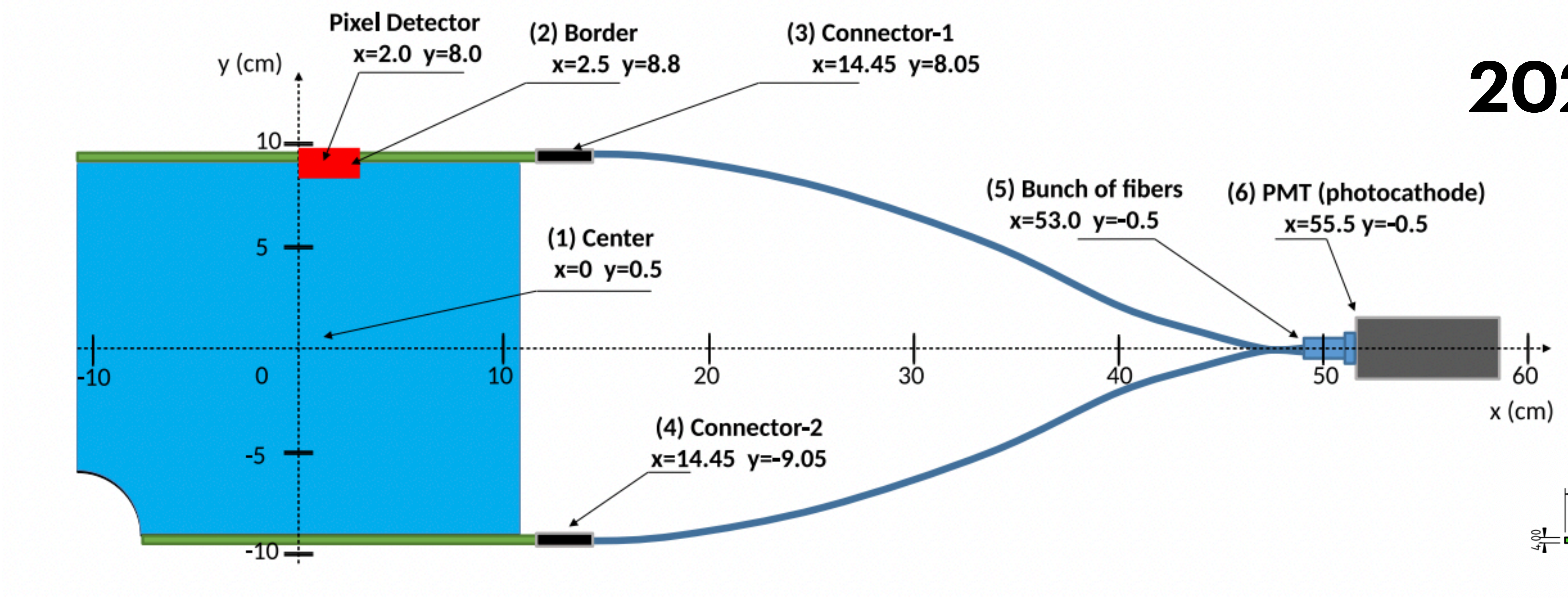


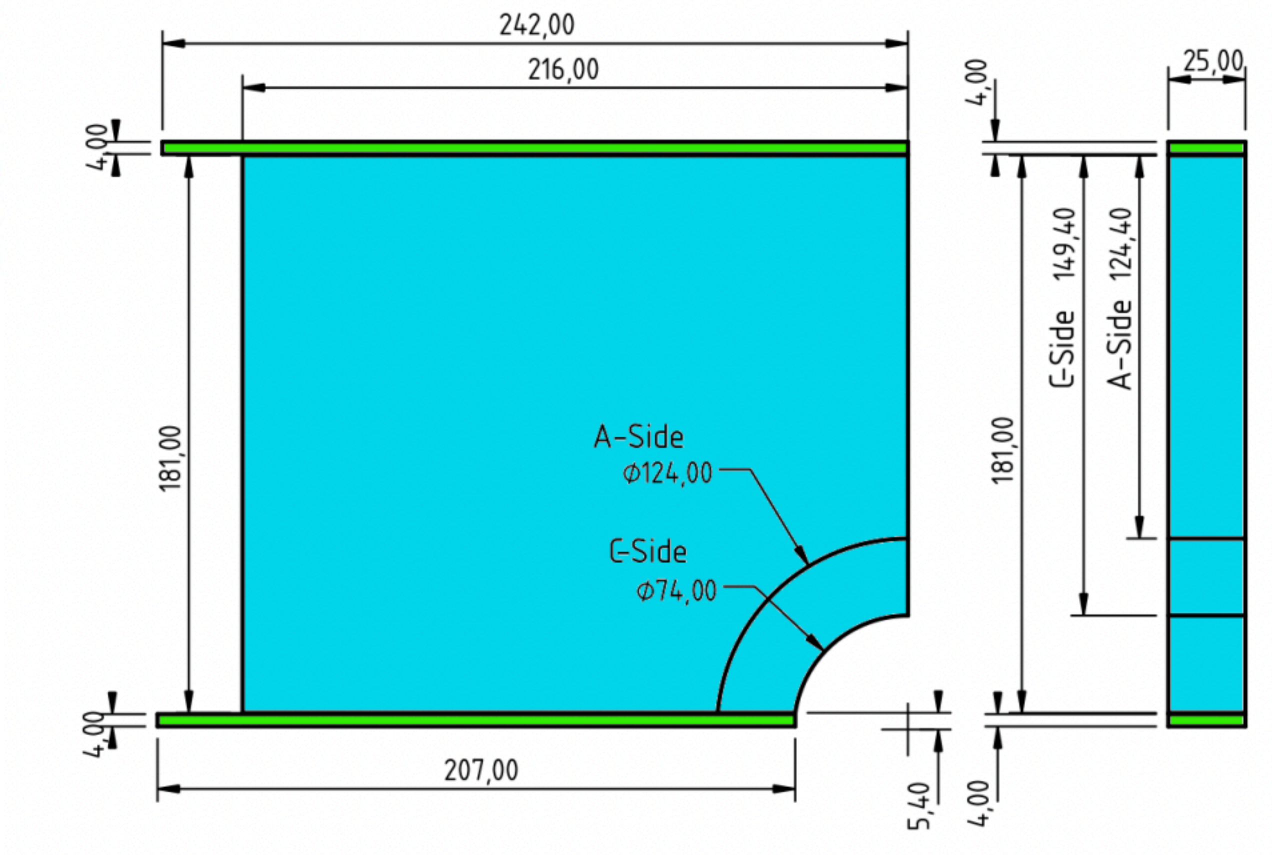


NIMA A 953 (2020) 163150, https://doi.org/10.1016/j.nima.2019.163150

AD detector: Beam test at T10/CERN

2021 JINST 16 P01017

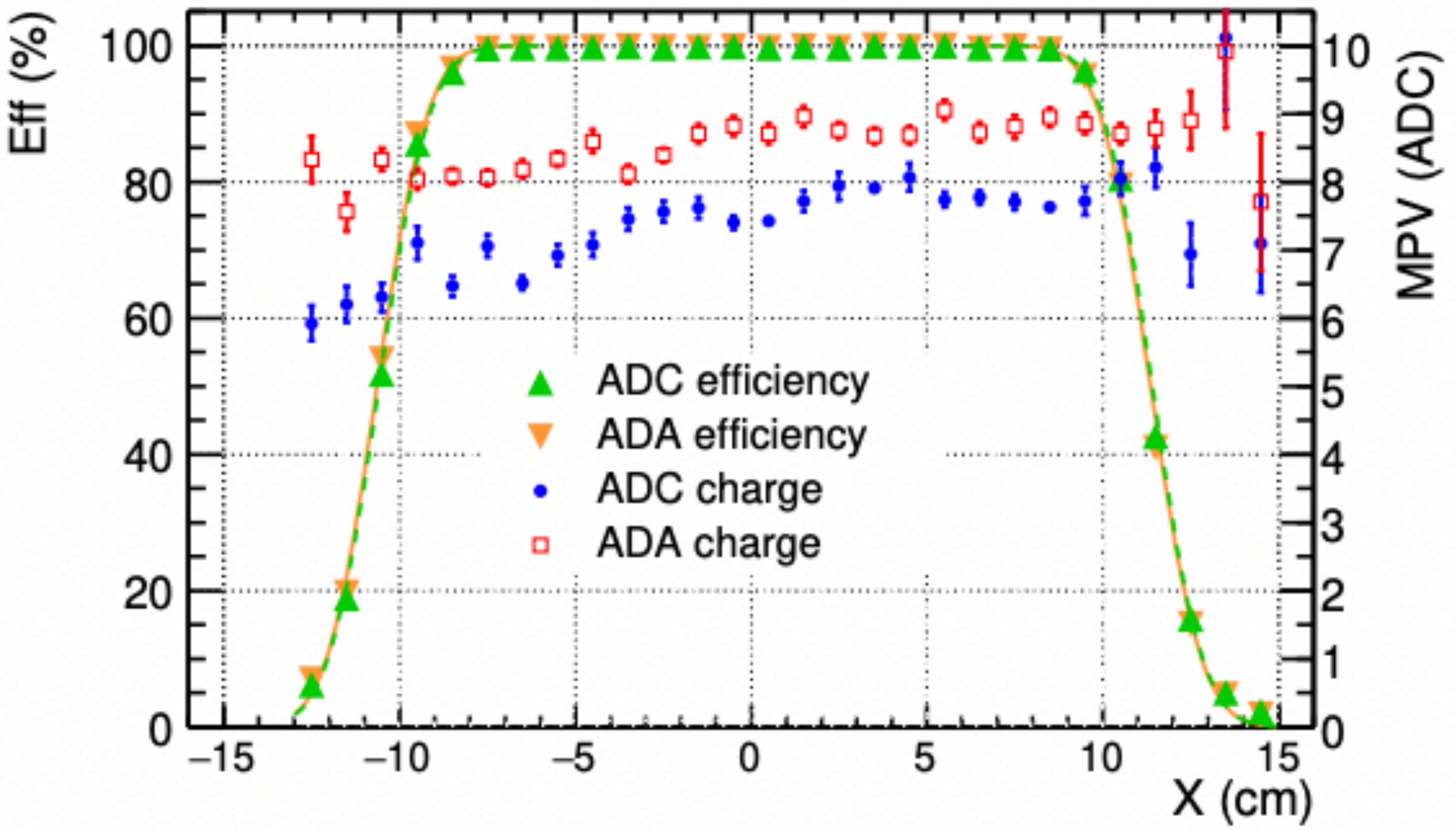


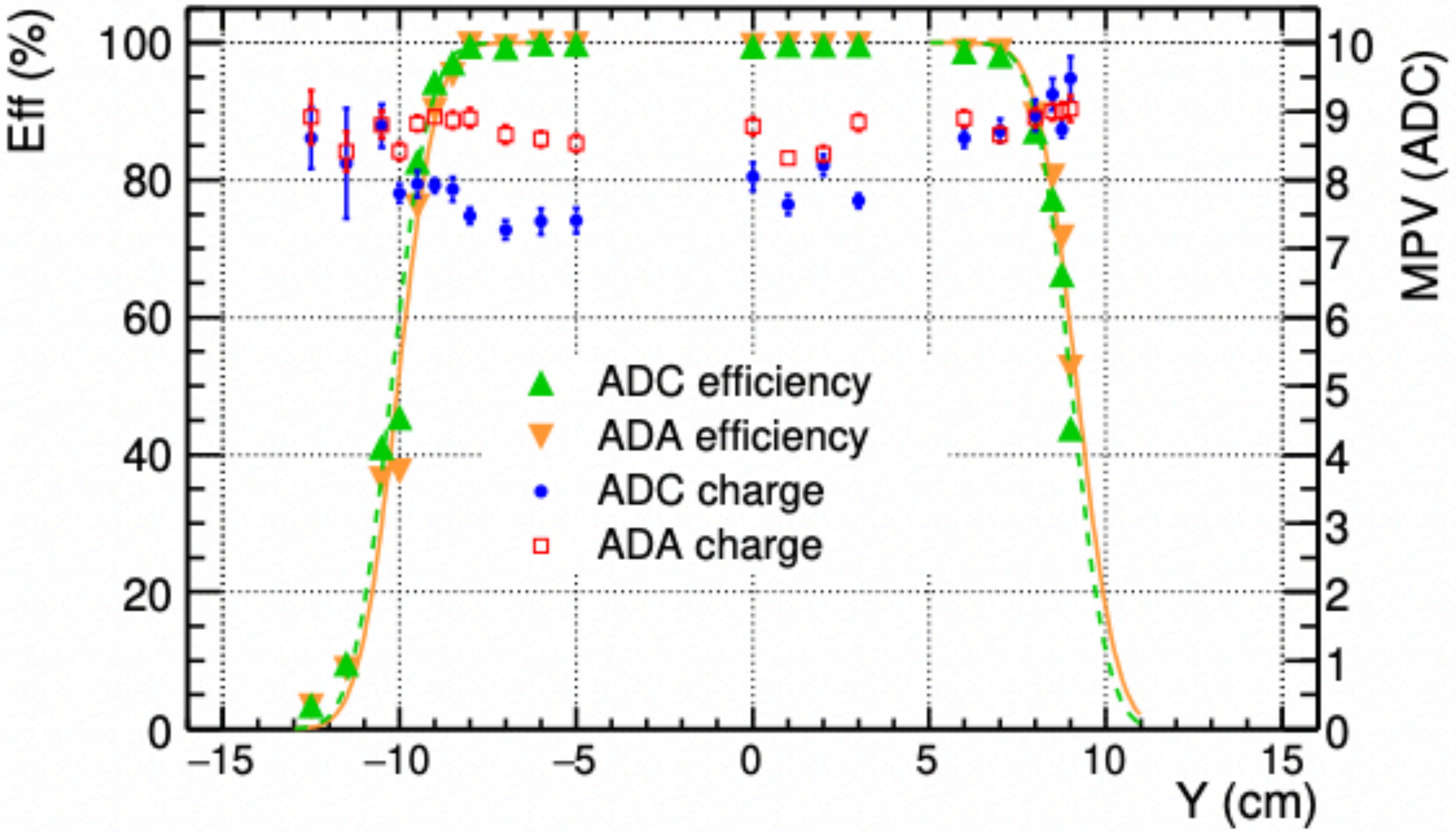


Solangel, Gaby, Luis Alberto, Abraham, ..

AD detector: Beam test at T10/CERN

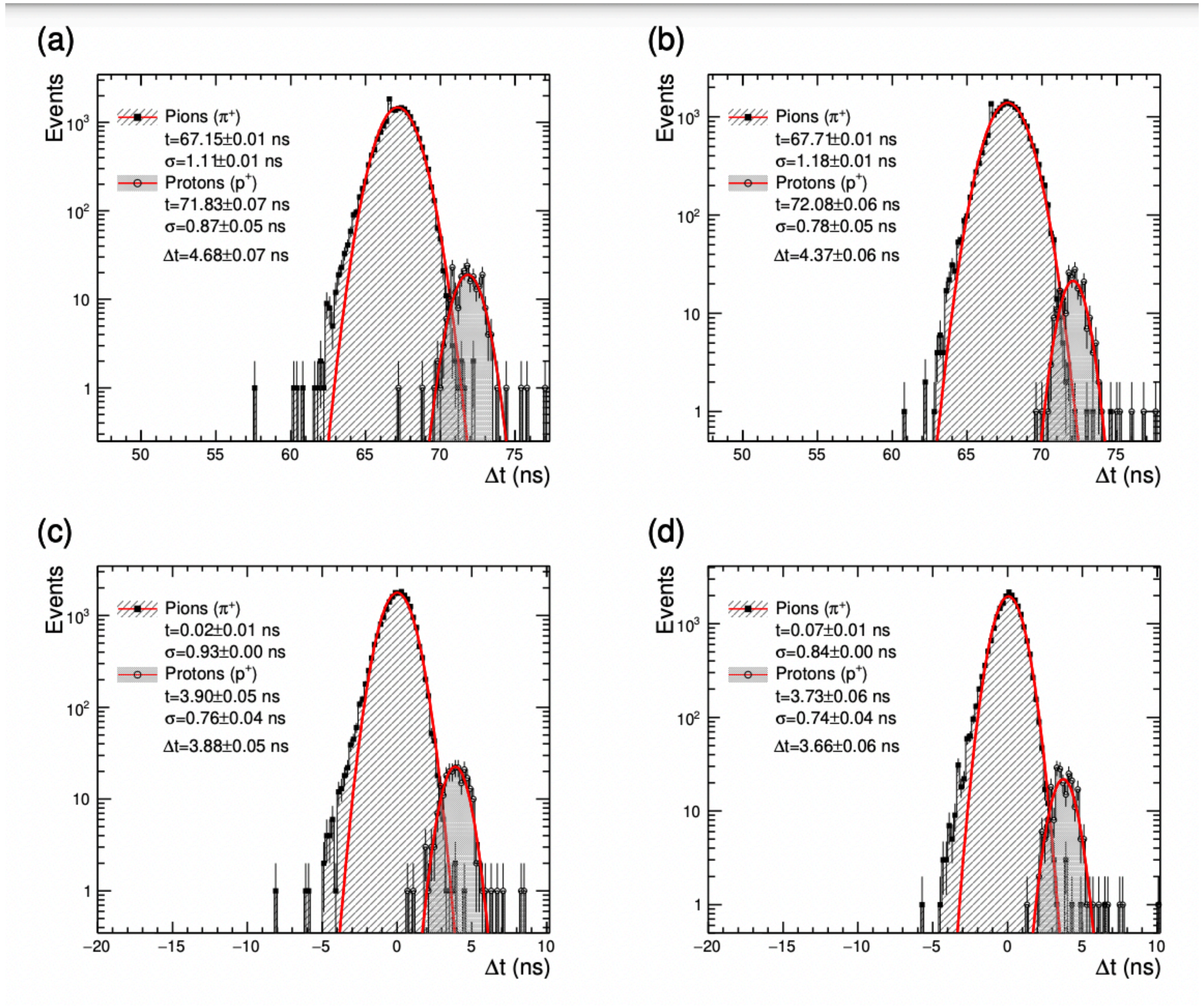
2021 JINST 16 P01017





Solangel, Gaby, Luis Alberto, Abraham, ..

AD detector: Beam test at T10/CERN



2021 JINST 16 P01017

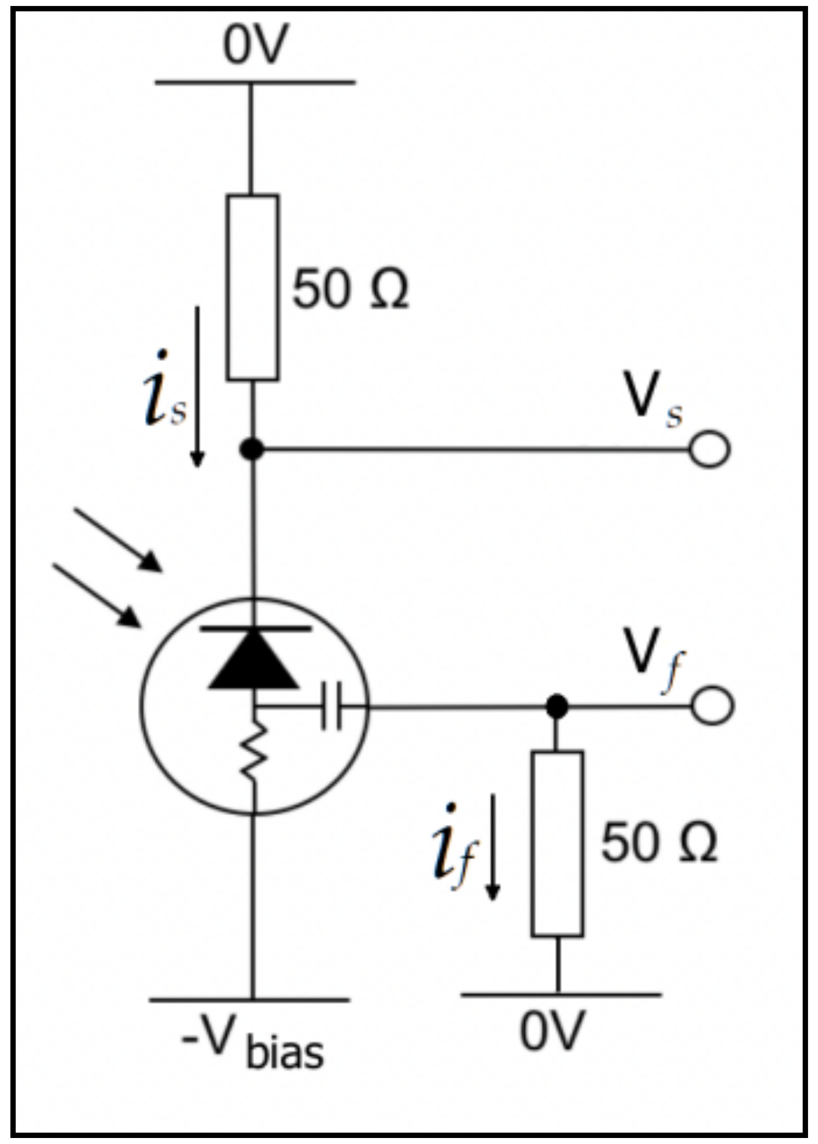
Momentum (GeV/c)	σ (ns) ADC		ADA	
	π^+	p^+	π^+	p^+
1.0	0.93 ± 0.01	0.76 ± 0.04	0.84 ± 0.01	0.74 ± 0.04
1.5	1.26 ± 0.02	1.18 ± 0.07	1.17 ± 0.02	1.19 ± 0.06
2.0	1.32 ± 0.01	1.40 ± 0.04	1.22 ± 0.01	1.33 ± 0.02
6.0	1.12 ± 0.02		1.18 ± 0.02	

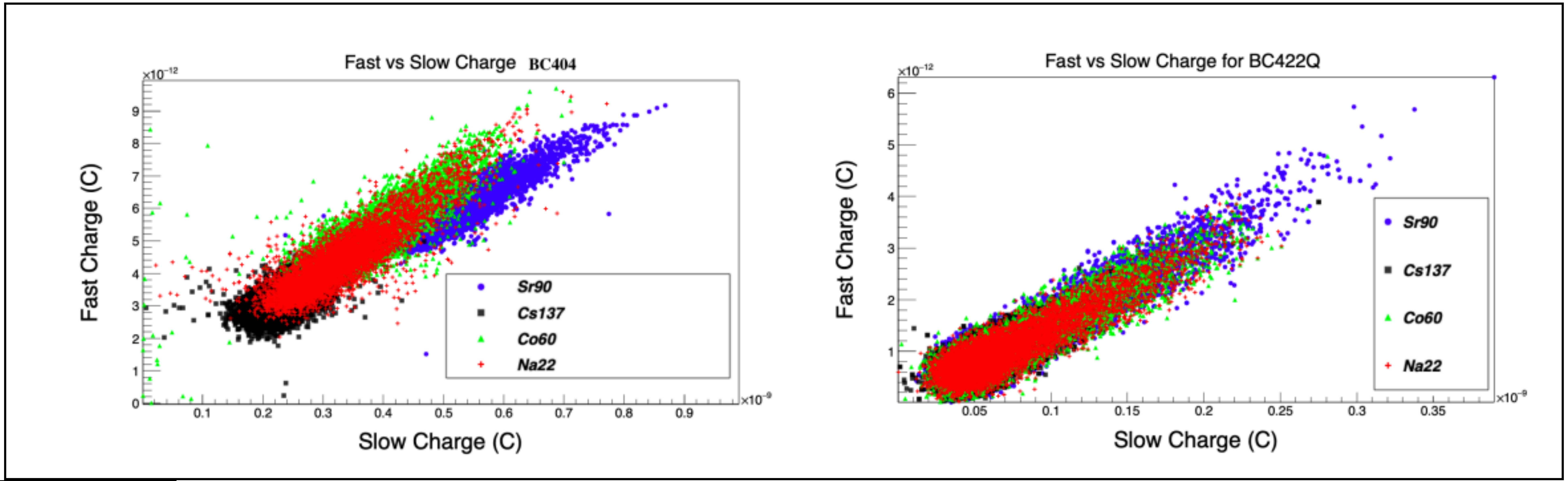
Solangel, Gaby, Luis Alberto, Abraham, ..

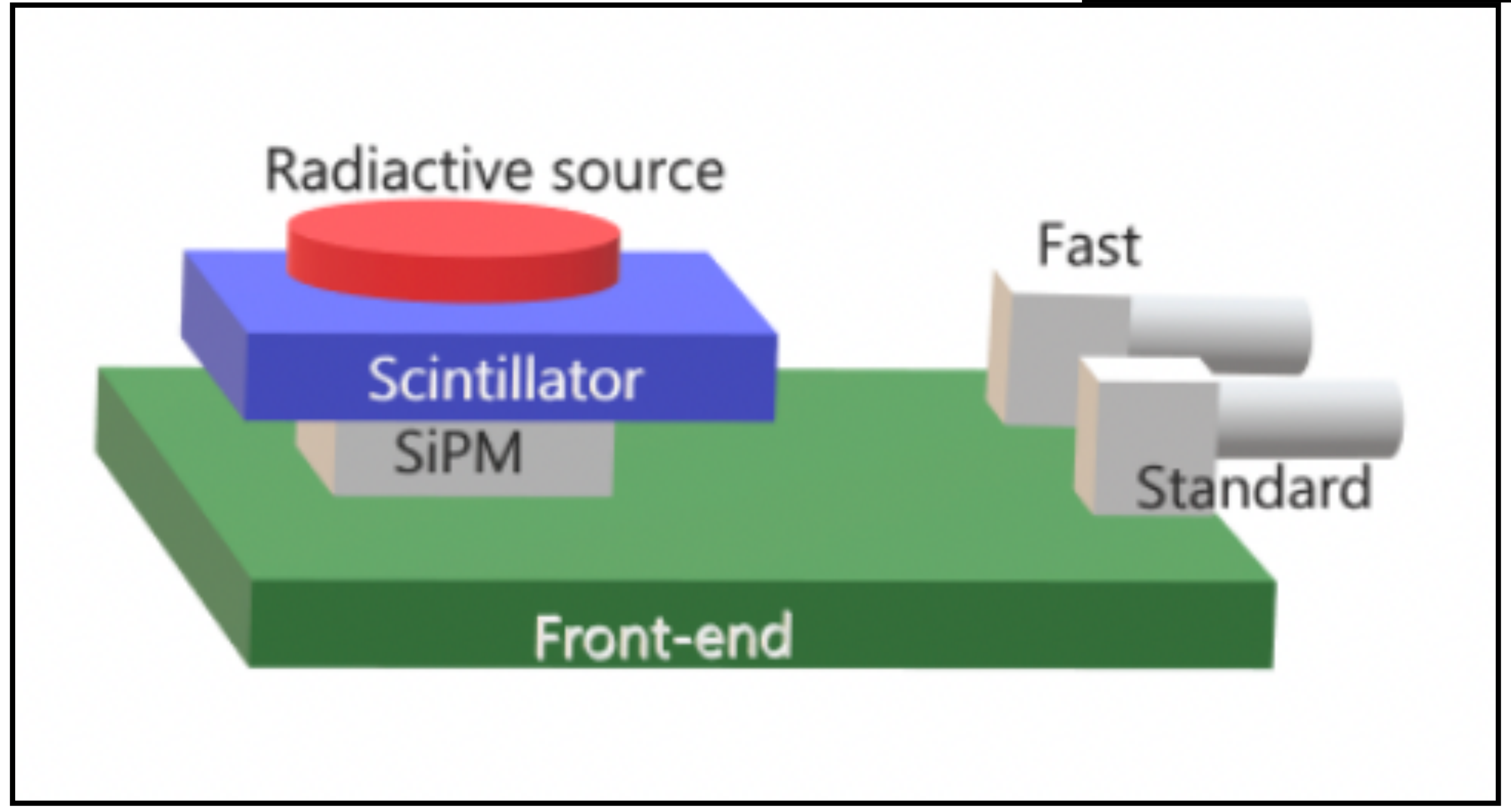
SiPM charge studies

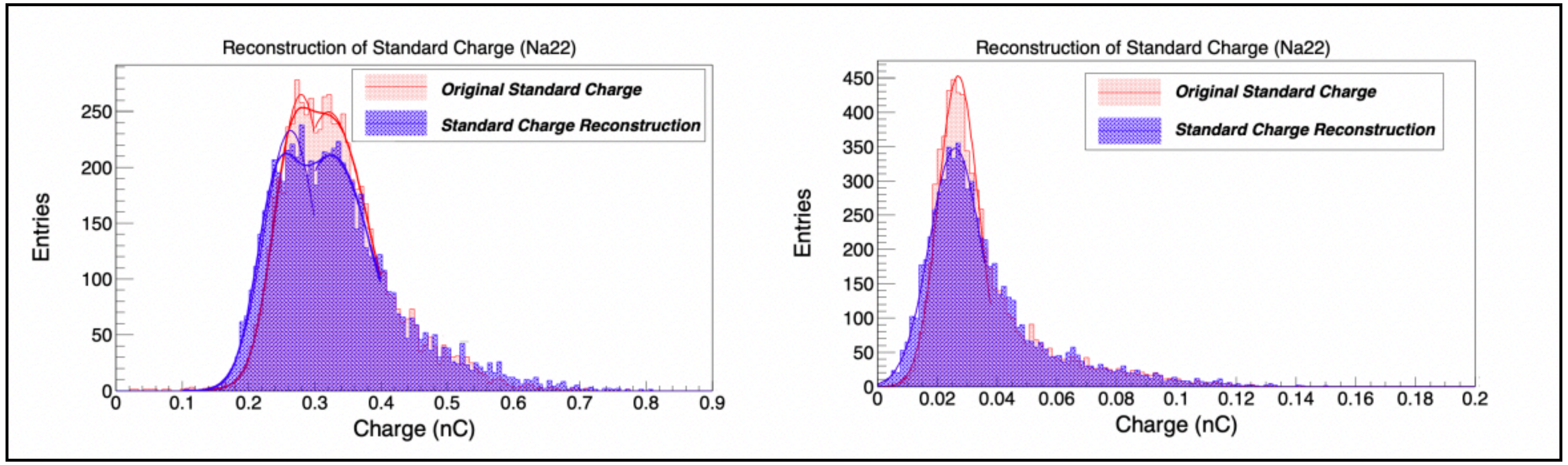
2020 JINST 15 P09008

BUAP



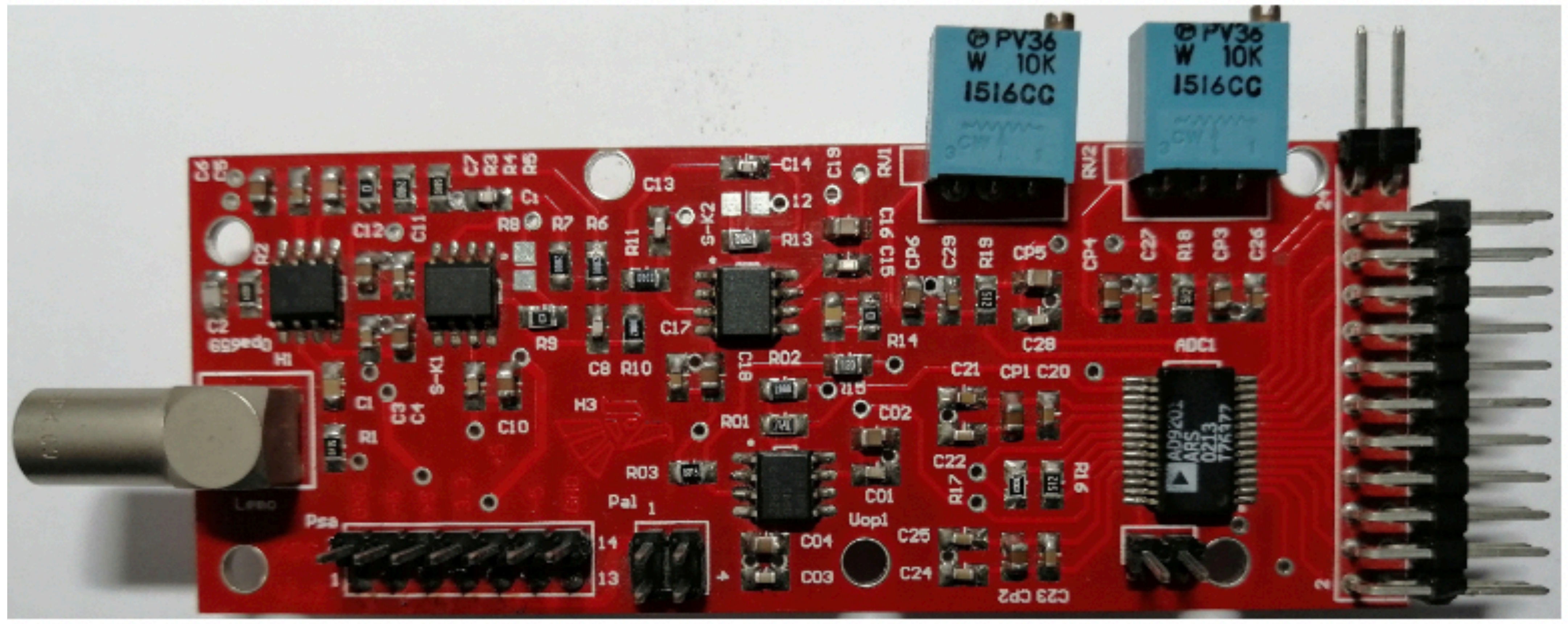


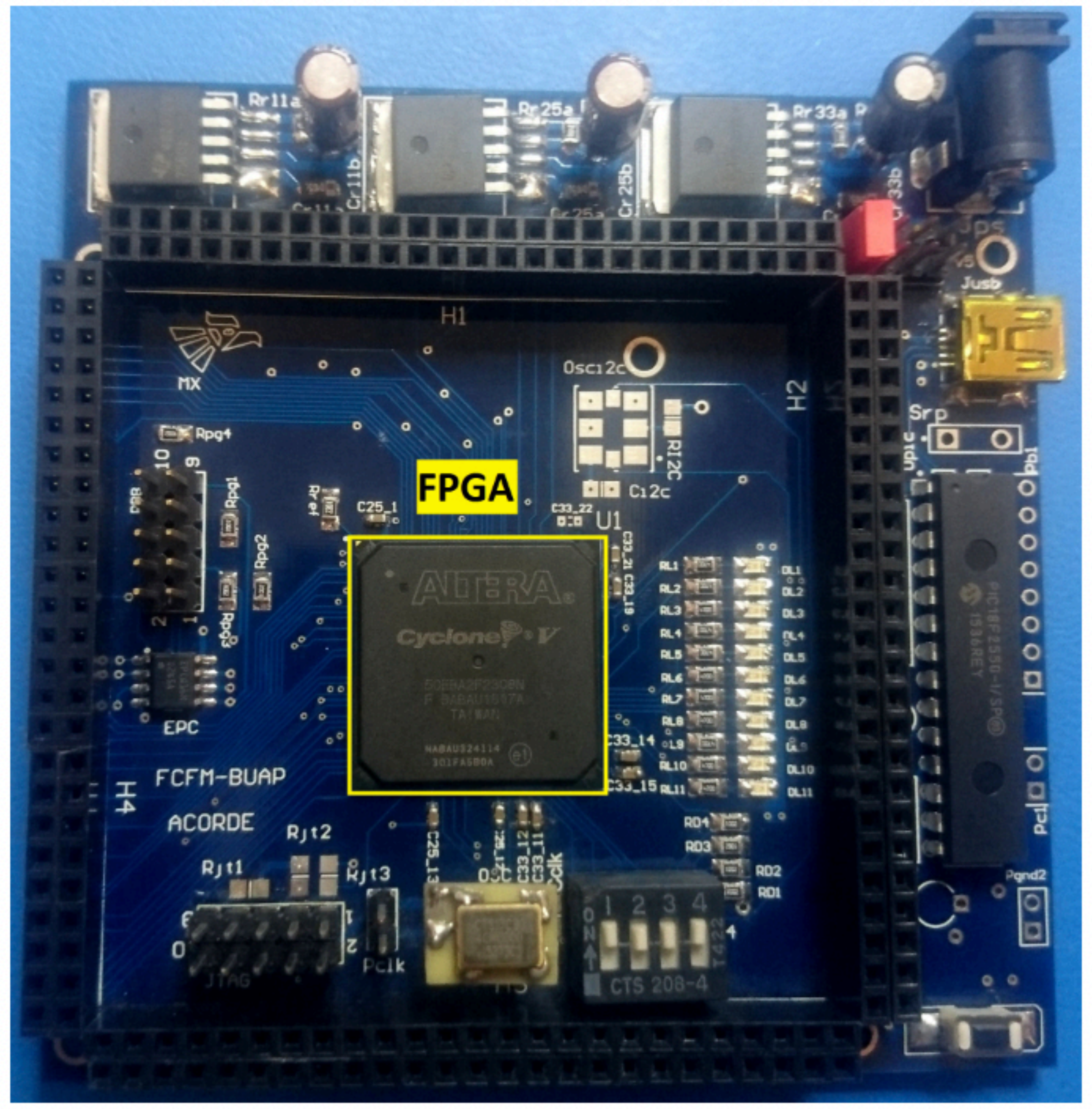


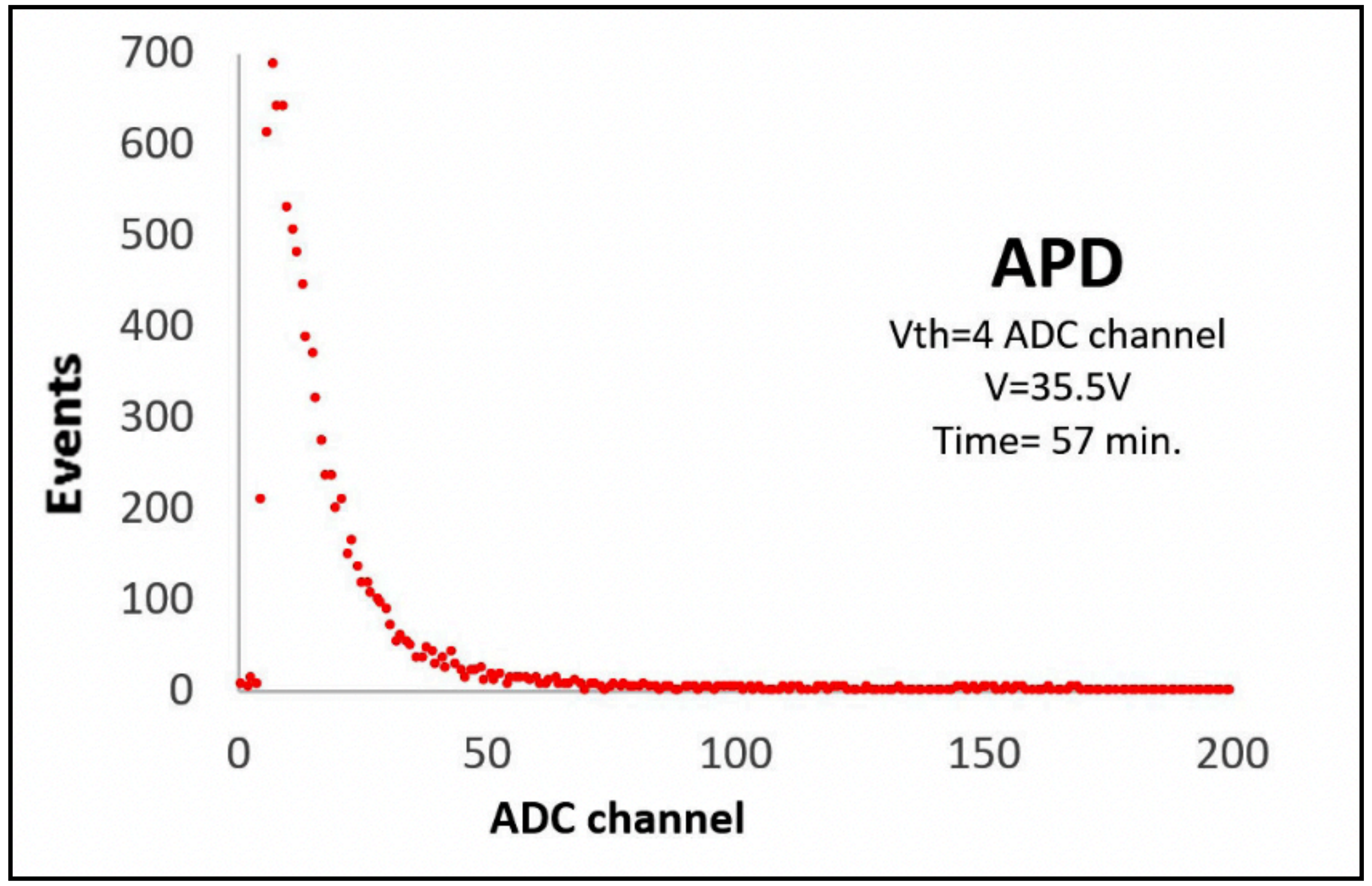


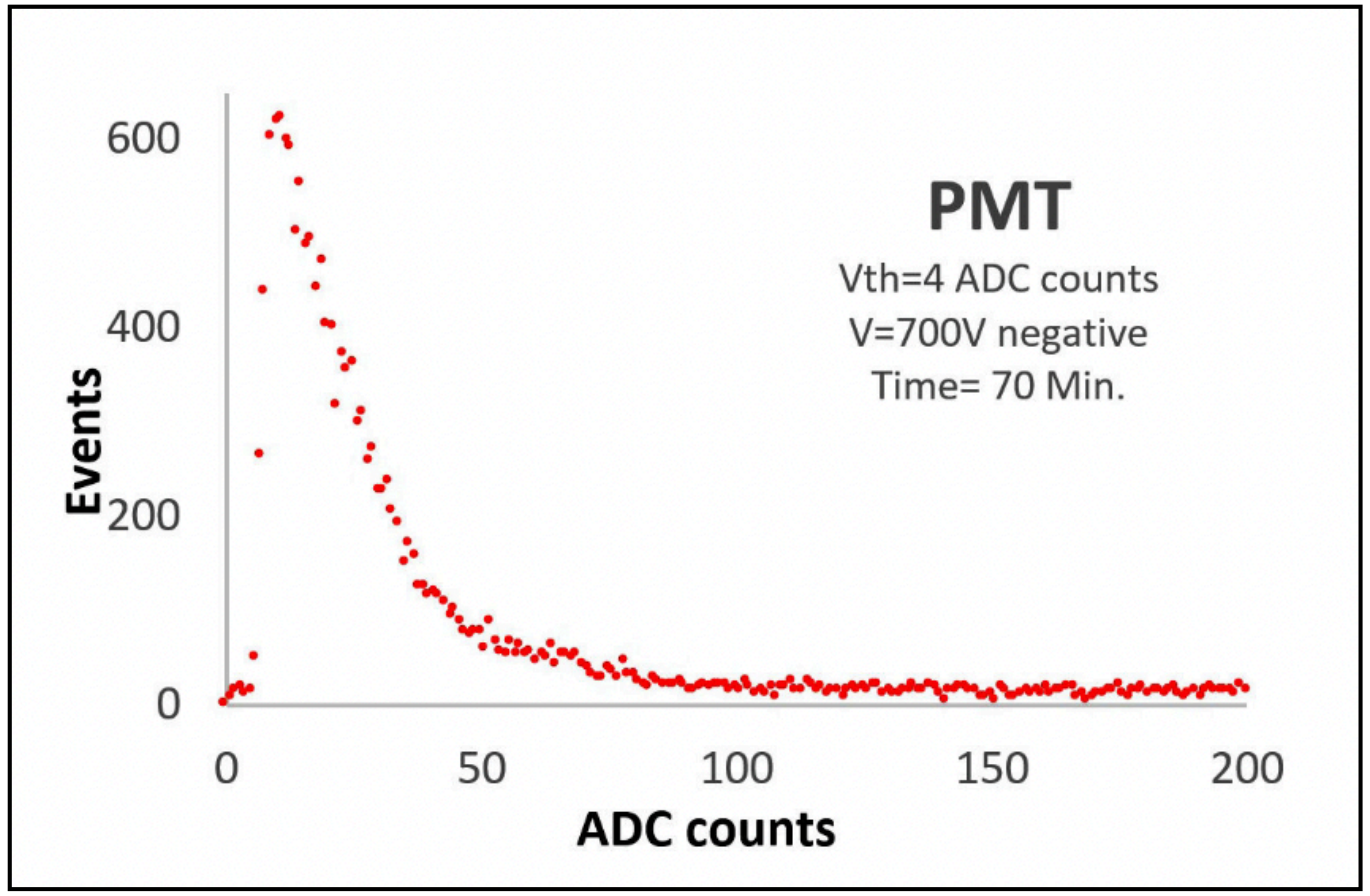
DAQ's system

Rev. Mex. Fis. 66 (4) 475 - 478









ALICE BUAP group

Arturo Fernández
Mario Iván Martínez
Guillermo Tejeda
Mario Rodríguez

DCS / Electronics / Data Analysis/ Detector development

BUAP

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MANCILLA, Omar (Master)
MARTÍNEZ GARCÍA, Josué (Master)
PAISANO GUZMAN, Sergio (Phd)
RAMÍREZ ÁLVAREZ, César Omar (Master)
RÉGULES MEDEL, Héctor David (PhD)
VASQUEZ-BELTRAN, Yael Antonio (PhD)
YOVAL POZOS, Irandheny (PhD)

It is time to define dedicated working groups. See my talk of tomorrow.

Simulations / DCS / Electronics / Data Analysis/ Detector development