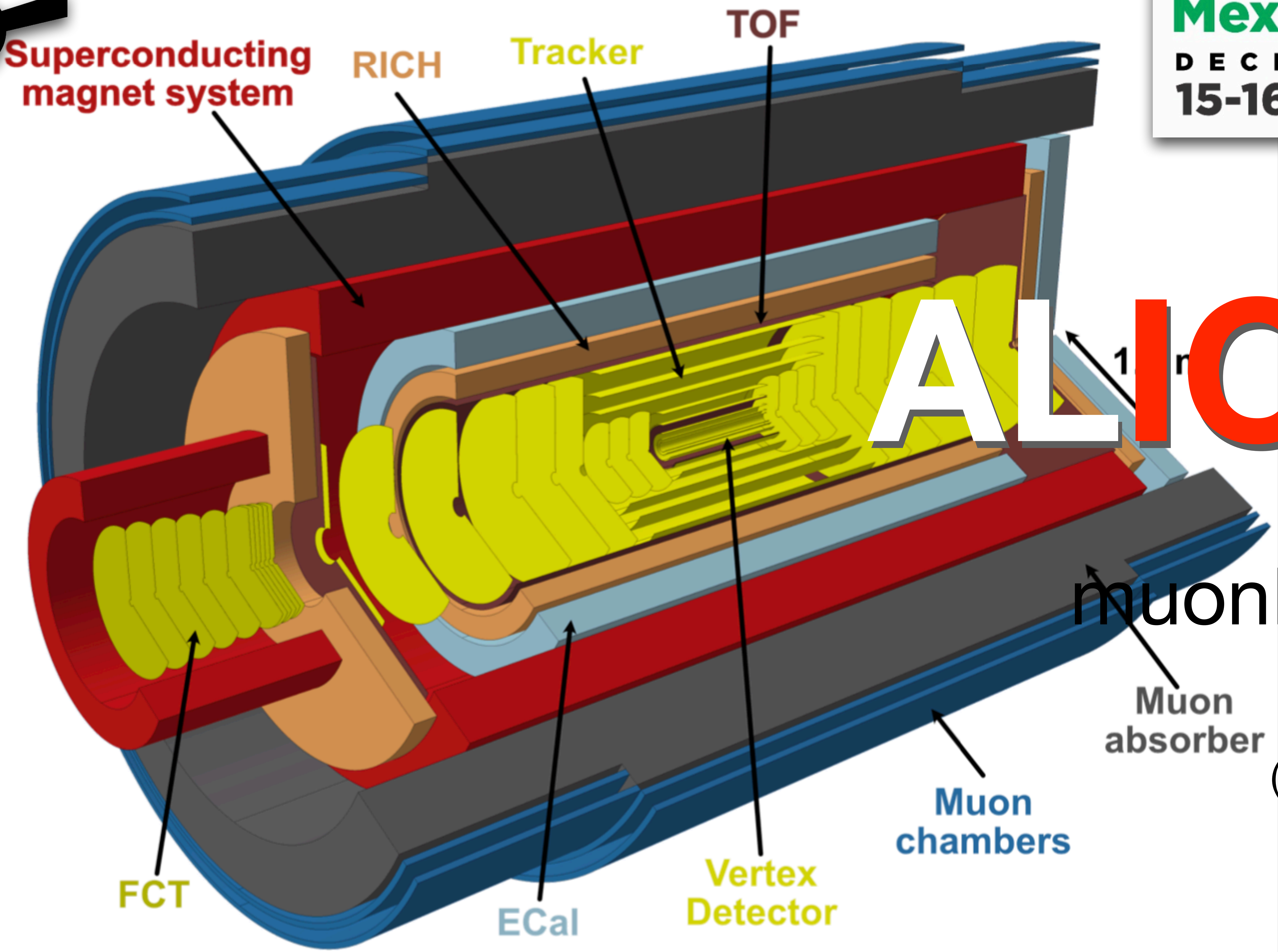
Instituto de Ciencias Nucleares UNAM

FirstMuonID
Mexico Meeting
DECEMBER 15-16, 2022

ALICE 3 and the muonID project

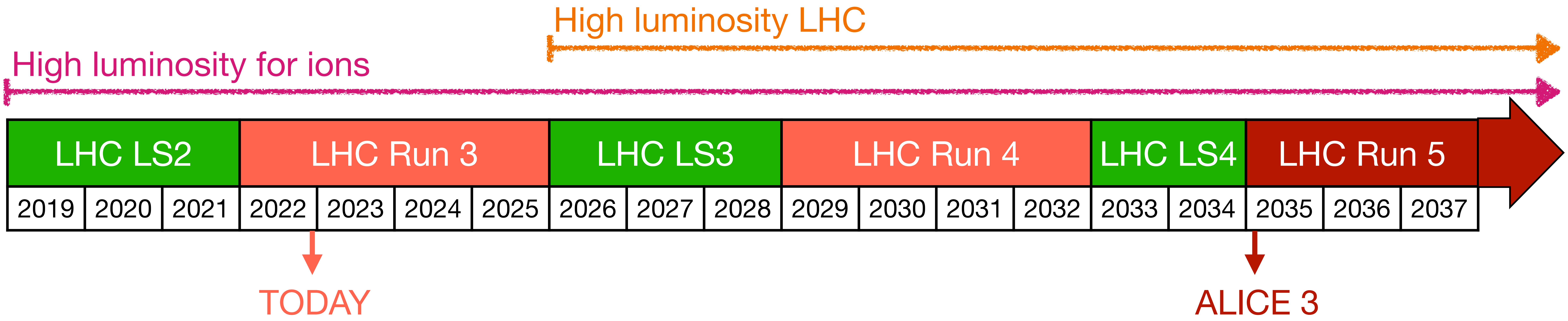


The ALICE collaboration, arXiv:2211.02491

Antonio Ortiz
(CERN, ICN-UNAM)

HL-LHC

High-luminosity era of the LHC
- LHC programme



The LHC program and the ALICE upgrade

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Run	Period	Systems
Run 1	2009-2013	pp, p-Pb, Pb-Pb
Run 2	2015-2018	pp, p-Pb, Xe-Xe, Pb-Pb
Run 3	2022-2025	pp, p-O, O-O, p-Pb, Pb-Pb
Run 4	2029-2032	pp, p-Pb, Pb-Pb
Run 5		pp, p-A?, A-A
Run 6		pp, p-A?, A-A

High luminosity for ions

Higher luminosity for ions

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BUAP

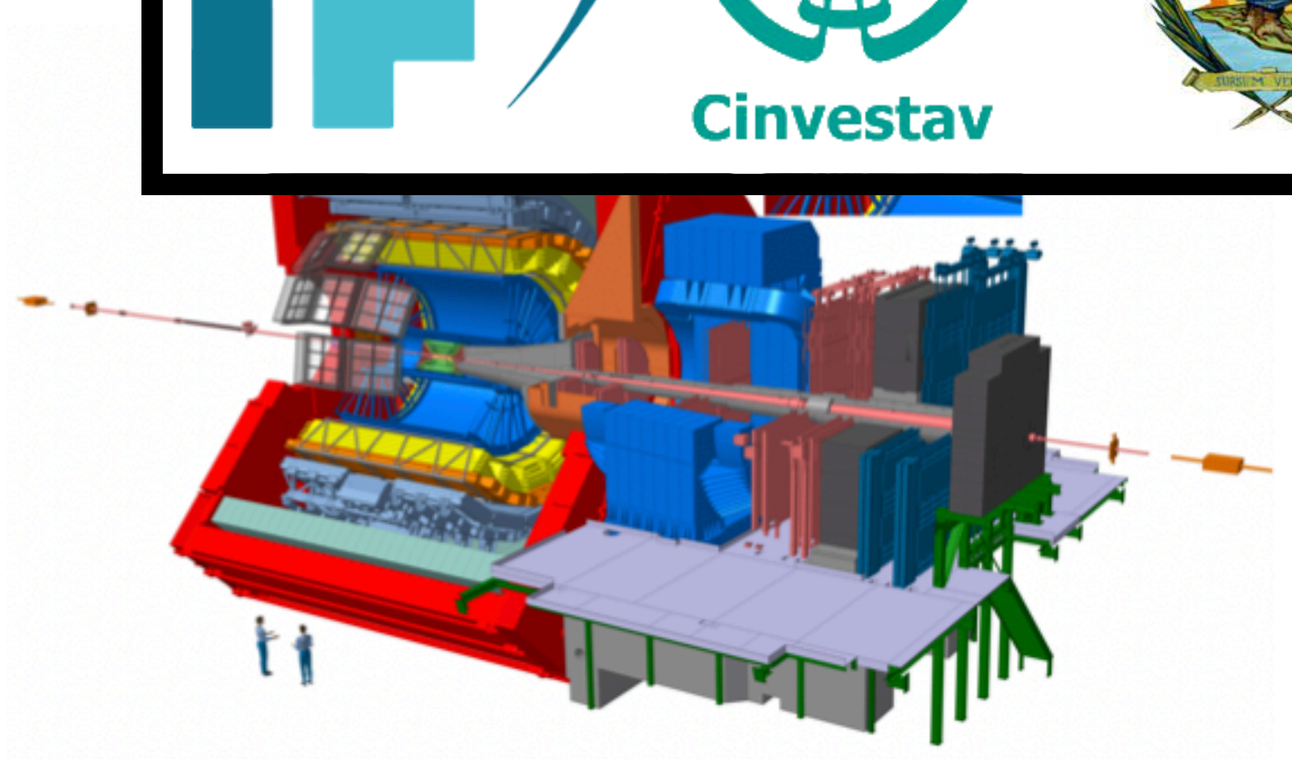
Cinvestav

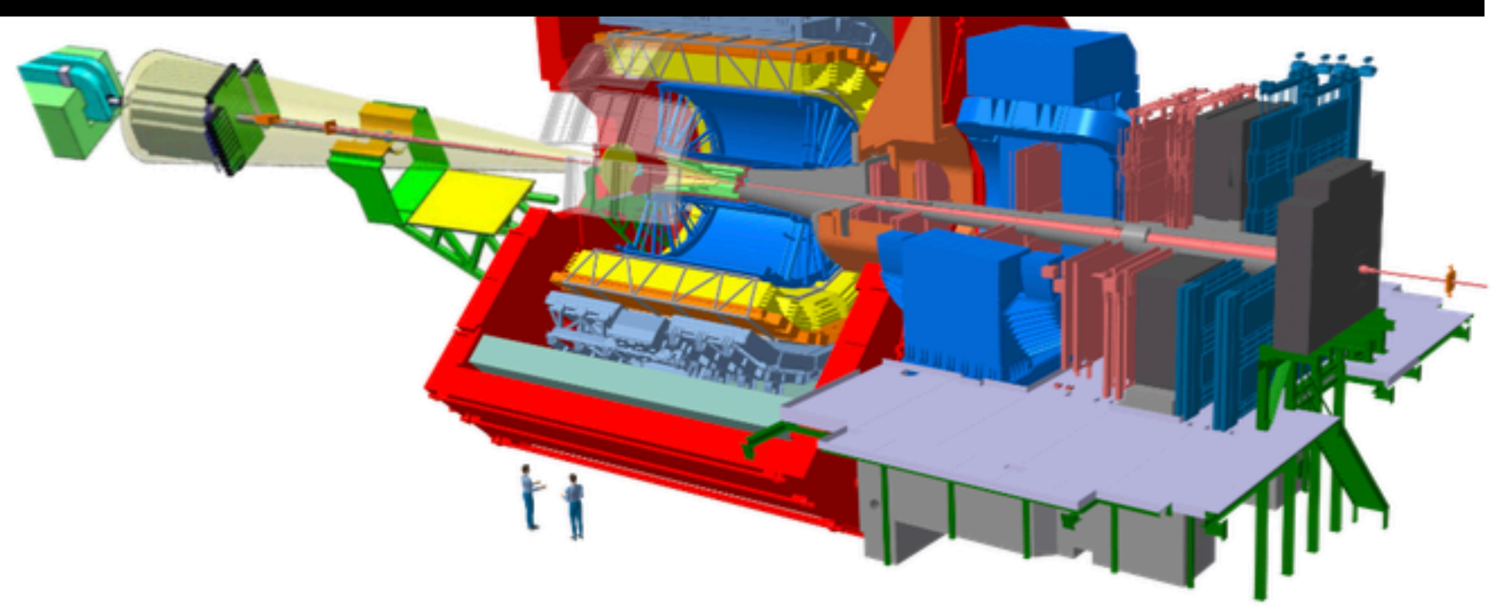
Detectors: ACORDE, VZERO, AD FIT (FDD, FV0), TPC

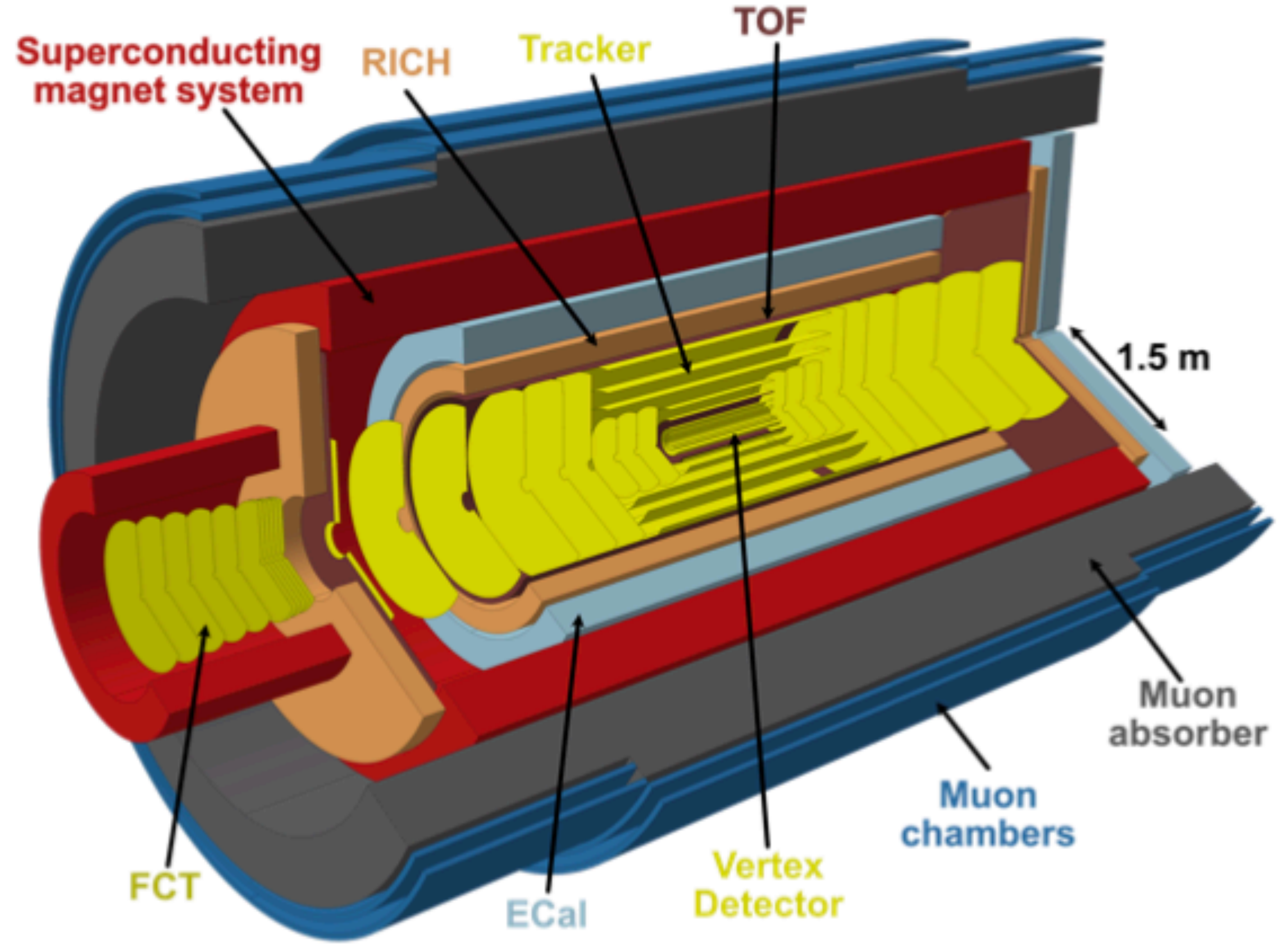
Computing Resources

Physics: participation in the publication of 18 scientific publications of ALICE

ALICE 3





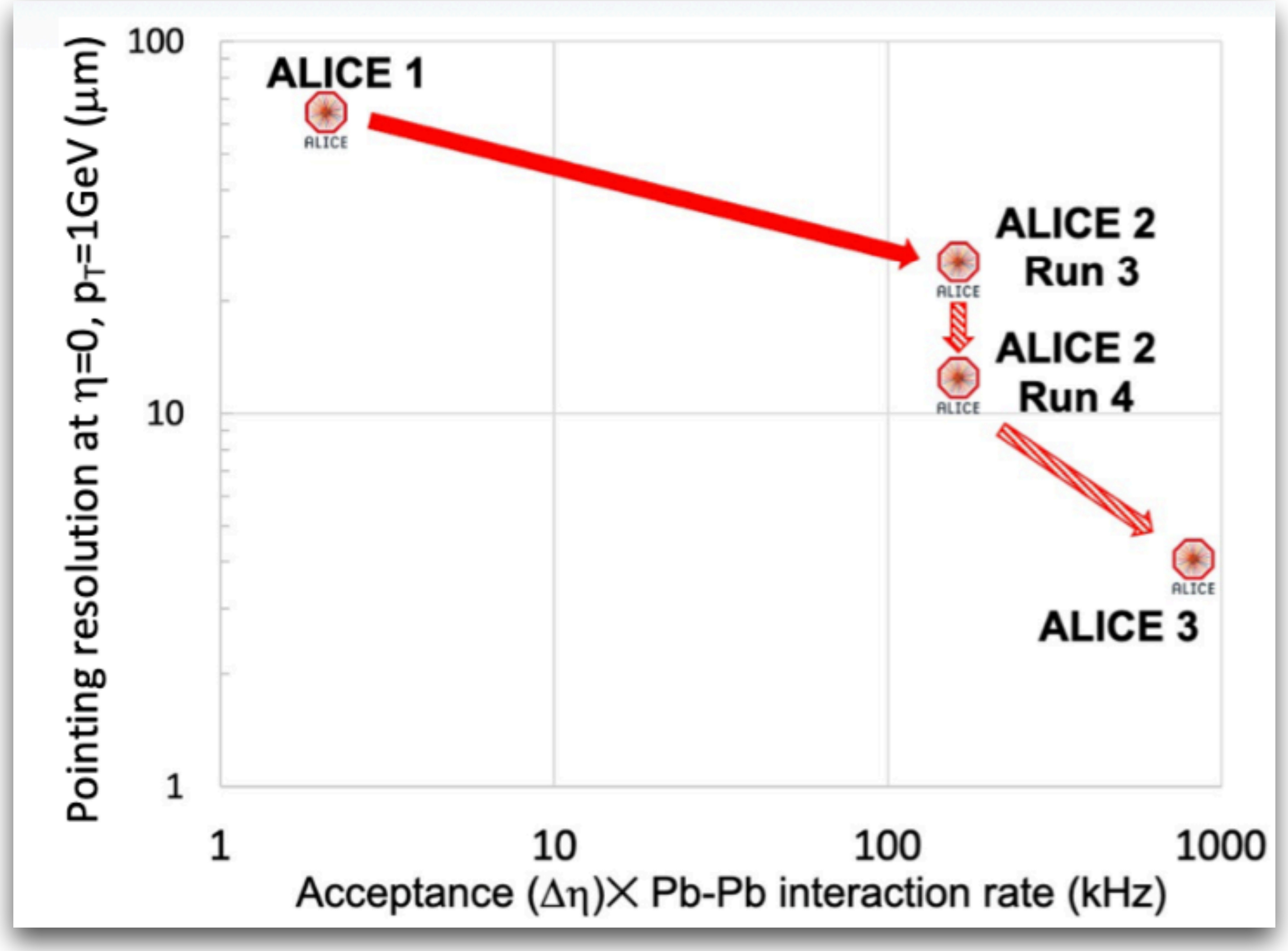


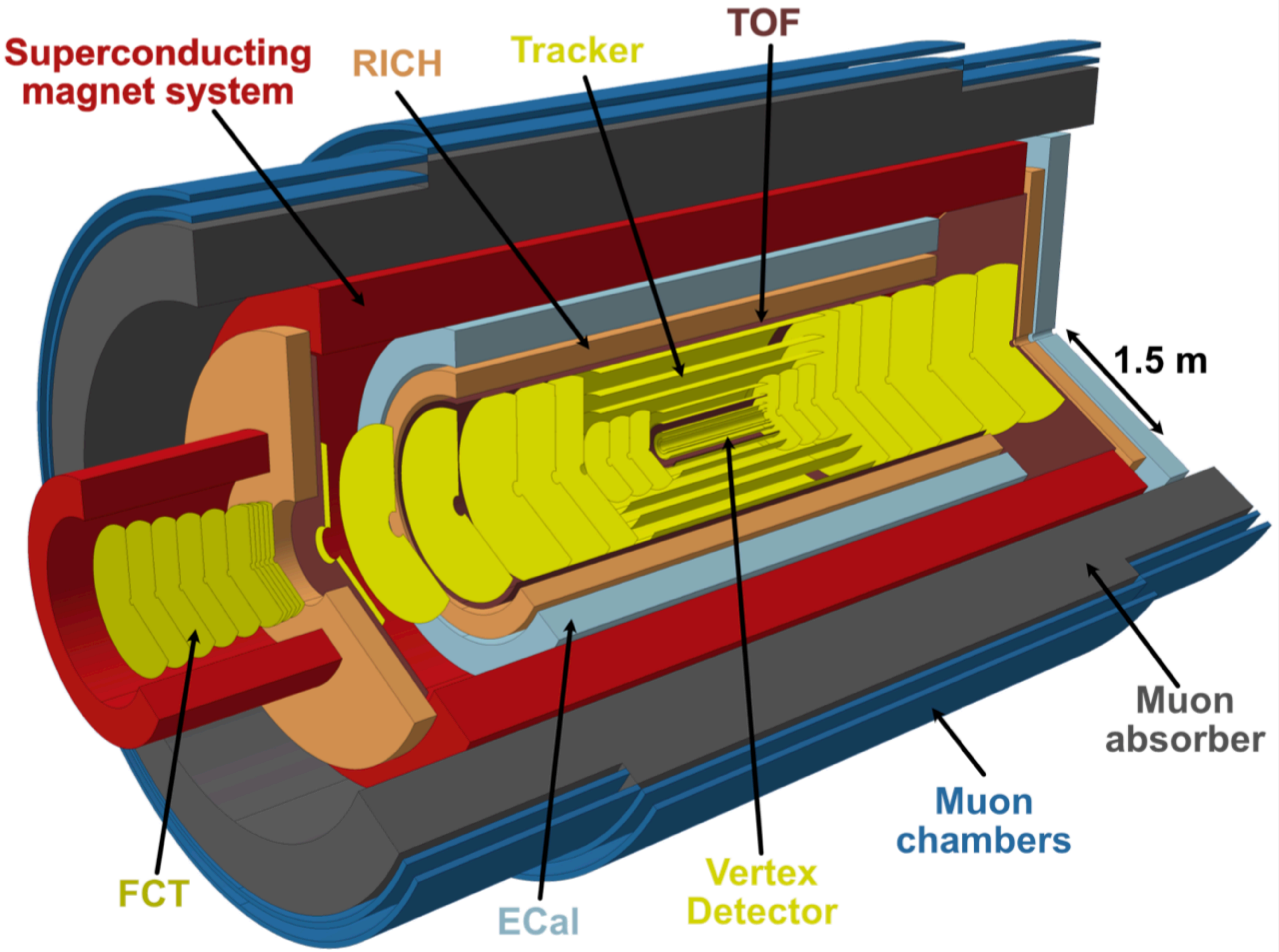
Major upgrade | Intermediate upgrade

ALICE 3

Novel and innovative detector concept

- Compact and lightweight all-silicon tracker
- Retractable vertex detector
- Particle identification systems
- Large acceptance





- Superconducting magnet system / Continuous read-out and online processing

Status and planning ALICE 3

Physics case and detector concept developed in the course of 2020-2021 → Letter of Intent

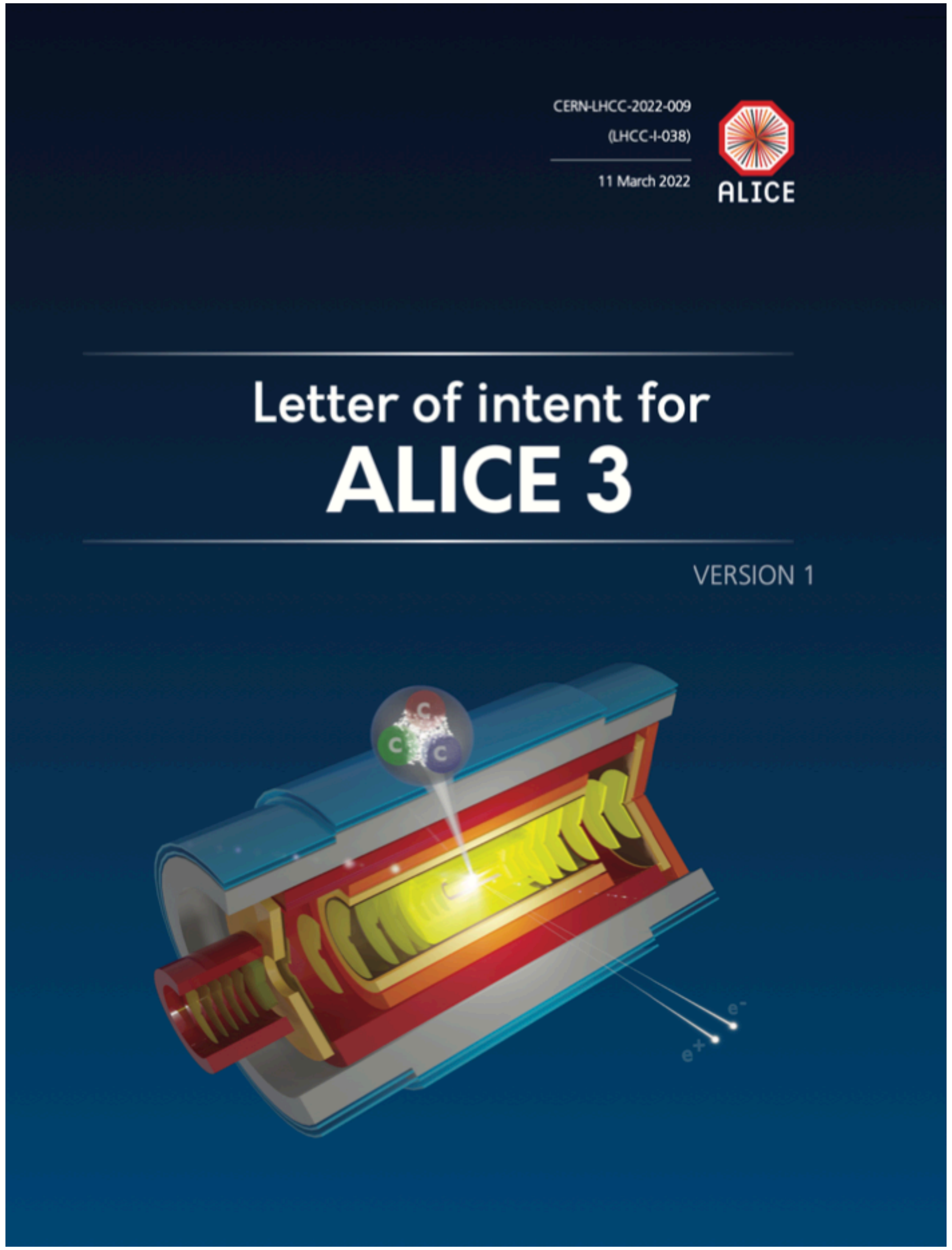
- endorsed by Collaboration Board in January 2022
- LHCC review concluded in March 2022

  → very positive evaluation [LHCC-149]

  - Exciting physics program
  - Detector well matched with physics program and strategically interesting R&D opportunities
- R&D activities have started

Timeline

2023-25: selection of technologies, small-scale proof of concept prototypes
2026-27: large-scale engineered prototypes
Technical Design Reports
2028-31: construction and testing
2032: contingency
2033-34: Preparation of cavern and installation of ALICE 3



MuonID (3 options)

ALICE
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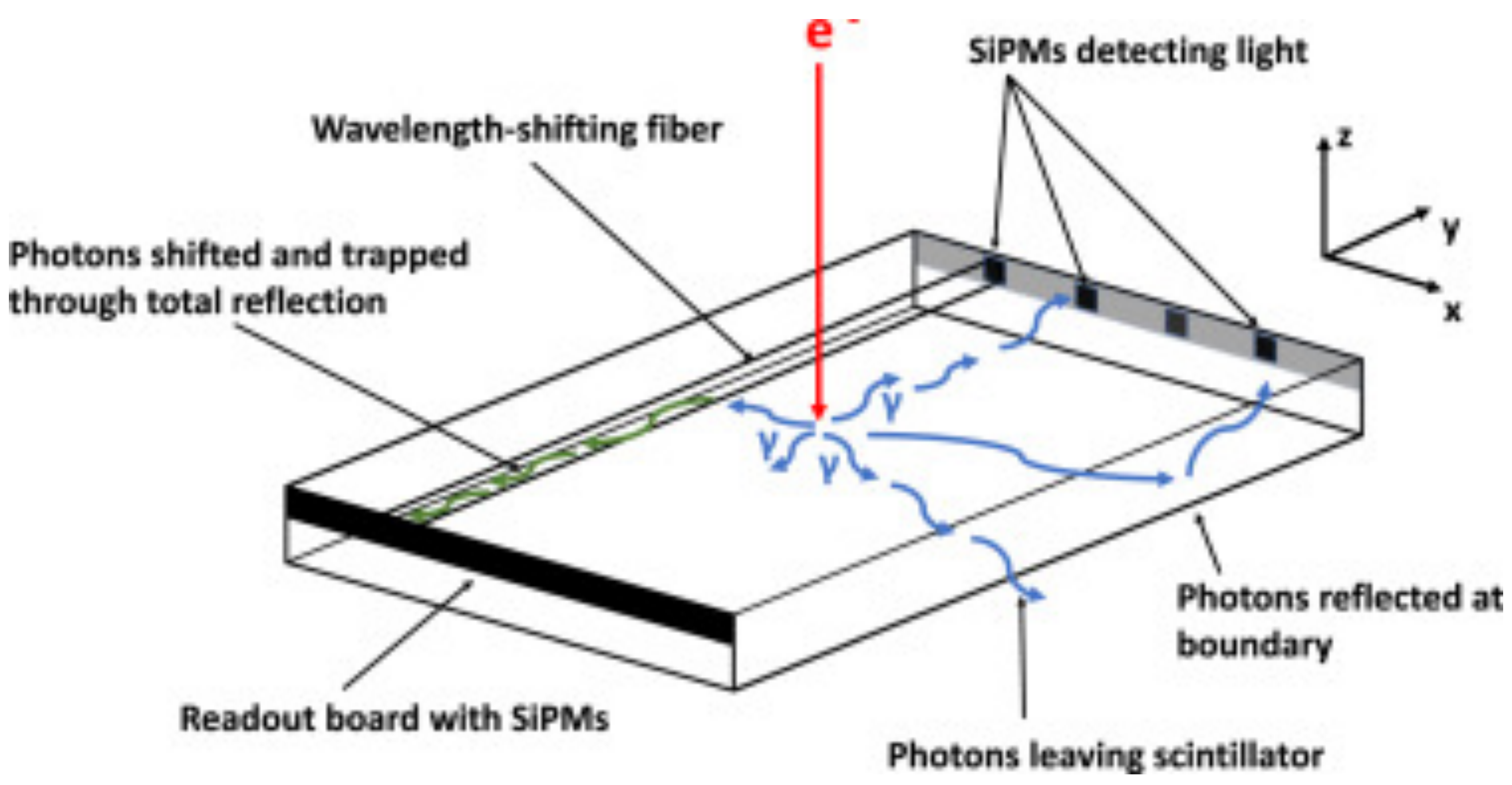
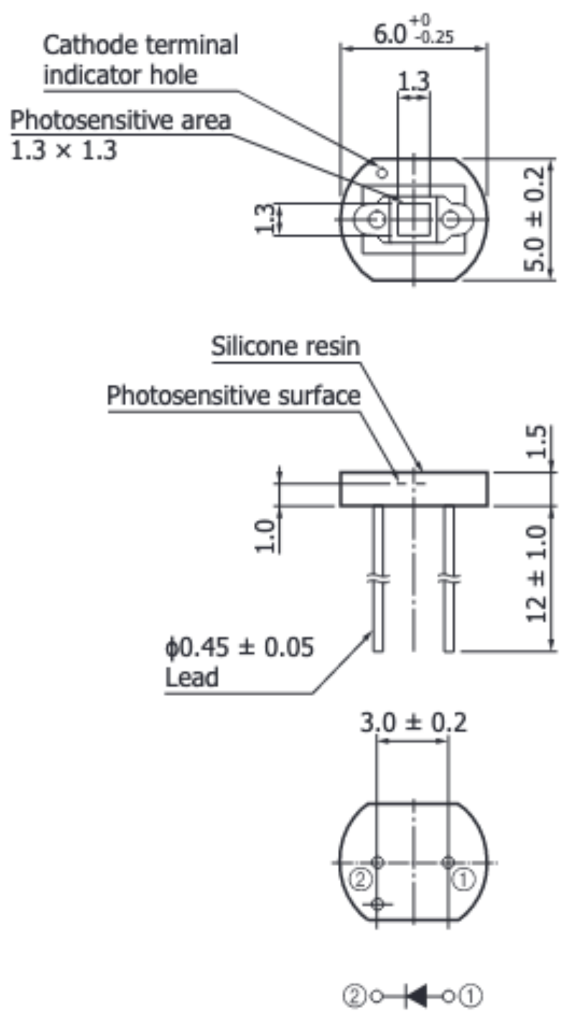
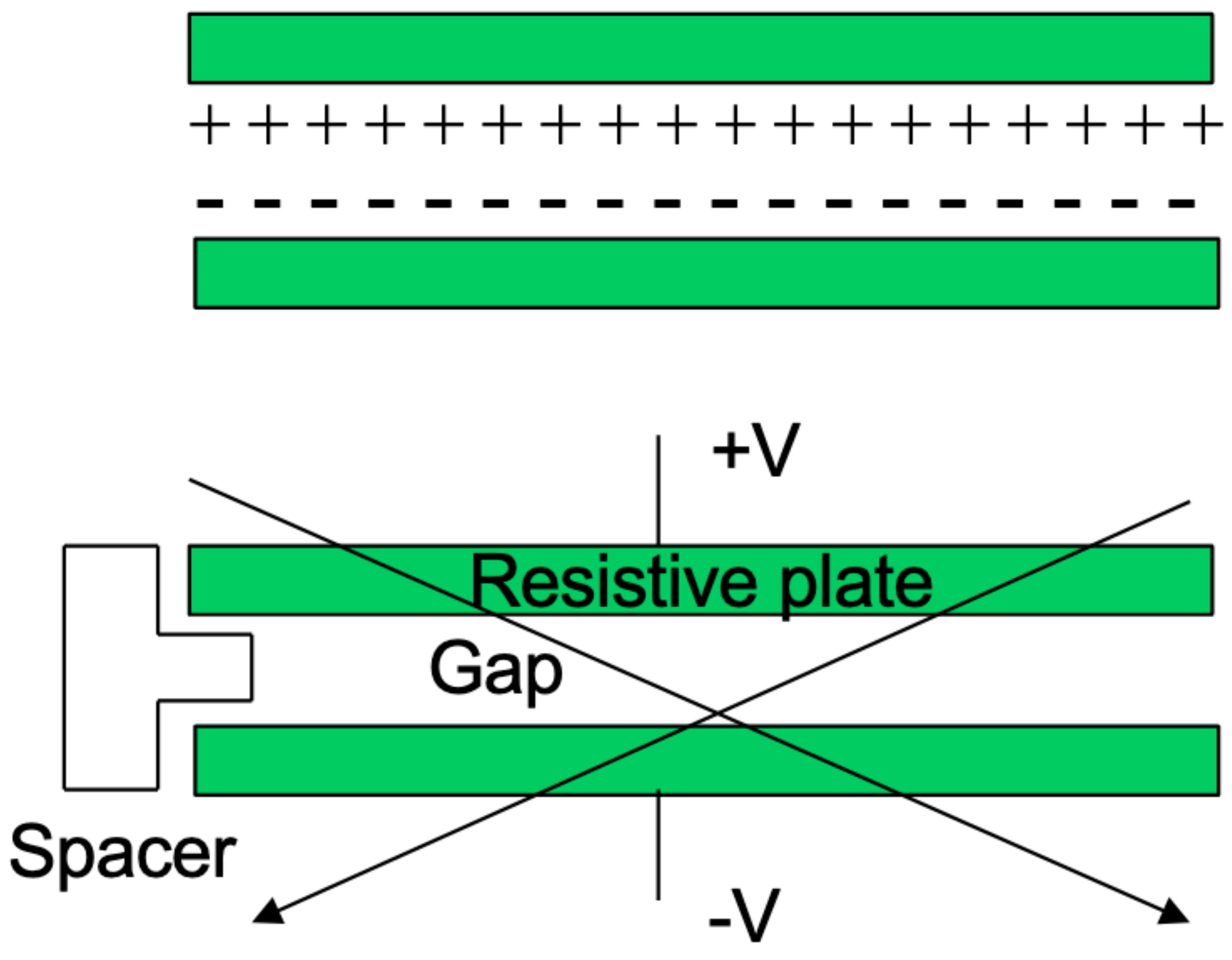
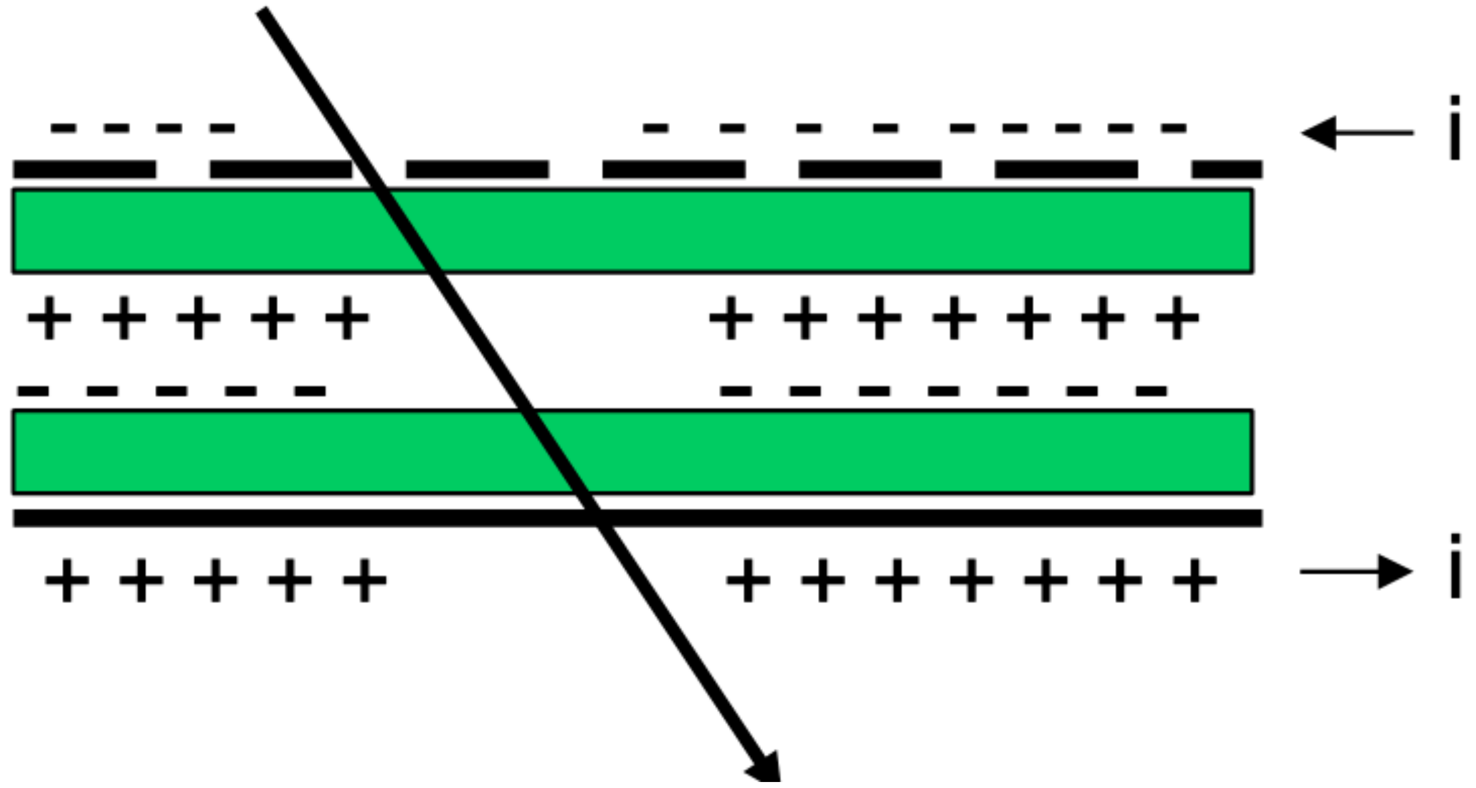


Figure taken from: NIM A 1012 (2021) 165617

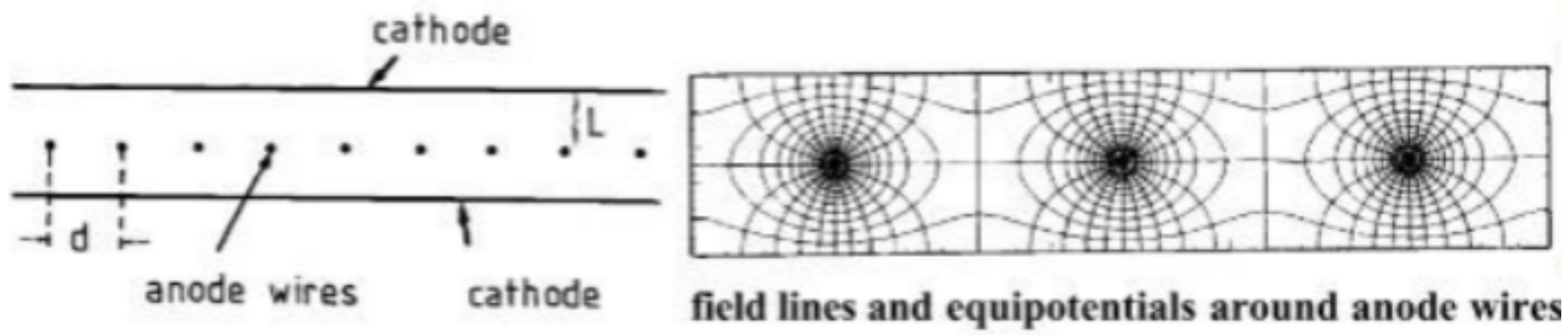
S13360 series







Plastic scintillator + SiPM for readout
(talks by Ildefonso León, Mario Rodríguez, Varlen Grabski)



MWPC (talk by Dezso Varga)

RPC (talks by Varchaswi Kashyap, Zubayer Ahammed, Saikat Biswas)

Organisation (muonID)

Physics performance + offline

Voluntarios: ¿?

- MC simulations (detector + physics performance)

Plastic scintillator and WLS fibres

Voluntarios: ¿?

- characterisation of photosensors, machine the bars, chemical reflectors, adhesive, …

RPCs (eco gases), MWPC

Voluntarios: ¿?

Mechanical structure

Electronics

Voluntarios: ¿?

- FEE **and** DAQ

In this workshop we will define responsibilities for the different tasks

Backup

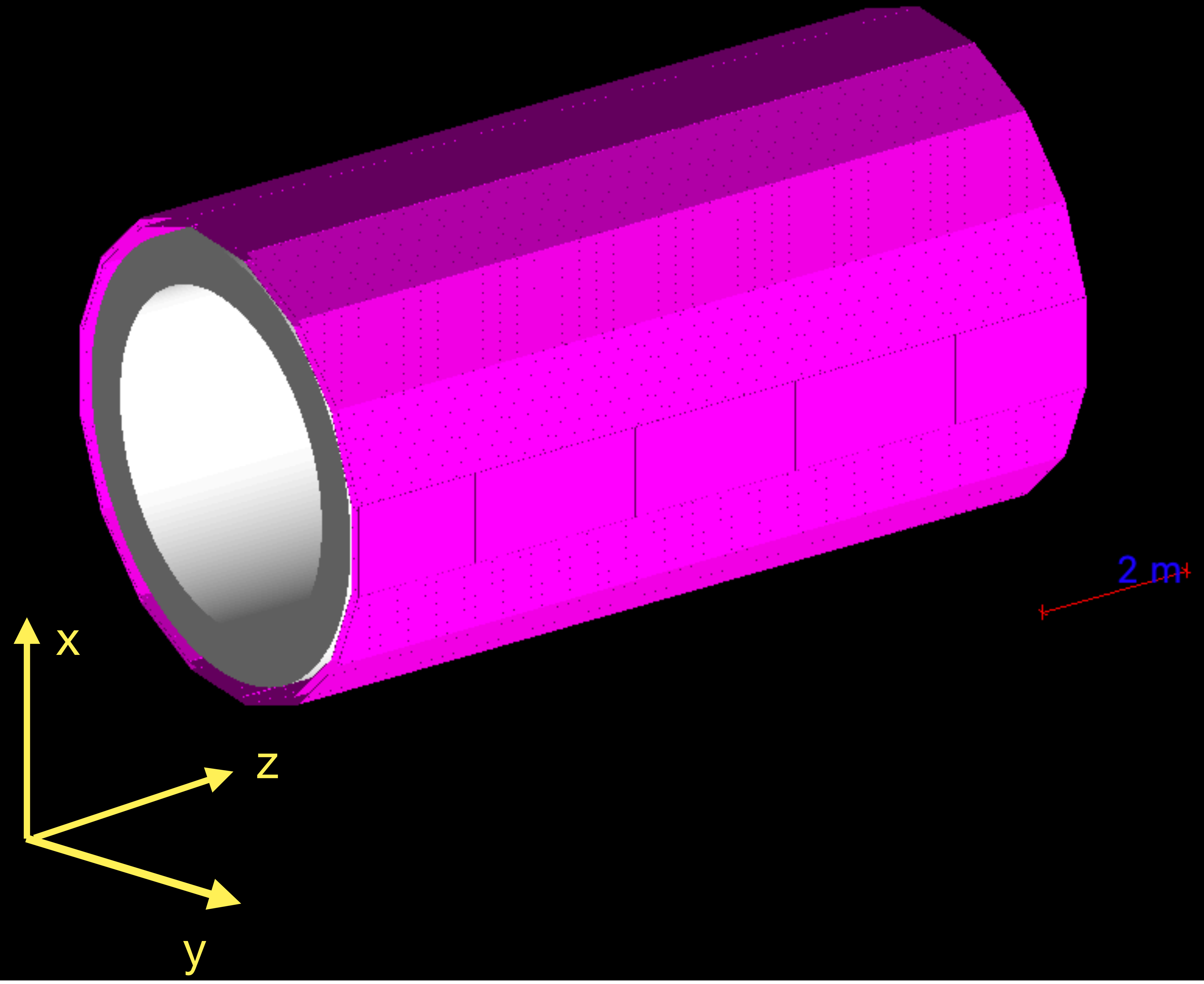
MuonID (absorber)

Absorber: $R_{\mathrm{in}} = 2.05\,\mathrm{m},\ R_{\mathrm{out}} = 2.75\,\mathrm{m},$
length: 10 m, weight: ~1kt

MuonID (chambers, example with scintillator)

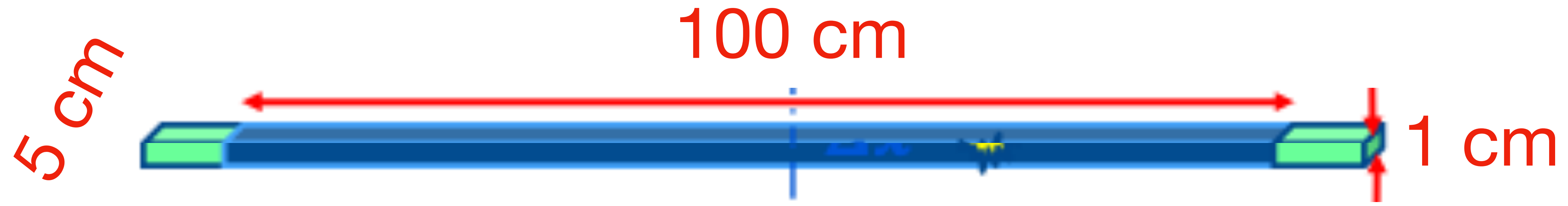
Absorber: $R_{\text{in}} = 2.05\,\text{m},\ R_{\text{out}} = 2.75\,\text{m},$
length: 10 m, weight: ~1kt

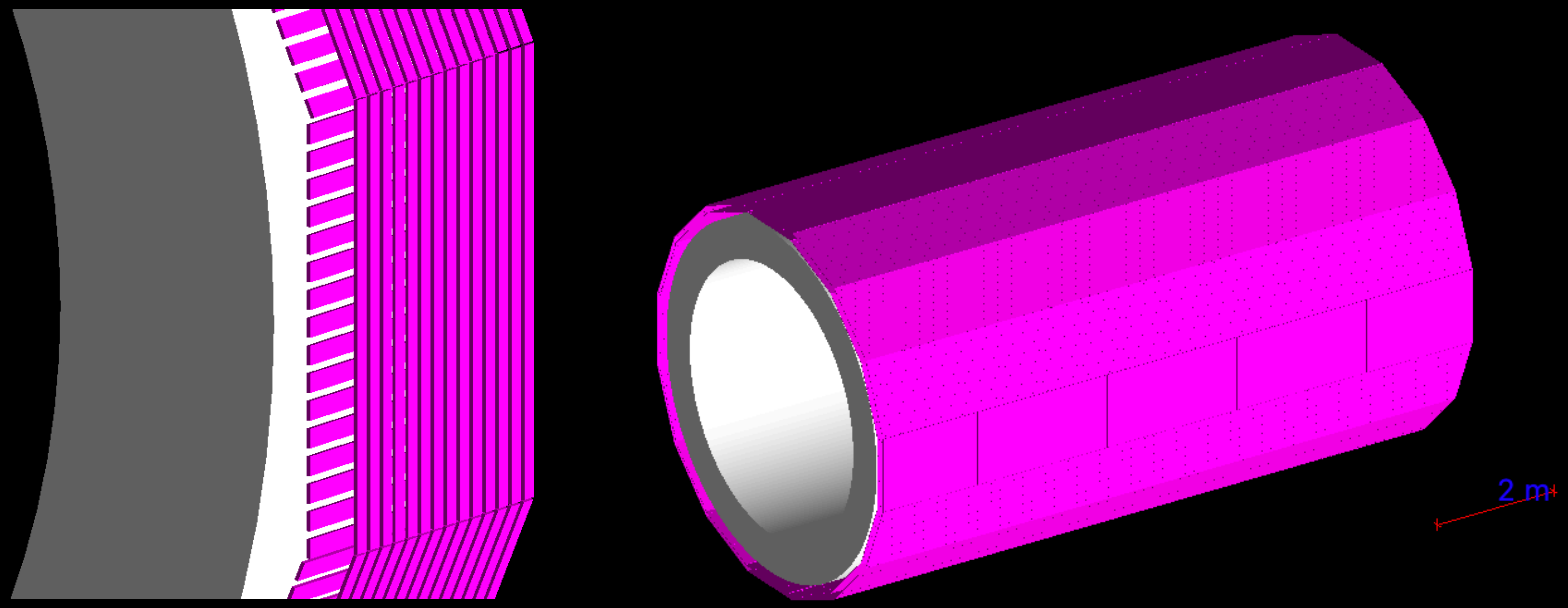
2 layers of muon chambers
Scintillator bars equipped with wave-length shifting fibres (width 5 cm, gap between layers 10 cm)



Absorber (iron)

MuonID (chambers)



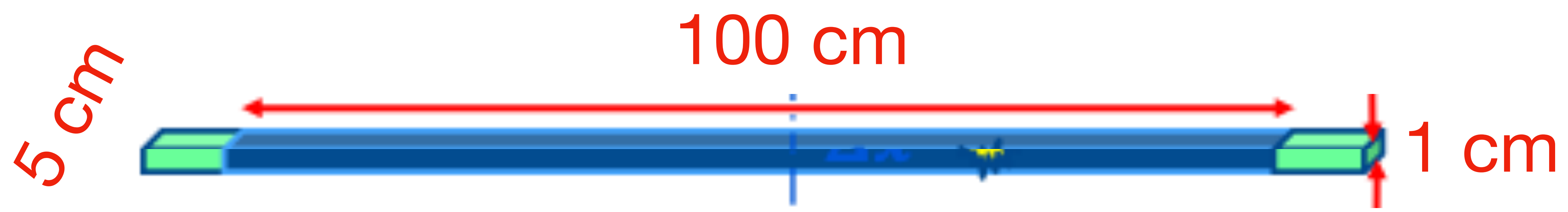


Muon chambers:

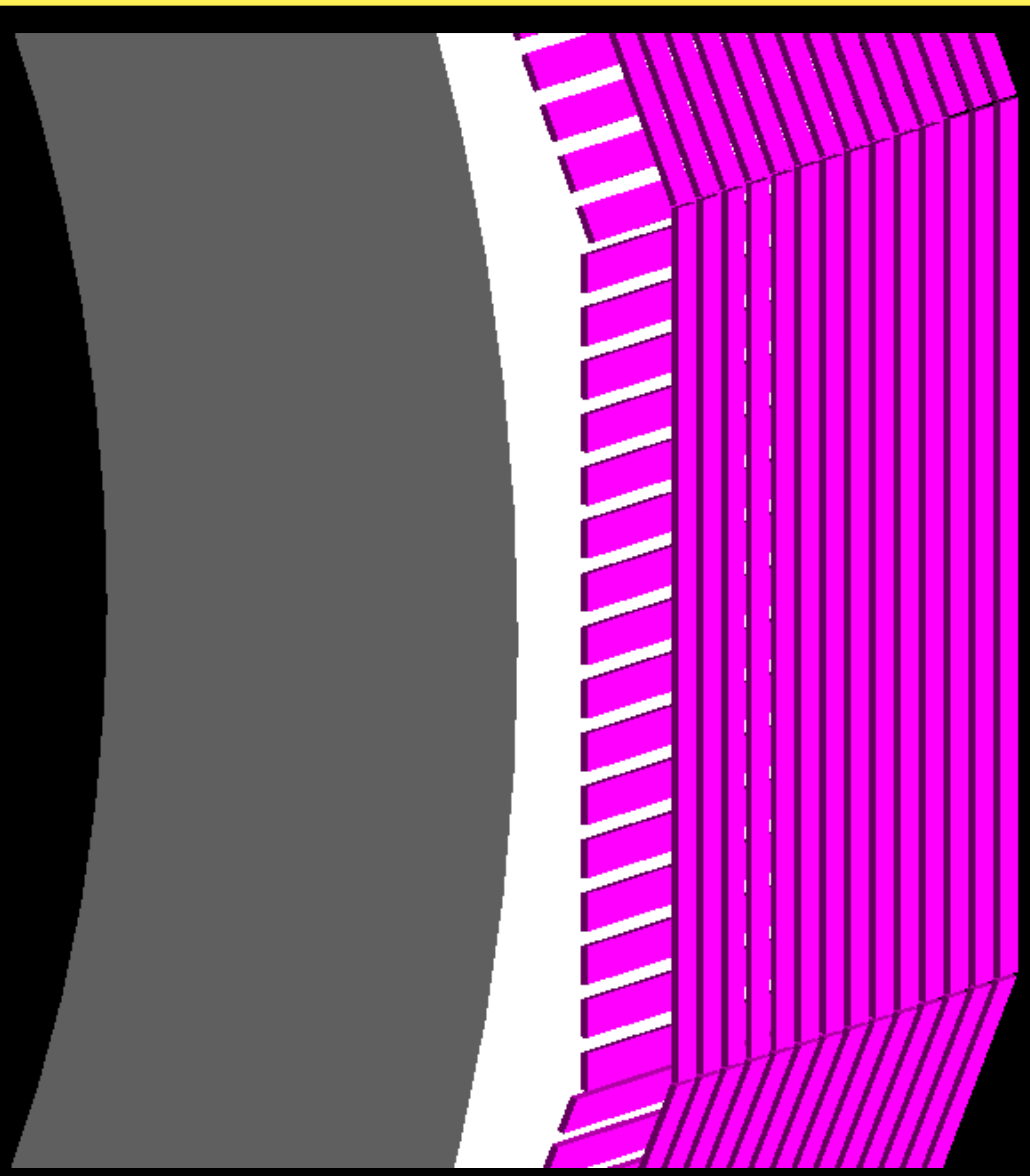
- inner layer (size of chambers 1.1x1.0m^2)
  3520 bars: w=5 cm, t: 1cm, length: 100 cm
- second layer (size of chambers: 1.15x1.0 m^2)
  3200 bars: w=5 cm, t: 1cm, length: 115 cm

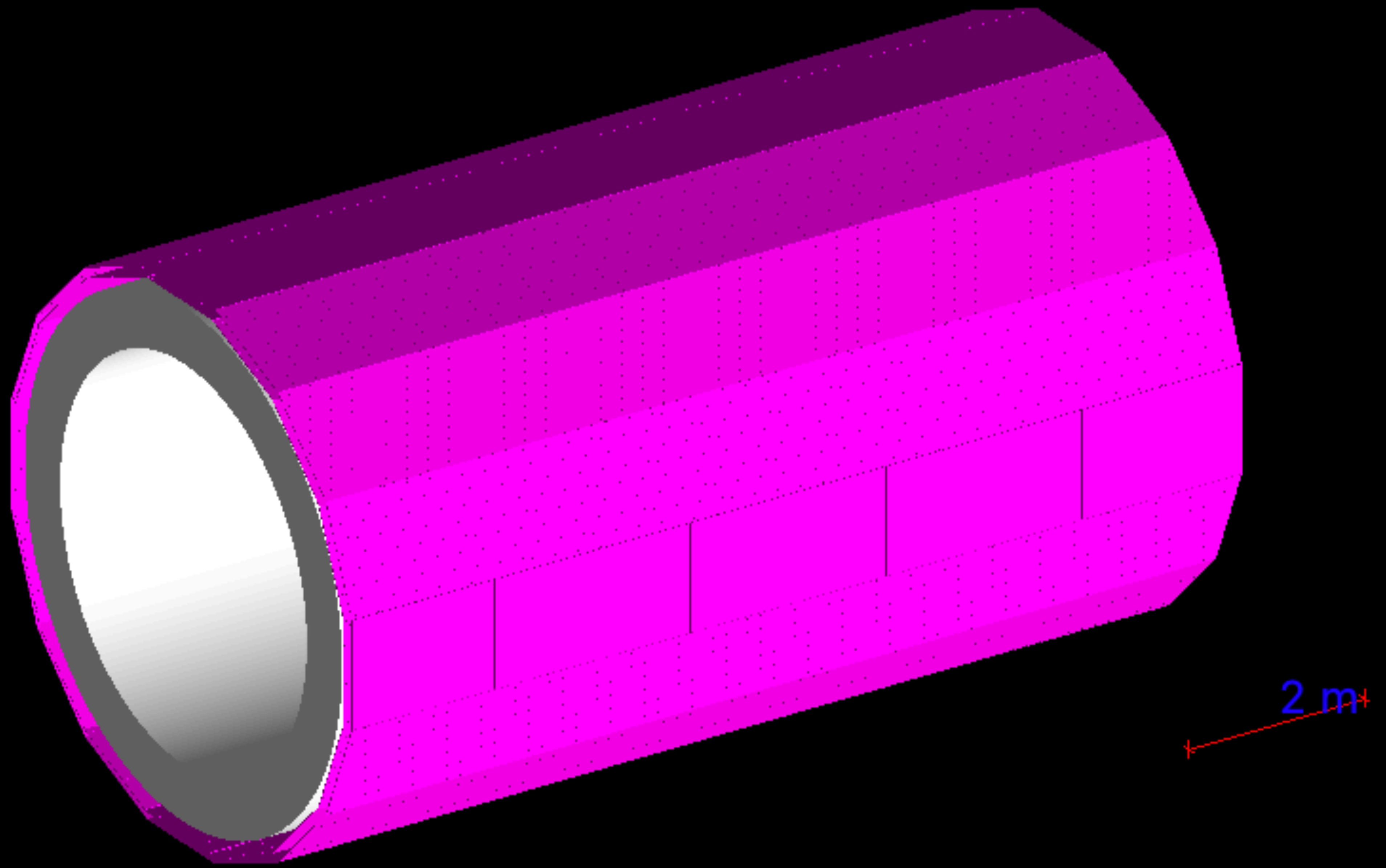
We should to cover ~360m^2 of area
Readout in both sides of bars: 13440 channels

MuonID (chambers)



We still need to consider the mechanical supports and PCBs which may slightly reduce the size of the active area





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We should to cover ~360m^2 of area
Readout in both sides of bars: 13440 channels

Timing requirements (preliminary ideas)

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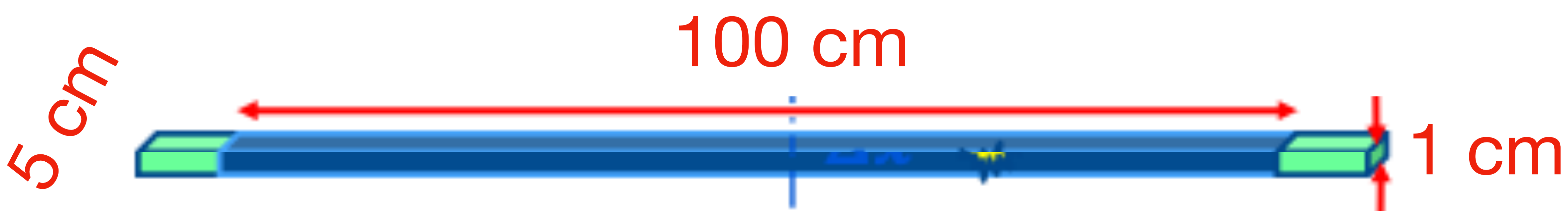
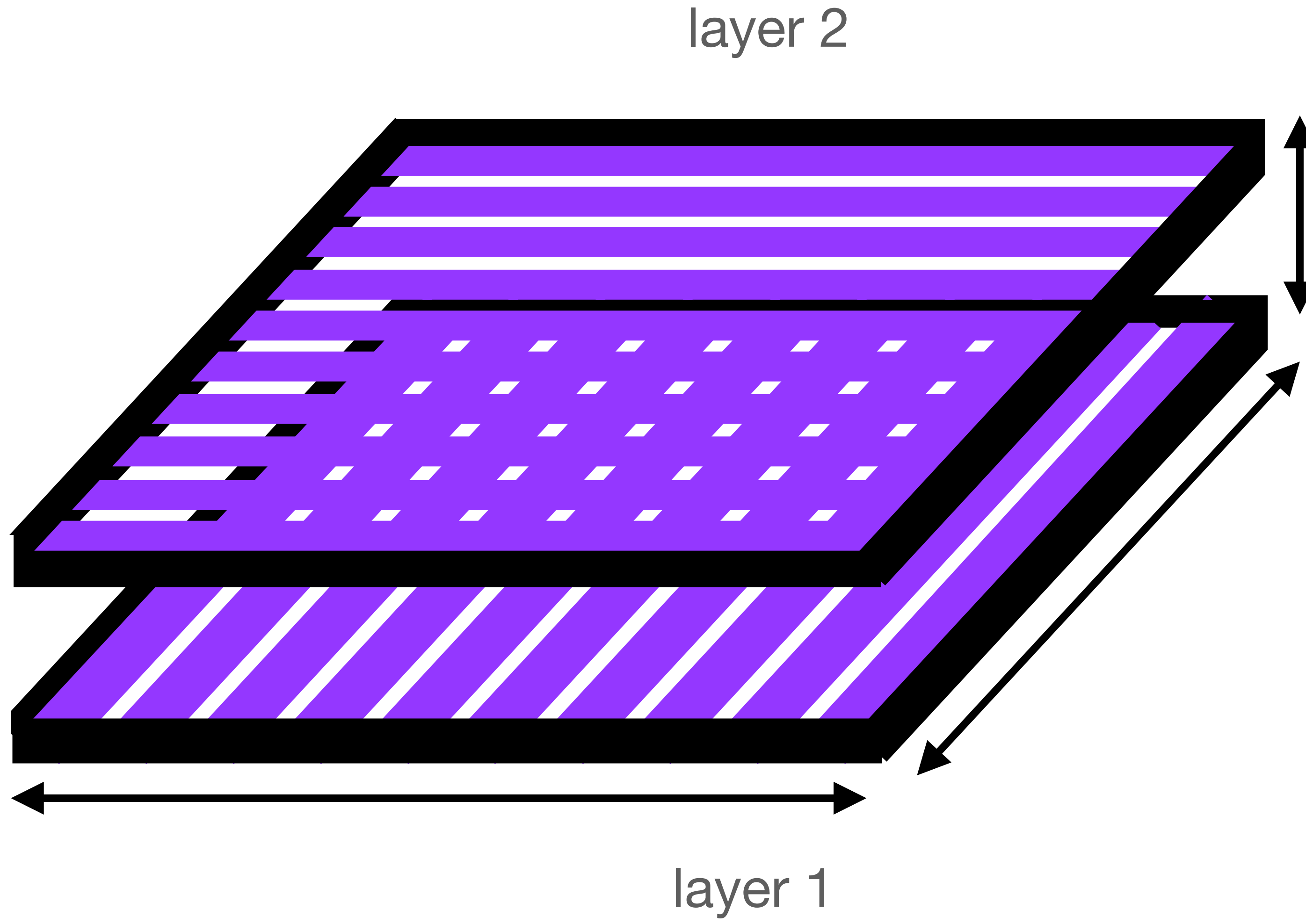
Typical time resolution of the detector (scintillator+WLS+SiPM) is of a few ns

Time information can be provided by the average of the times measured at both ends of the bars





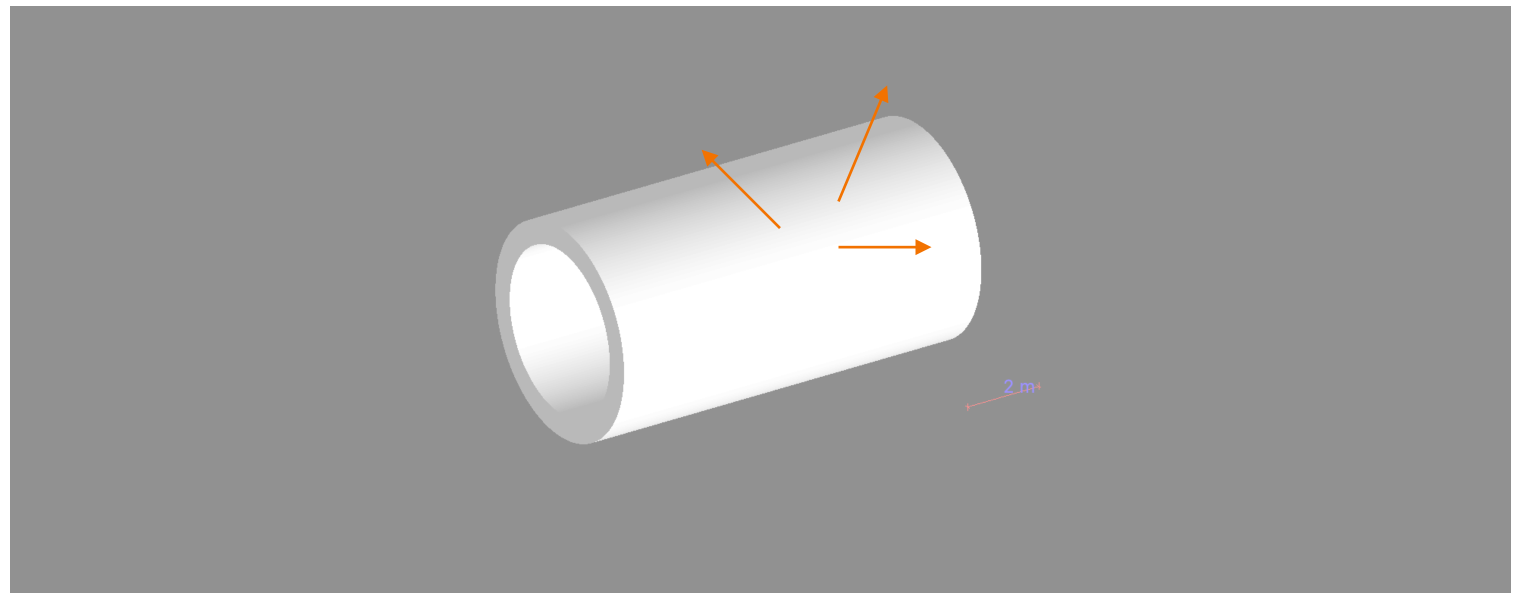
We are interested in events in which at least one bar (two channels) is activated in each layer of the muonID (keep in mind that we would have ~13500 channels). Using the centers of the fired bars a tracklet can be reconstructed

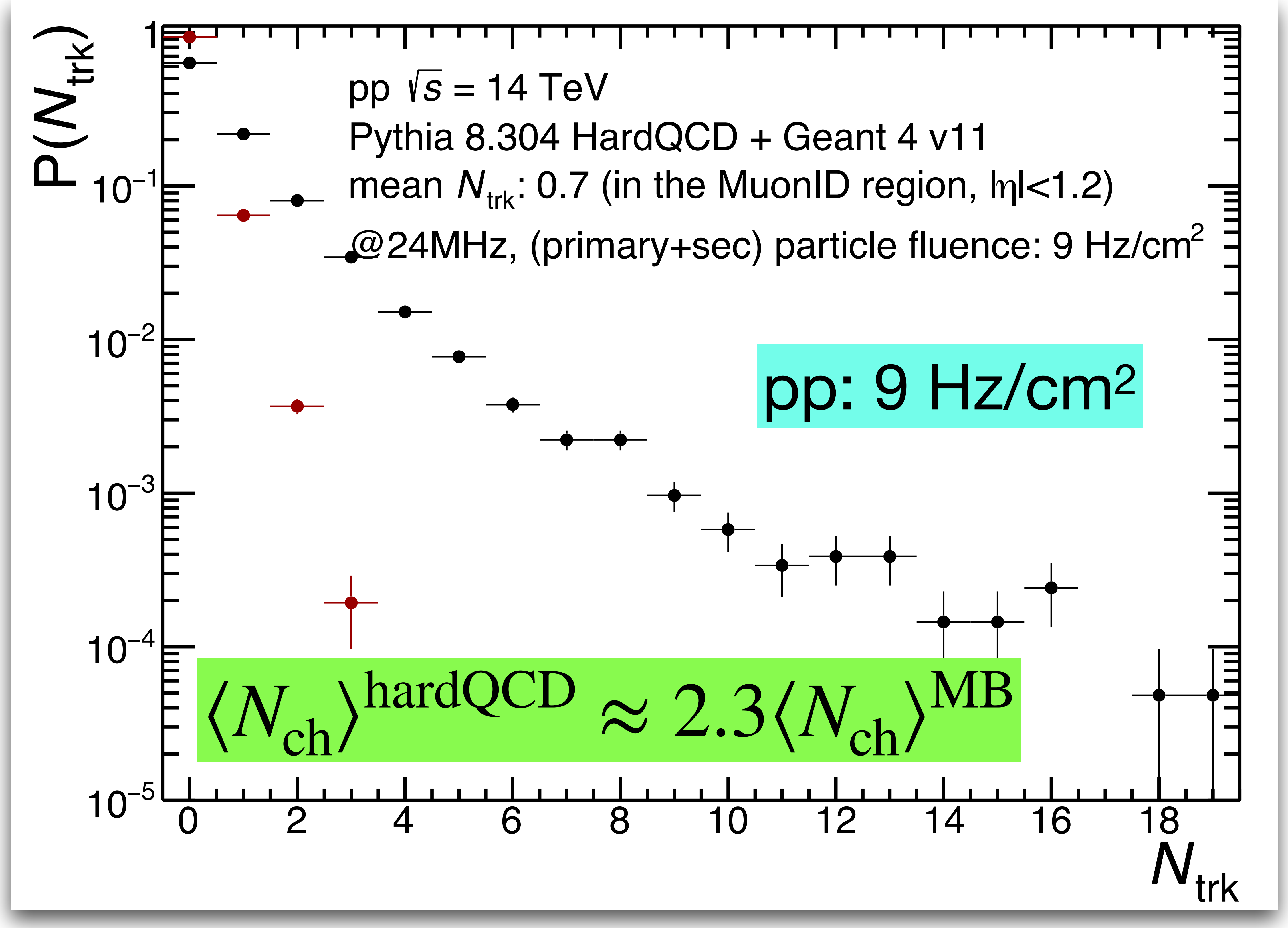
Since we will match muonID tracklets with tracks, maybe we can aim at a detector readout time of ~100 ns

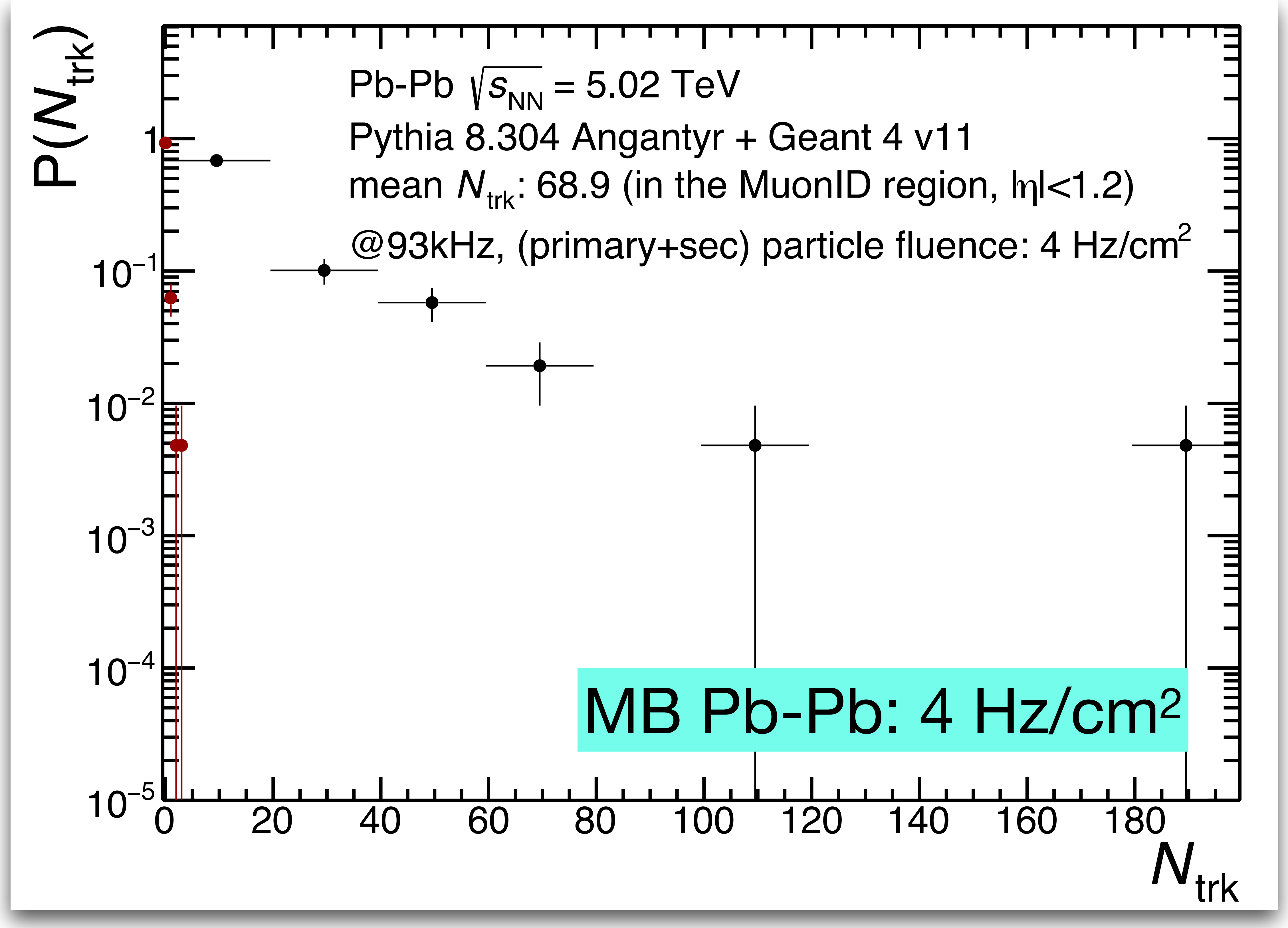
Particle fluence in the muonID region

Primary particles which were not filtered by the absorber

Secondary particles can be produced in the absorber

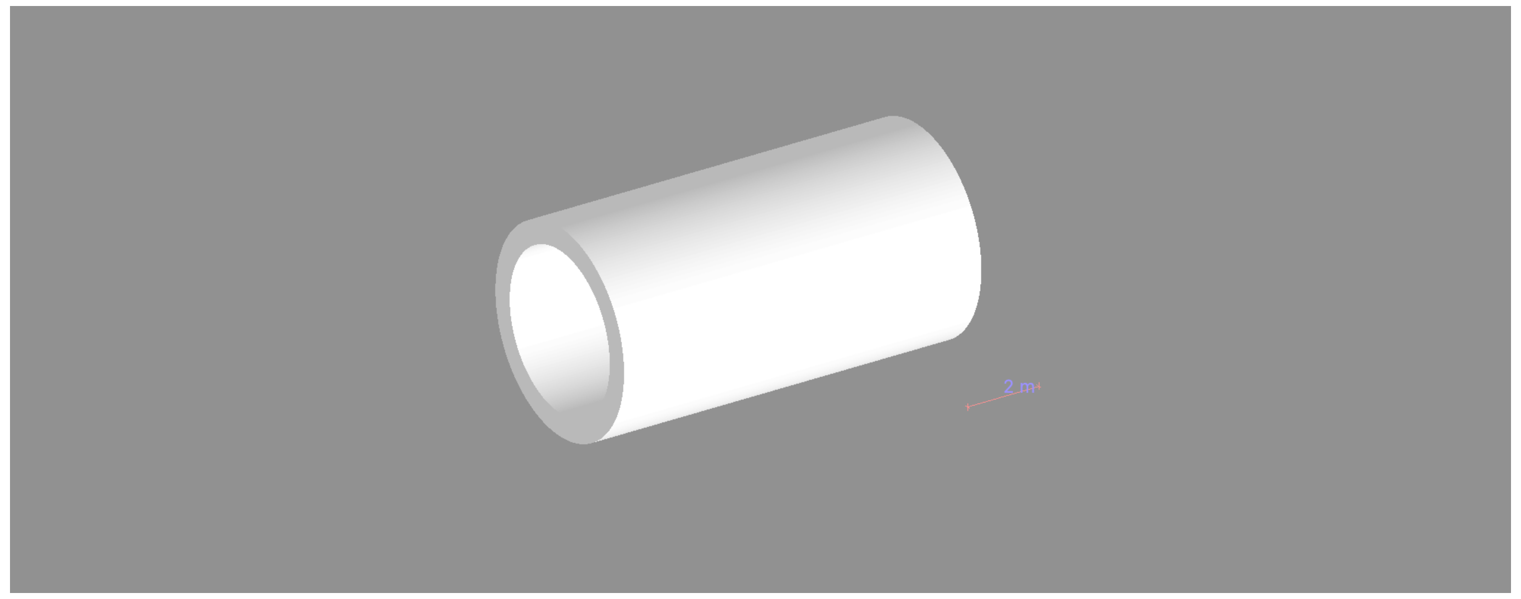


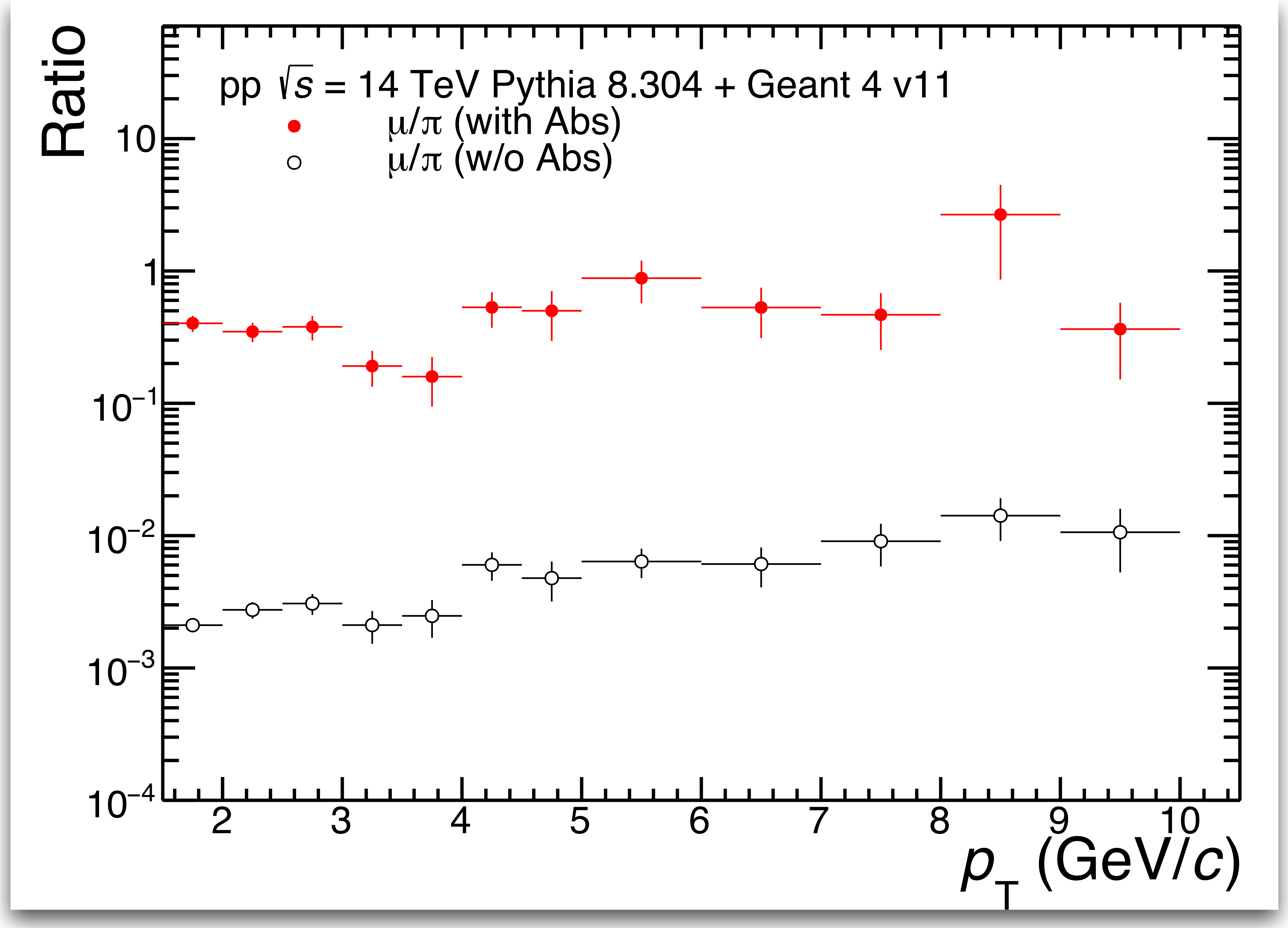


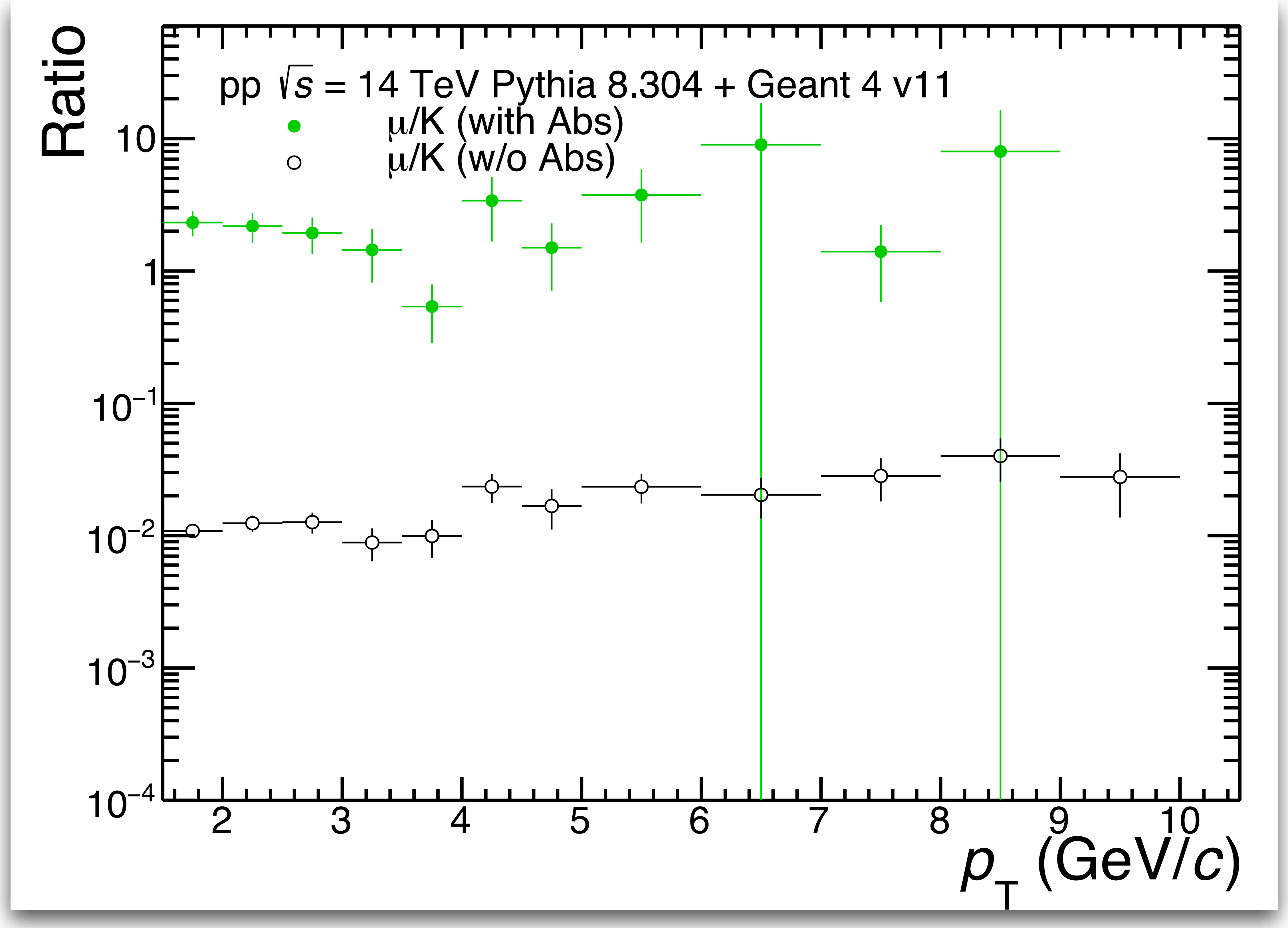


Rejection factors (just due to absorber)

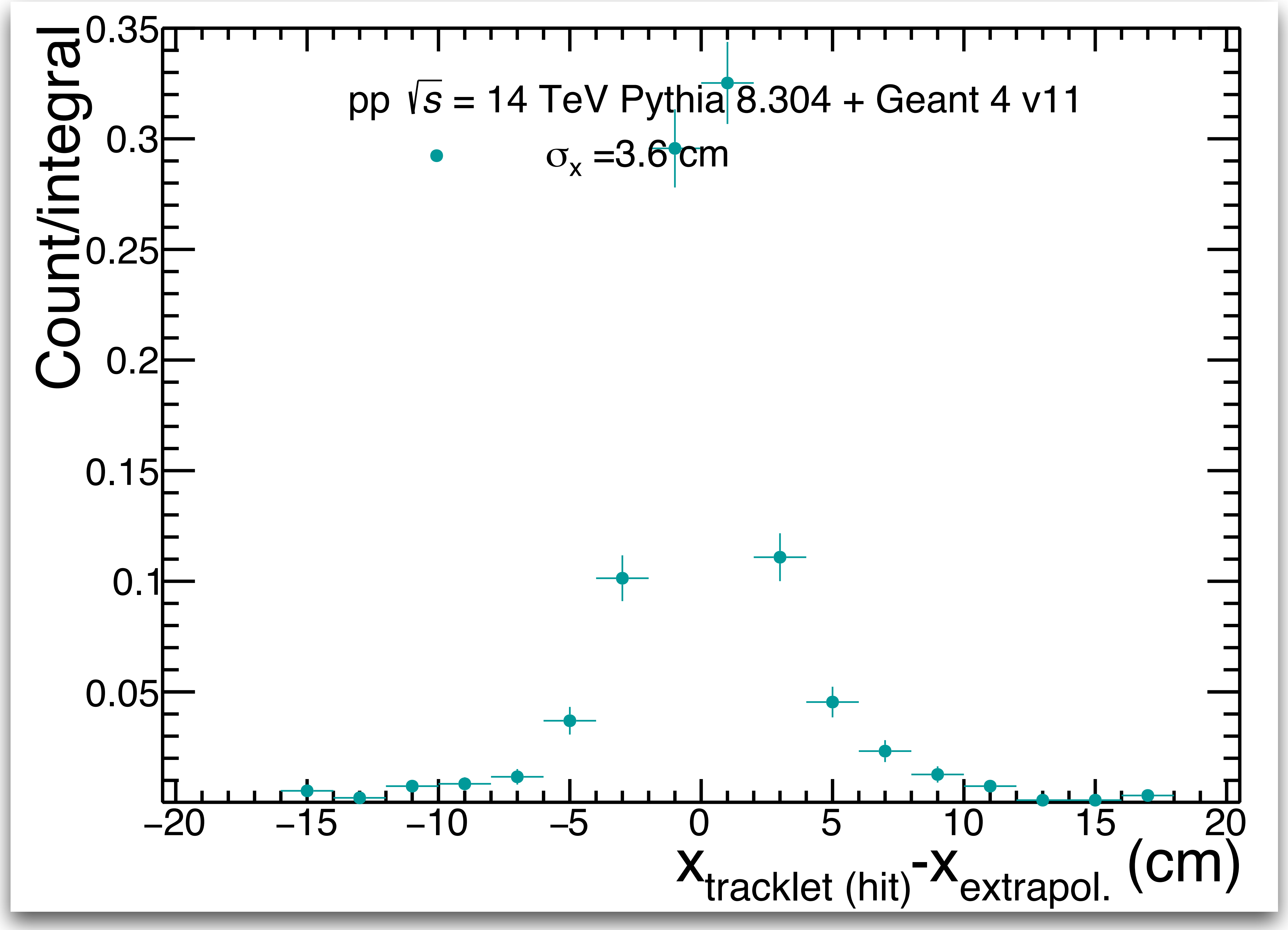
Only primary particles which reach the muonID region are considered, rejection factors between 50-100% are seen

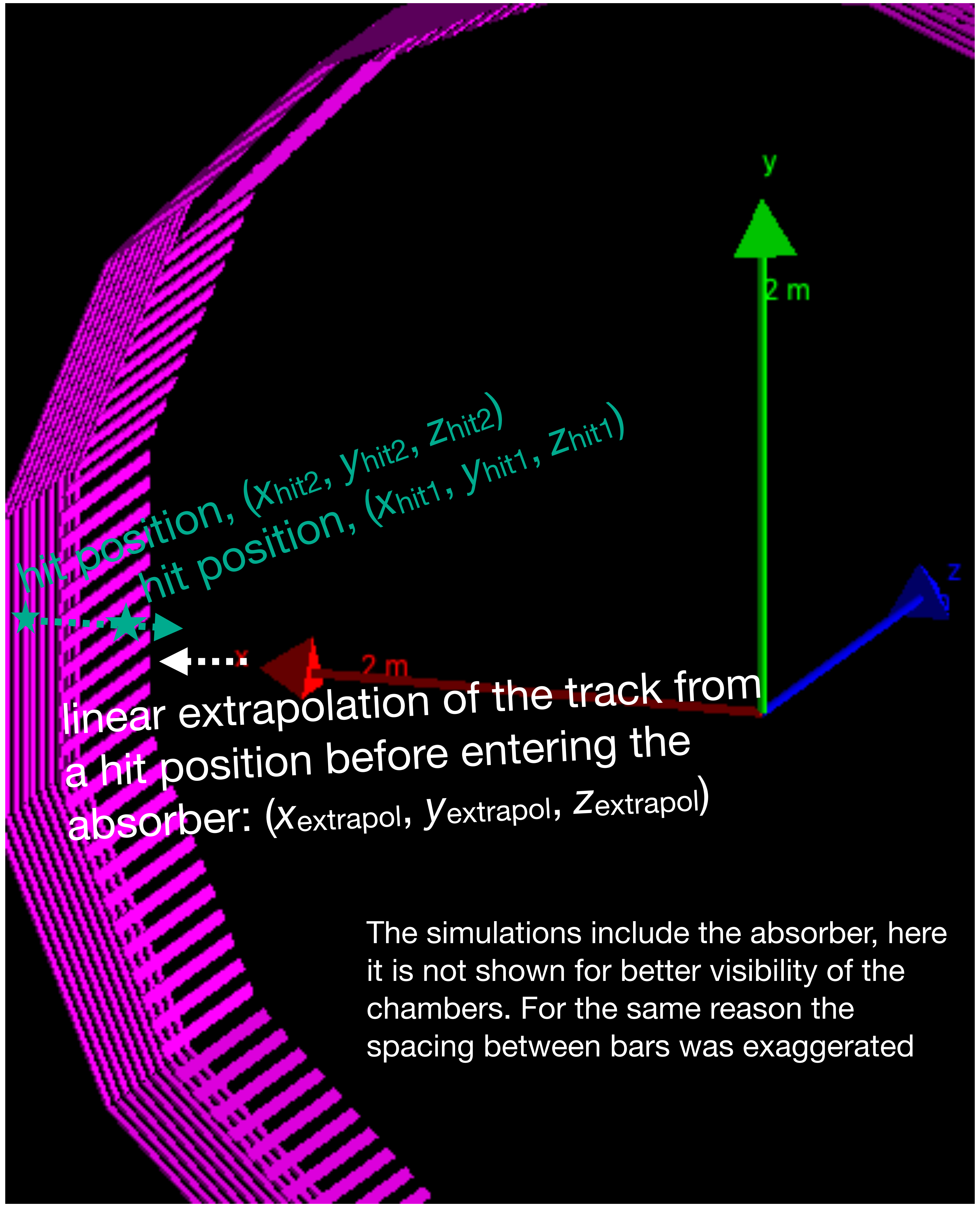




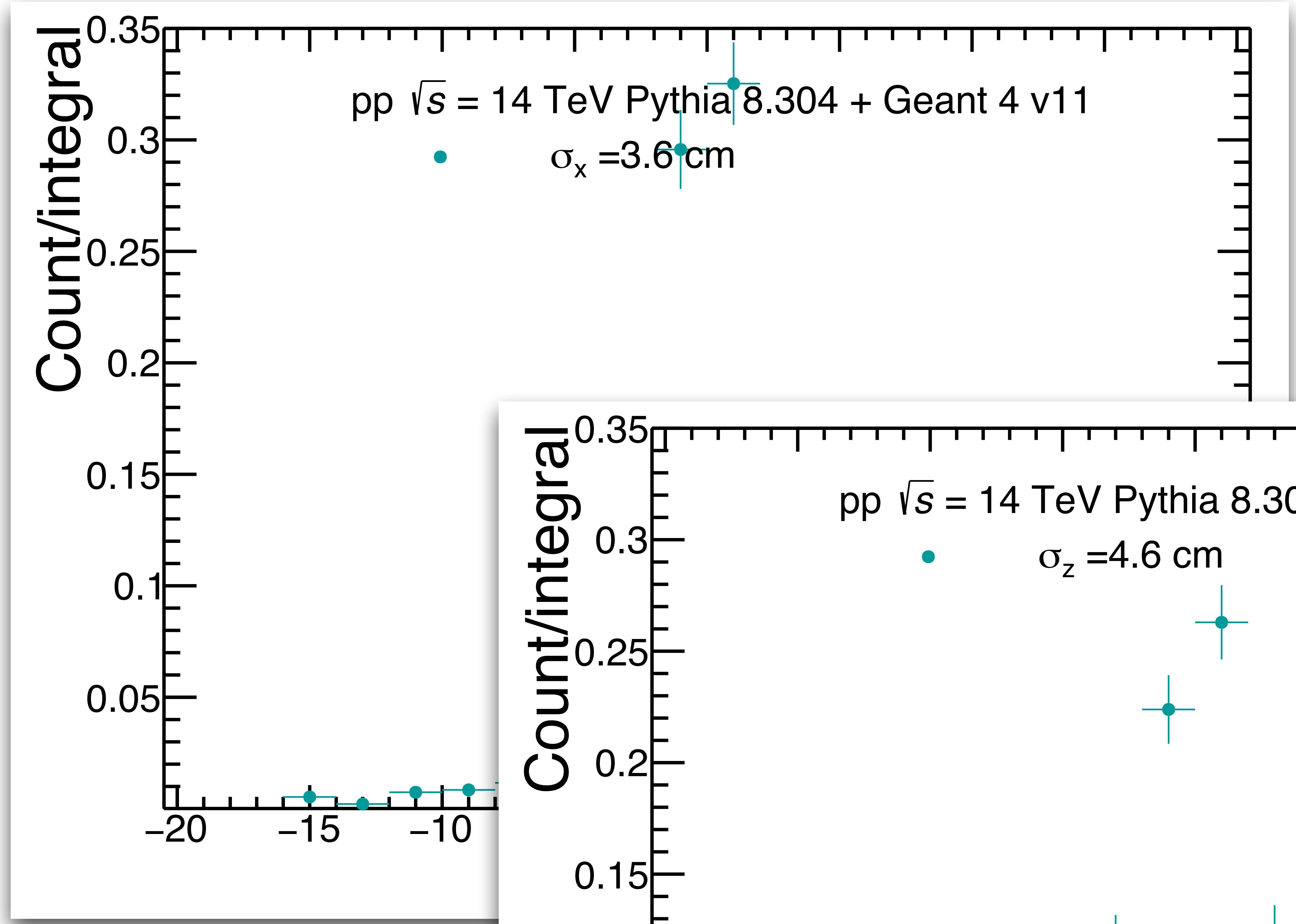


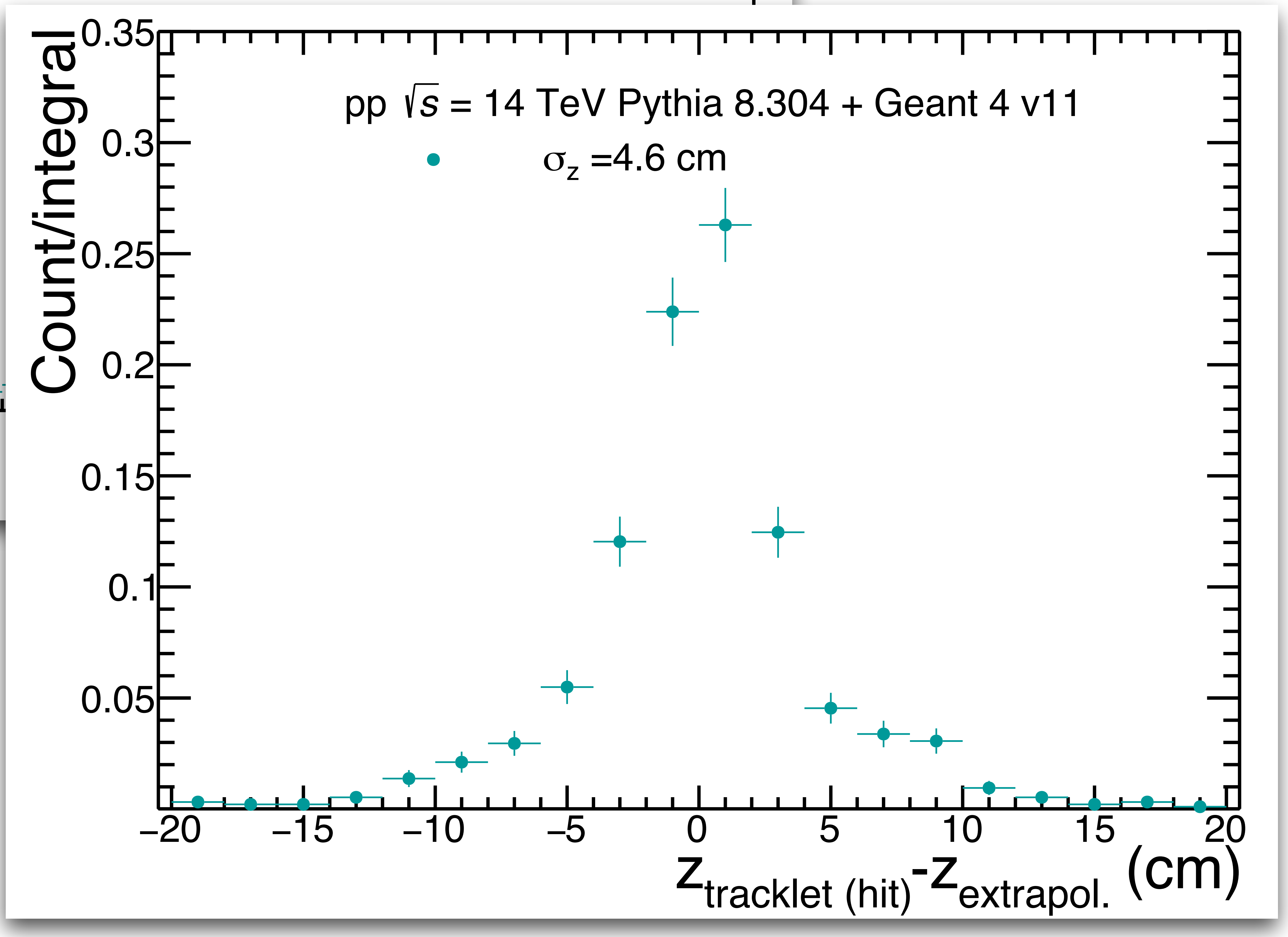
Tracklets from hits (ideal case)

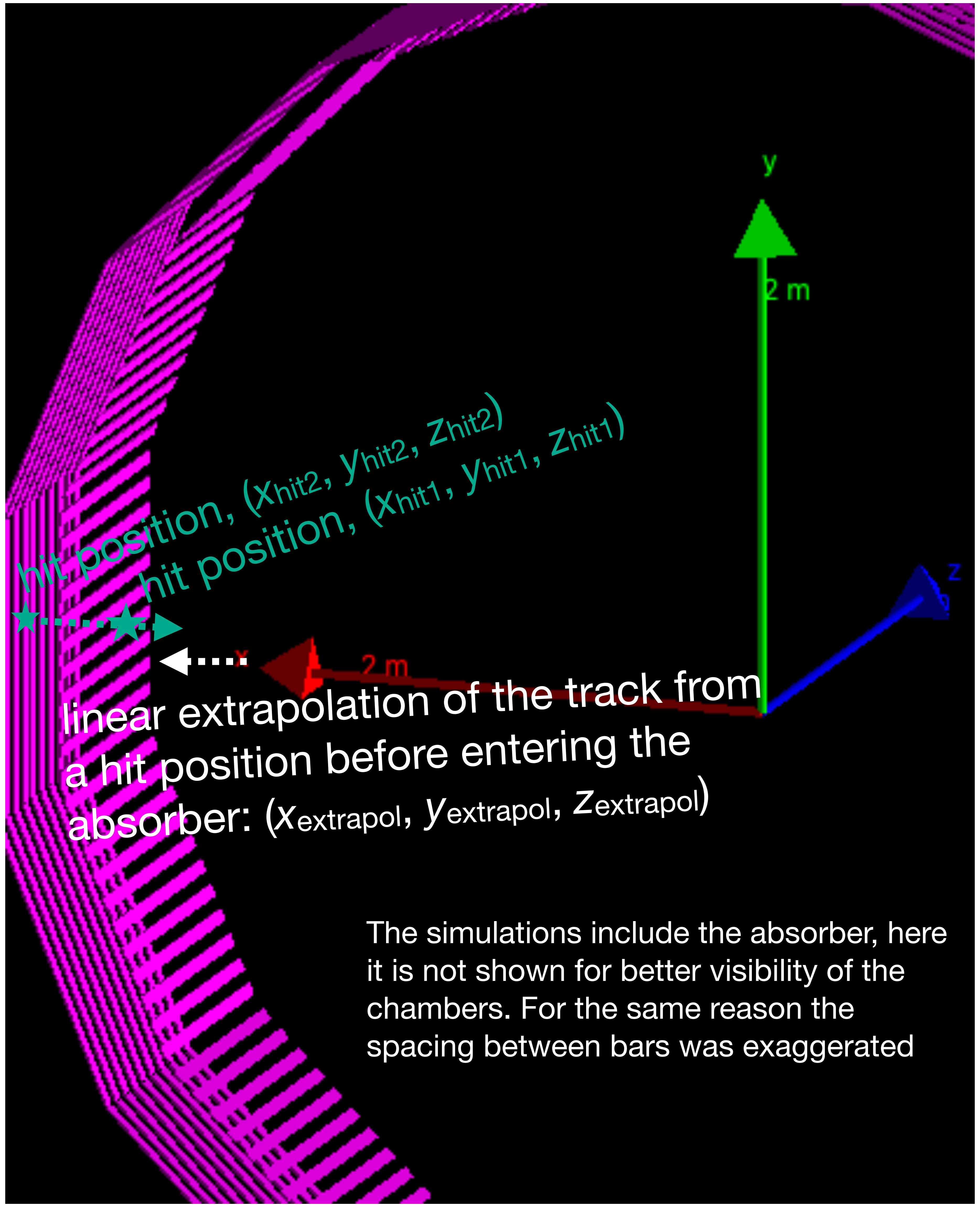




Tracklets from hits (ideal case)

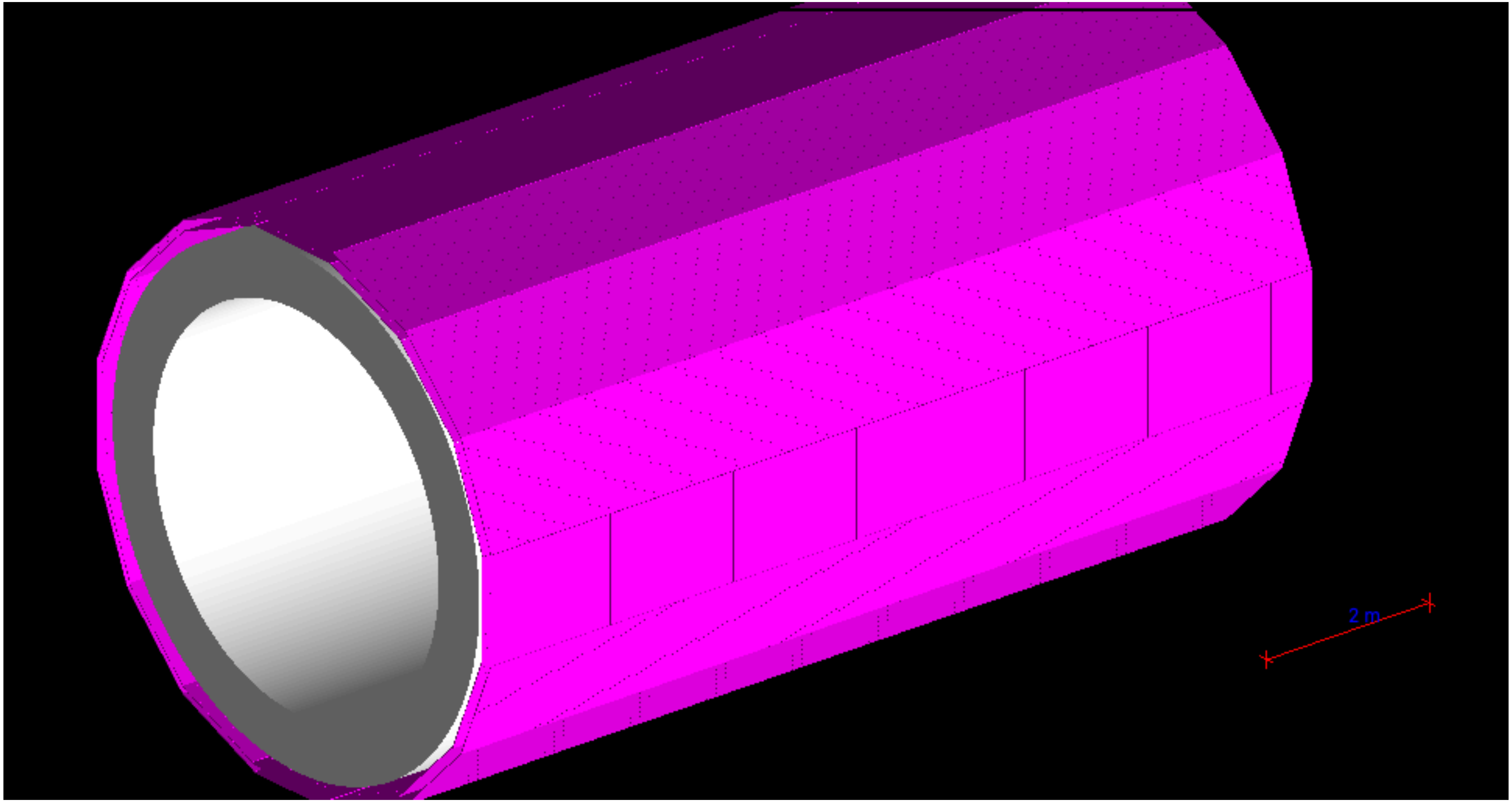






Backup

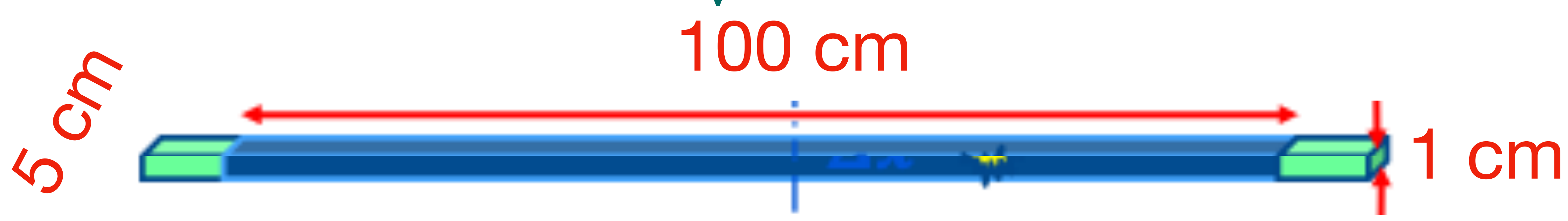
Muon chamber (baseline option)

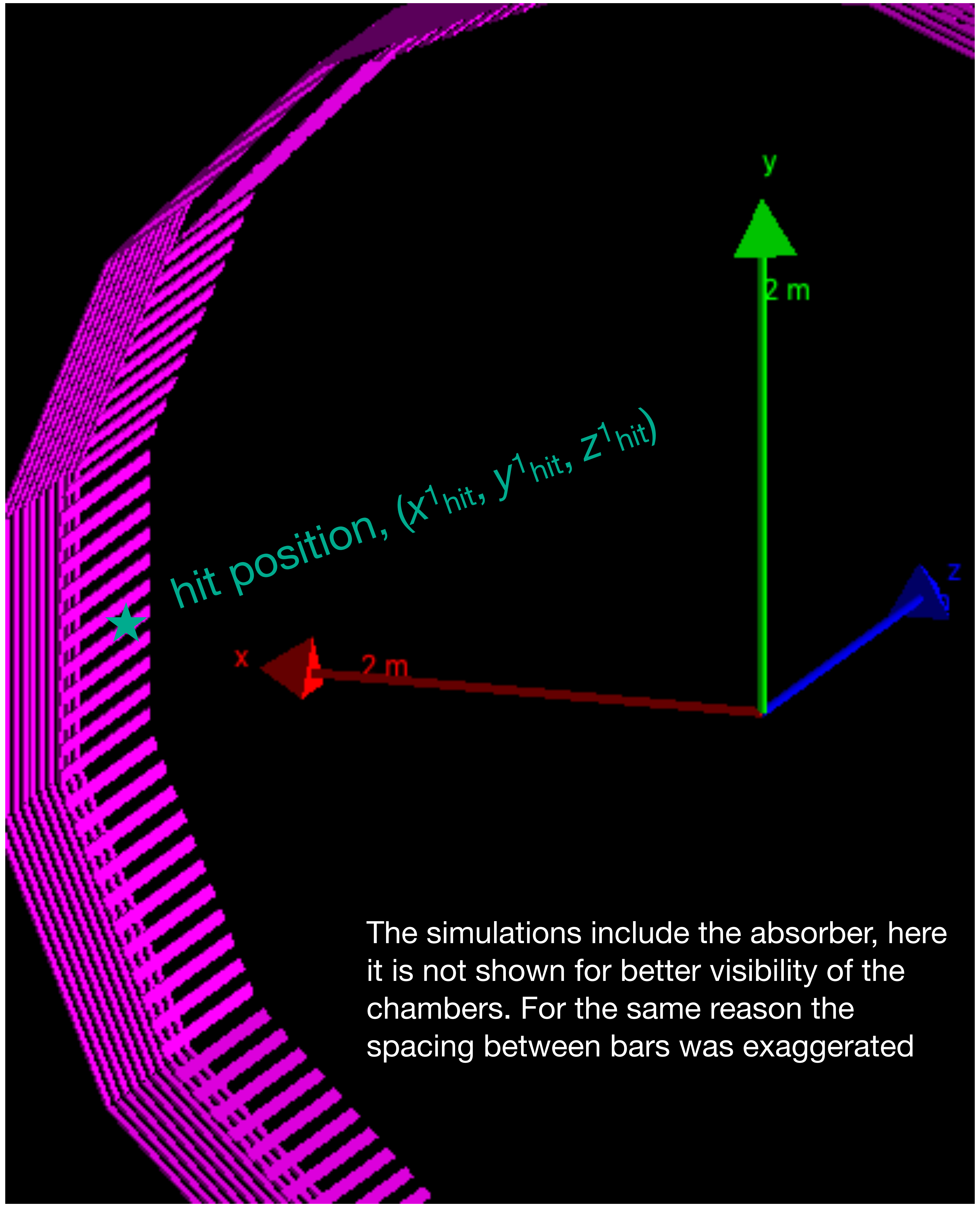


Spatial resolution

Bar width: 5 cm,

expected resolution ~ $5\,\mathrm{cm}/\sqrt{12} \approx 1.4\,\mathrm{cm}$





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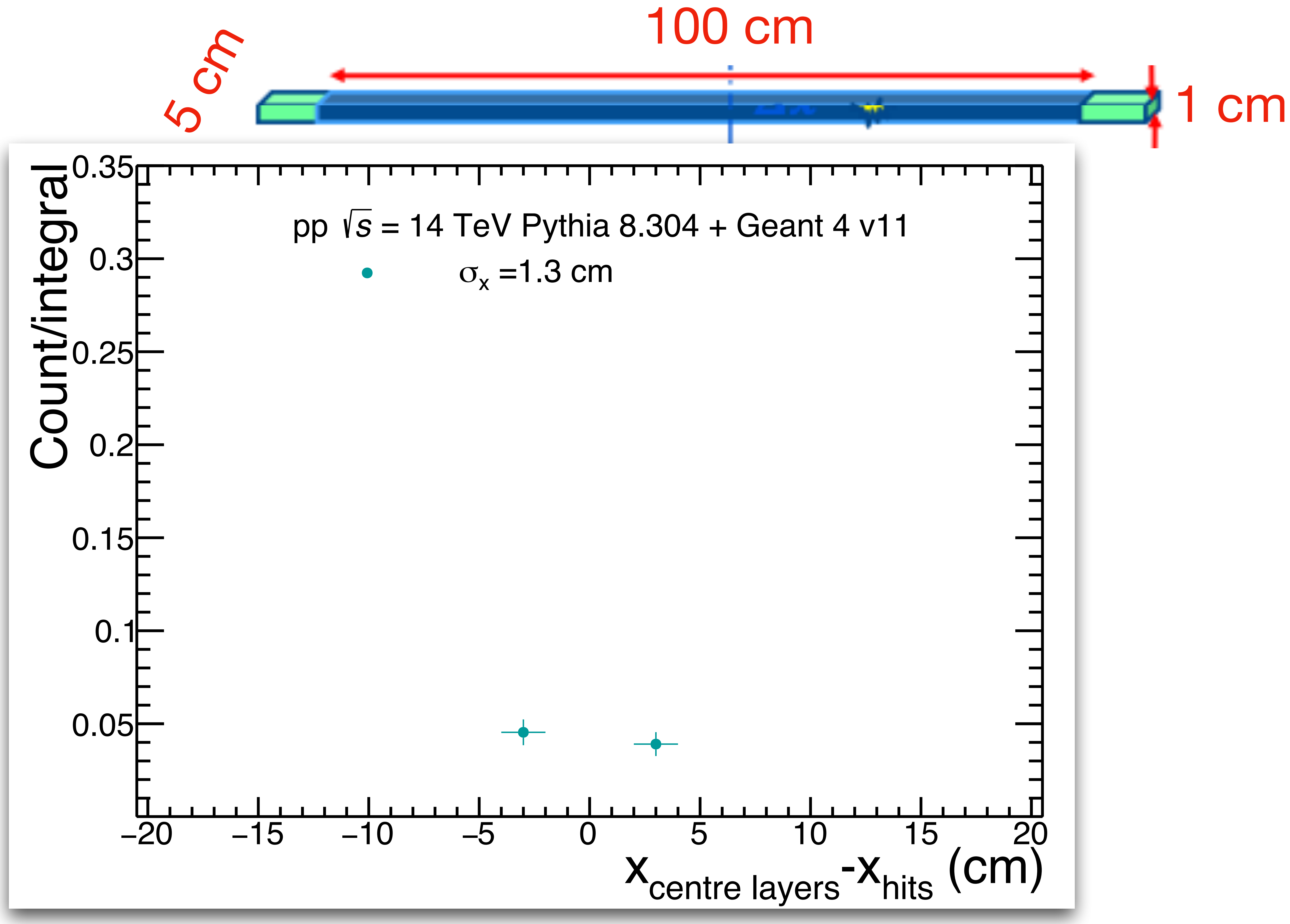
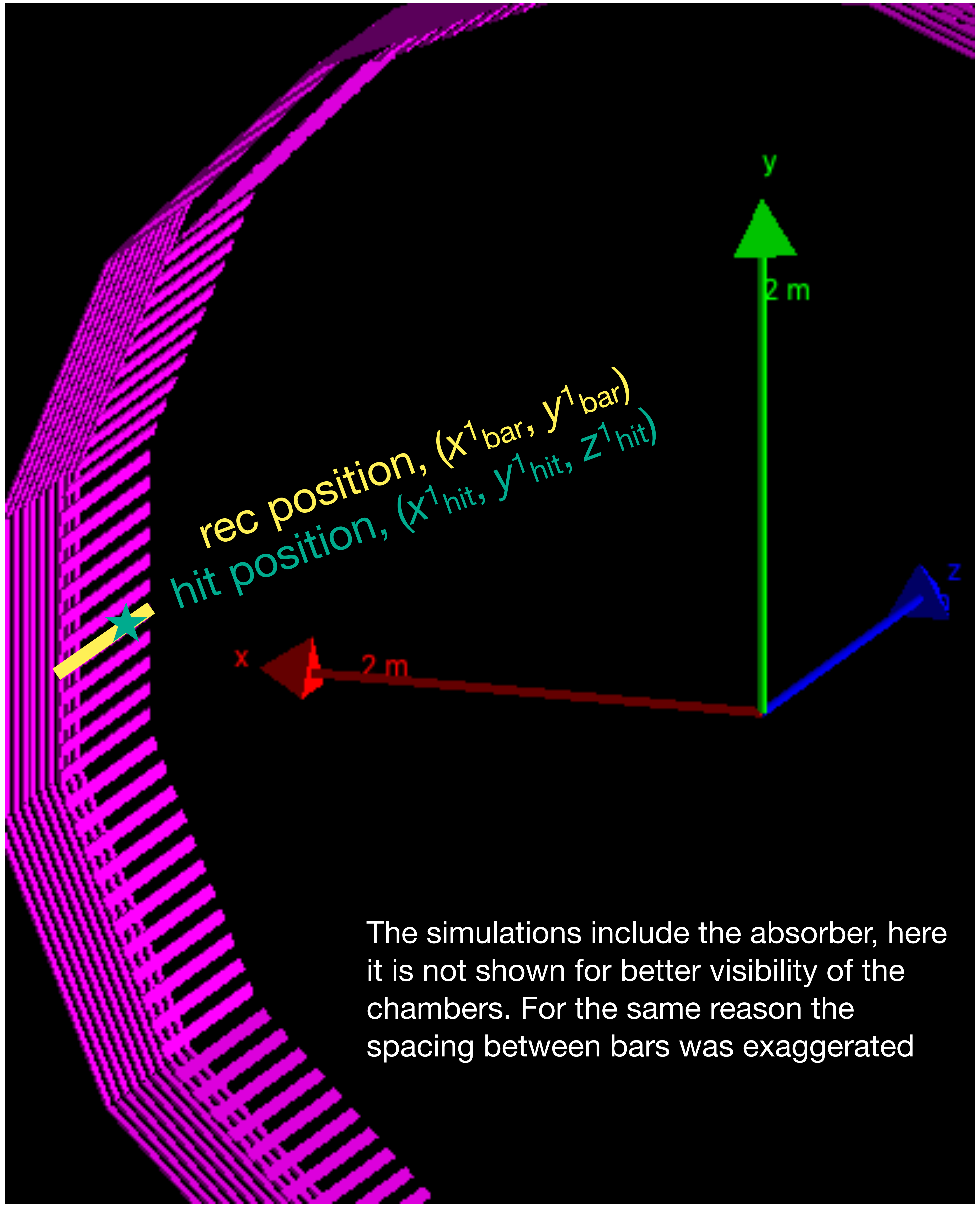
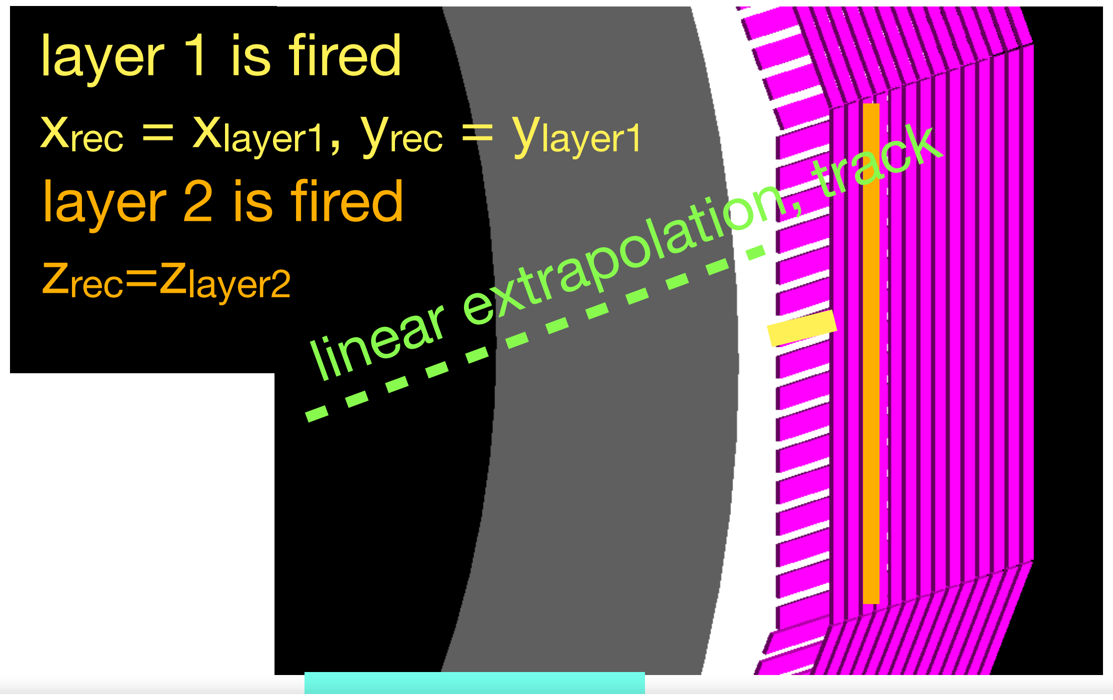
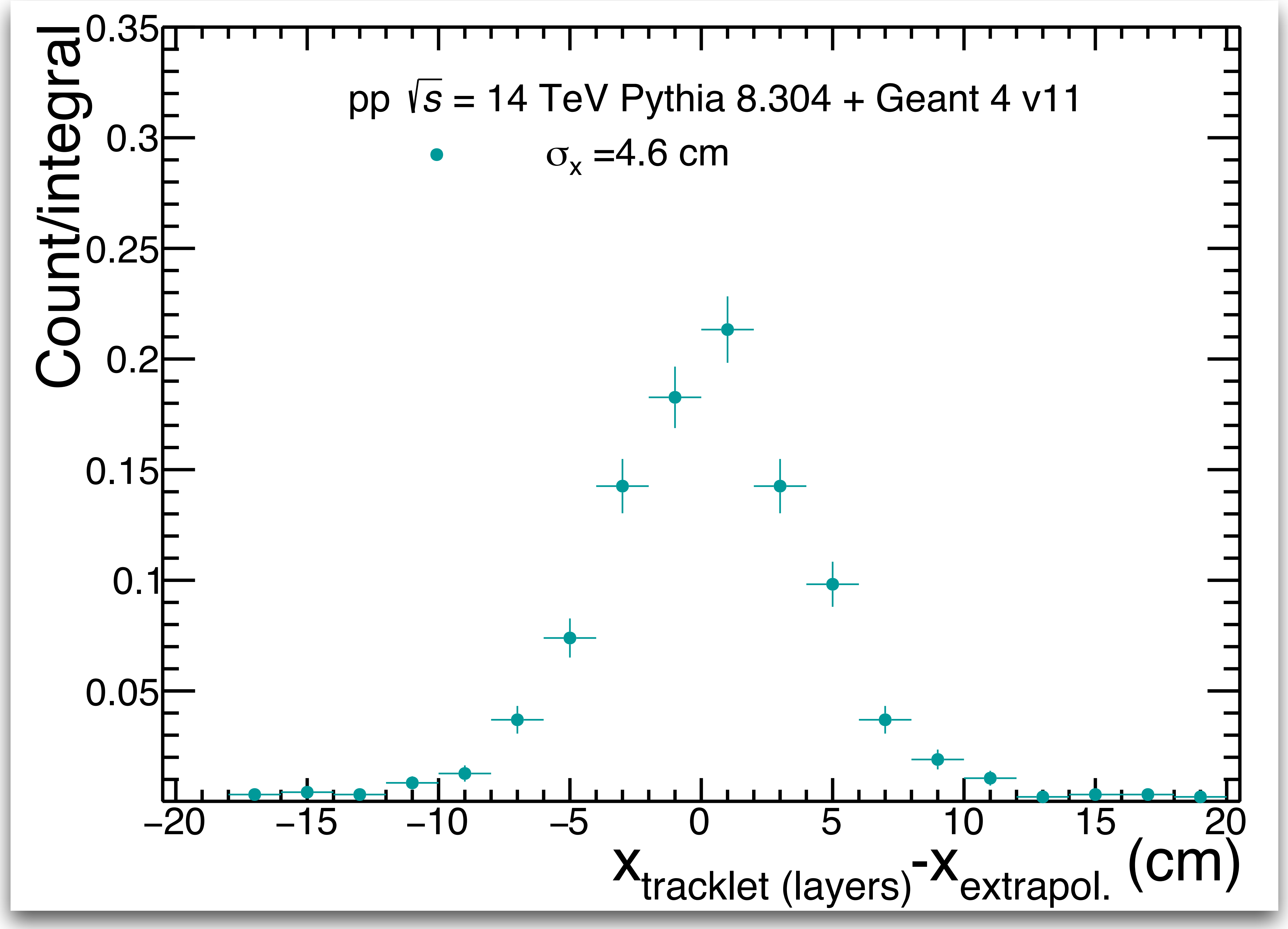


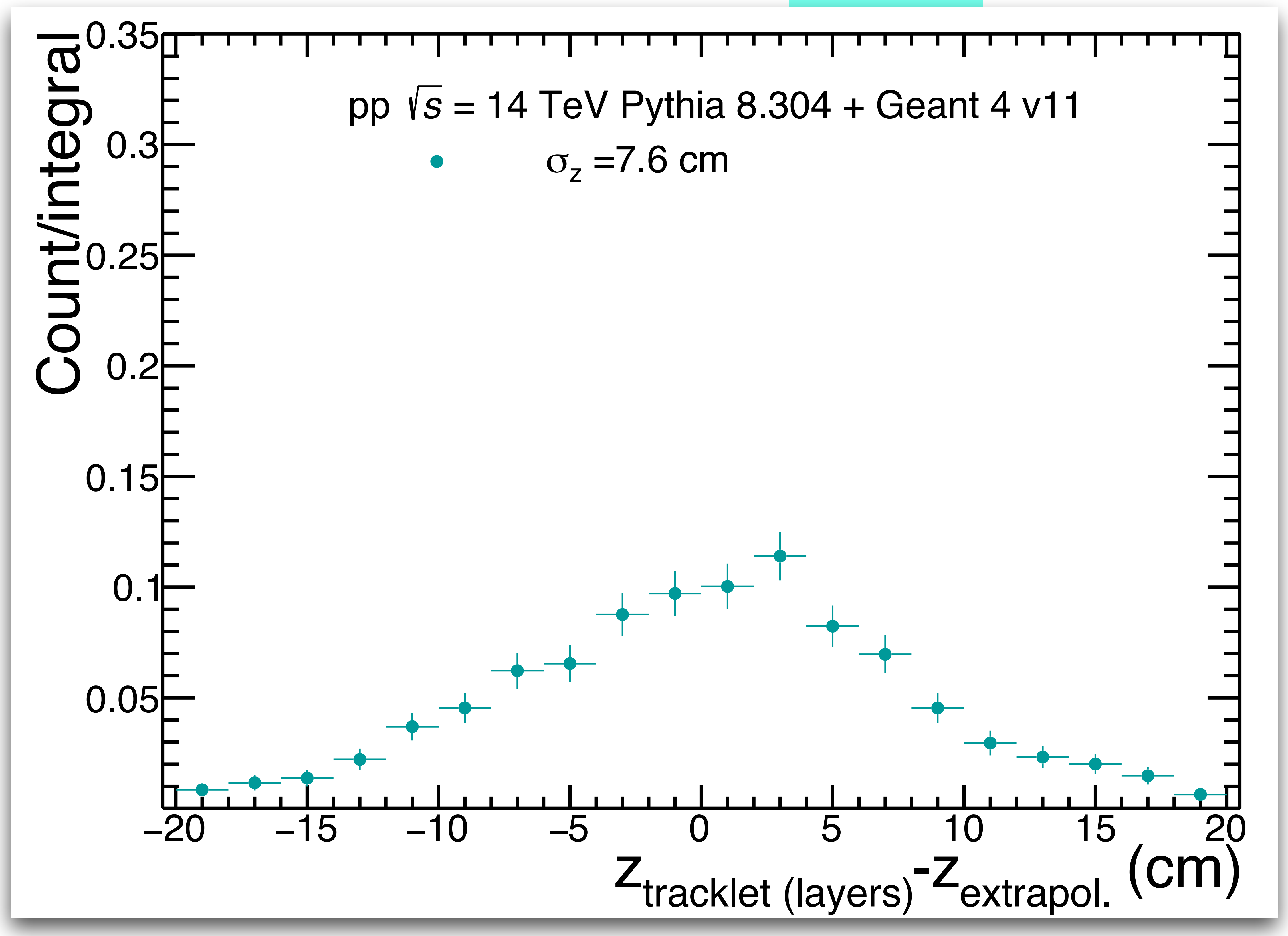


Tracklets reconstructed in muonID

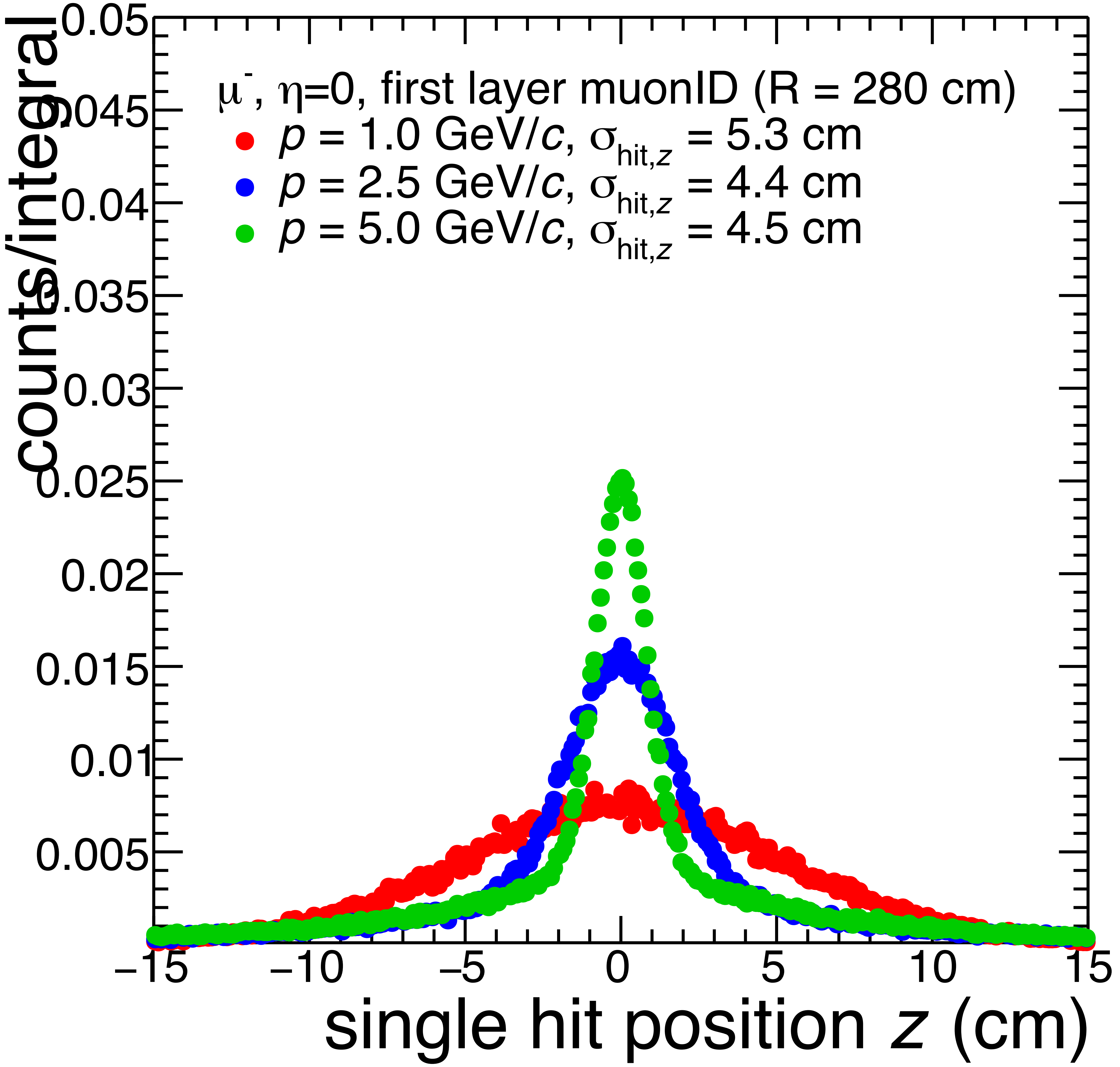
We only need to know which bars were fired

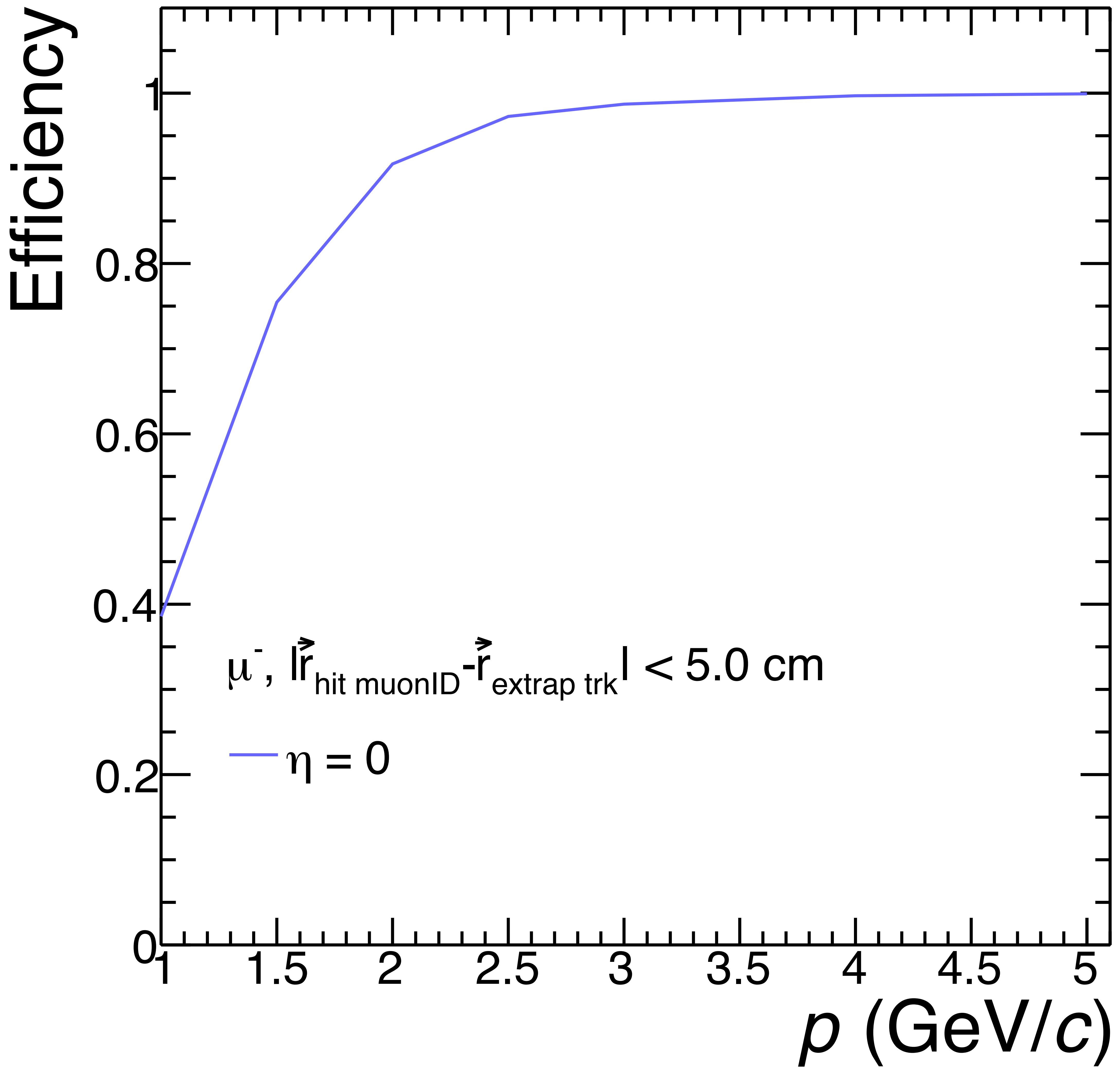






Geant4 simulations





Scintillator: vinyltoluene, gap between scintillator bars: 2mm

Charmonius states

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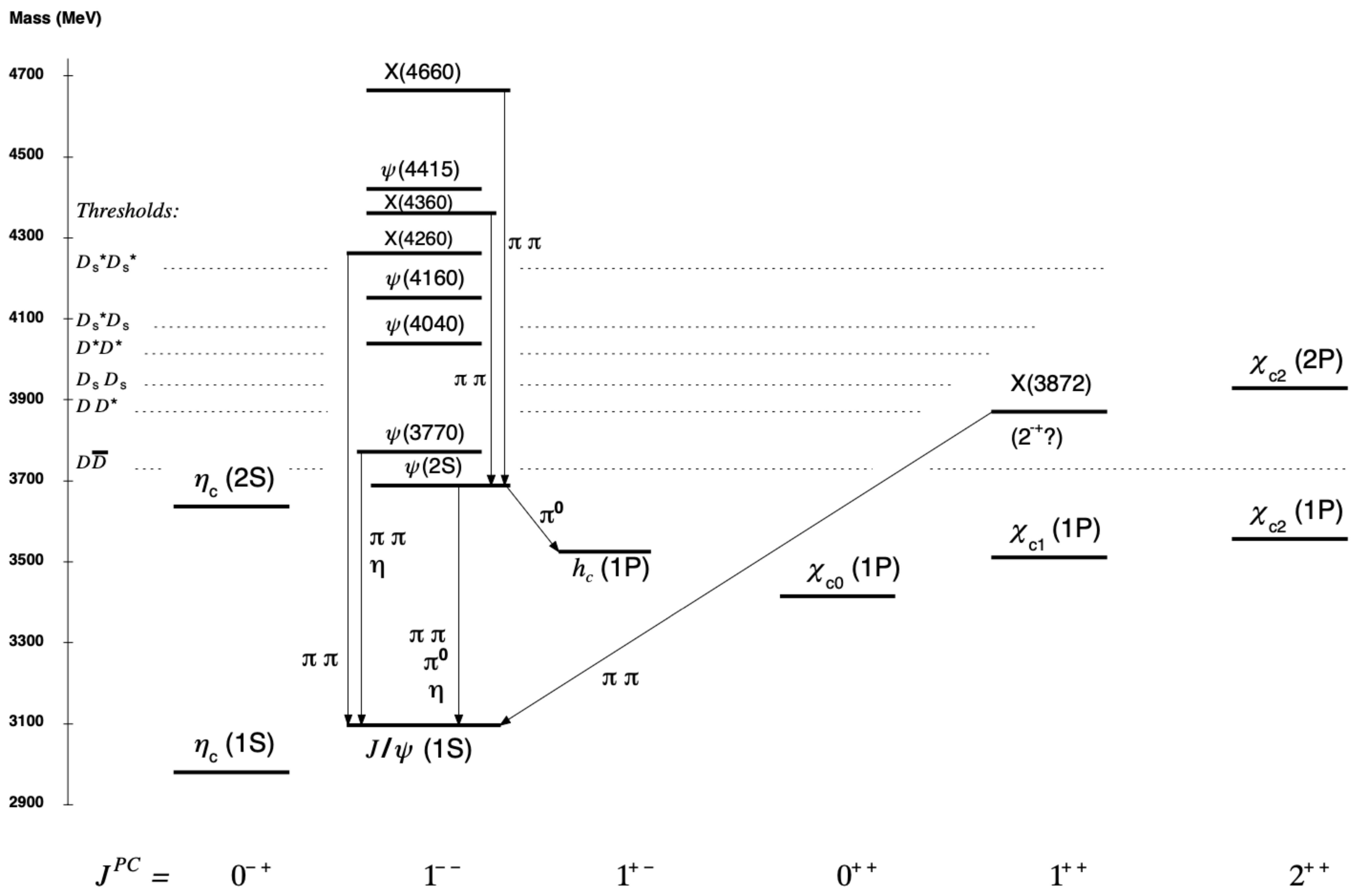


Figure 3.1: The experimentally observed charmonium states. The states labelled X, the nature of which is unknown, are not thought to be conventional charmonium states. Figure from Ref. [3].

Example: SiPM

MPPC (Multi-Pixel Photon Counter) | S13360 series

Selection guide

Type no.	Pixel pitch (μm)	Effective photosensitive area (mm)	Number of pixels	Package	Fill factor (%)
S13360-1325CS	25	1.3 × 1.3	2668	Ceramic	47
S13360-1325PE				Surface mount type	
S13360-3025CS		3.0 × 3.0	14400	Ceramic	
S13360-3025PE				Surface mount type	
S13360-6025CS		6.0 × 6.0	57600	Ceramic	
S13360-6025PE				Surface mount type	
S13360-1350CS	50	1.3 × 1.3	667	Ceramic	74
S13360-1350PE				Surface mount type	
S13360-3050CS		3.0 × 3.0	3600	Ceramic	
S13360-3050PE				Surface mount type	
S13360-6050CS		6.0 × 6.0	14400	Ceramic	
S13360-6050PE				Surface mount type	
S13360-1375CS	75	1.3 × 1.3	285	Ceramic	82
S13360-1375PE				Surface mount type	
S13360-3075CS		3.0 × 3.0	1600	Ceramic	
S13360-3075PE				Surface mount type	
S13360-6075CS		6.0 × 6.0	6400	Ceramic	
S13360-6075PE				Surface mount type	

Example: scintillator plastic, optical fibre

Material	Light output w.r.t. anthracene (%)	λ at max. emission (nm)	Decay constant (ns)	Rise time (ns)	Bulk light attenuation length (cm)	Refractive index	H/C ratio	Density (g/cm^3)
BC-404	68	408	1.8	0.7	160	1.58	1.107	1.023
BC-420	64	391	1.5	0.5	110	1.58	1.102	1.023

	λ at max abs. (nm)	Abs. Coeff. x10^4 (cm^2/g)	λ at max emiss. (nm)	Quantum Efficiency (%)	Index of refraction	Decay time (ns)
NOL 38	382	11.6	431, 458	88		0.95
EJ 280	427		490	86	1.58	8.5
EJ 282	390		481	93	1.58	1.9
EJ 286	355		425	92	1.58	1.2

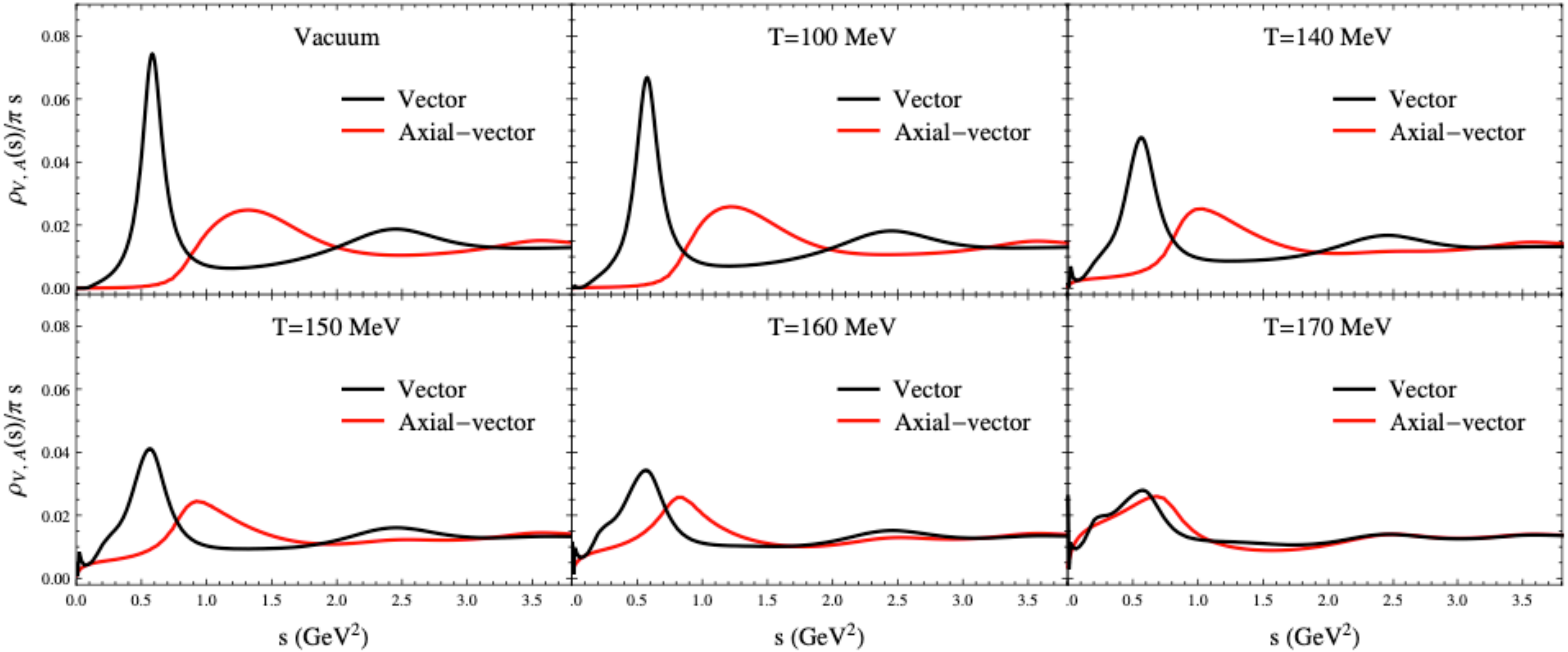
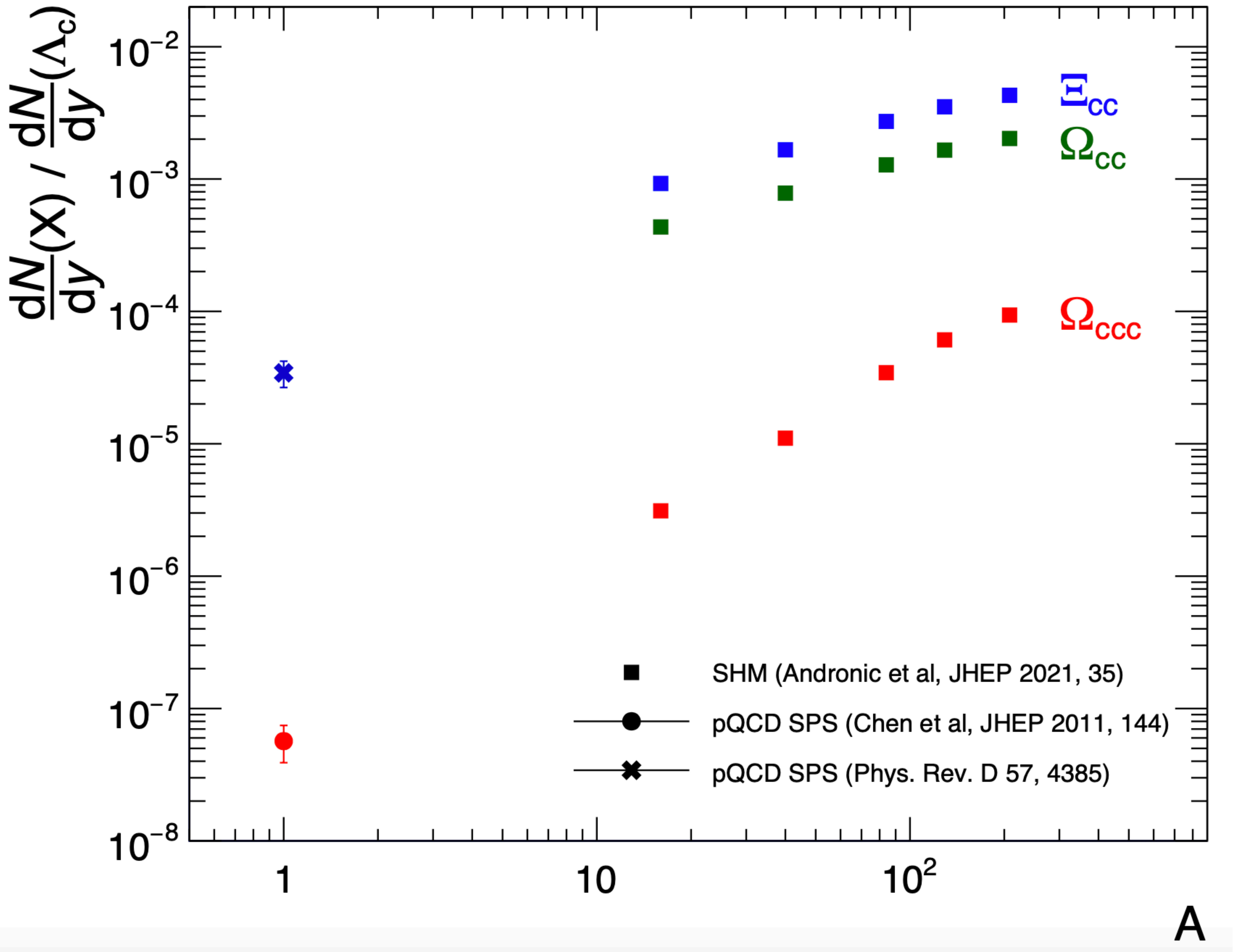


Figure 5: Temperature evolution of vector and axial-vector spectral functions (non-linear realization) [132].



$\Xi_{cc}^{+} \rightarrow \Xi_{c}^{+} + \pi^{+}$

$\Xi_{c}^{+} \rightarrow \Xi^{-} + 2\pi^{+}$

Selected physics cases: exotic hadrons

SCHEMATIC MODEL OF BARYONS AND MESONS *

M. GELL-MANN
California Institute of Technology, Pasadena, California

Received 4 January 1964

anti-triplet as anti-quarks $\bar{q}$. Baryons can now be constructed from quarks by using the combinations (qqq), $(qqqq\bar{q})$, etc., while mesons are made out of $(q\bar{q})$, $(qq\bar{q}\bar{q})$, etc. It is assuming that the lowes

AN SU_3 MODEL FOR STRONG INTERACTION SYMMETRY AND ITS BREAKING

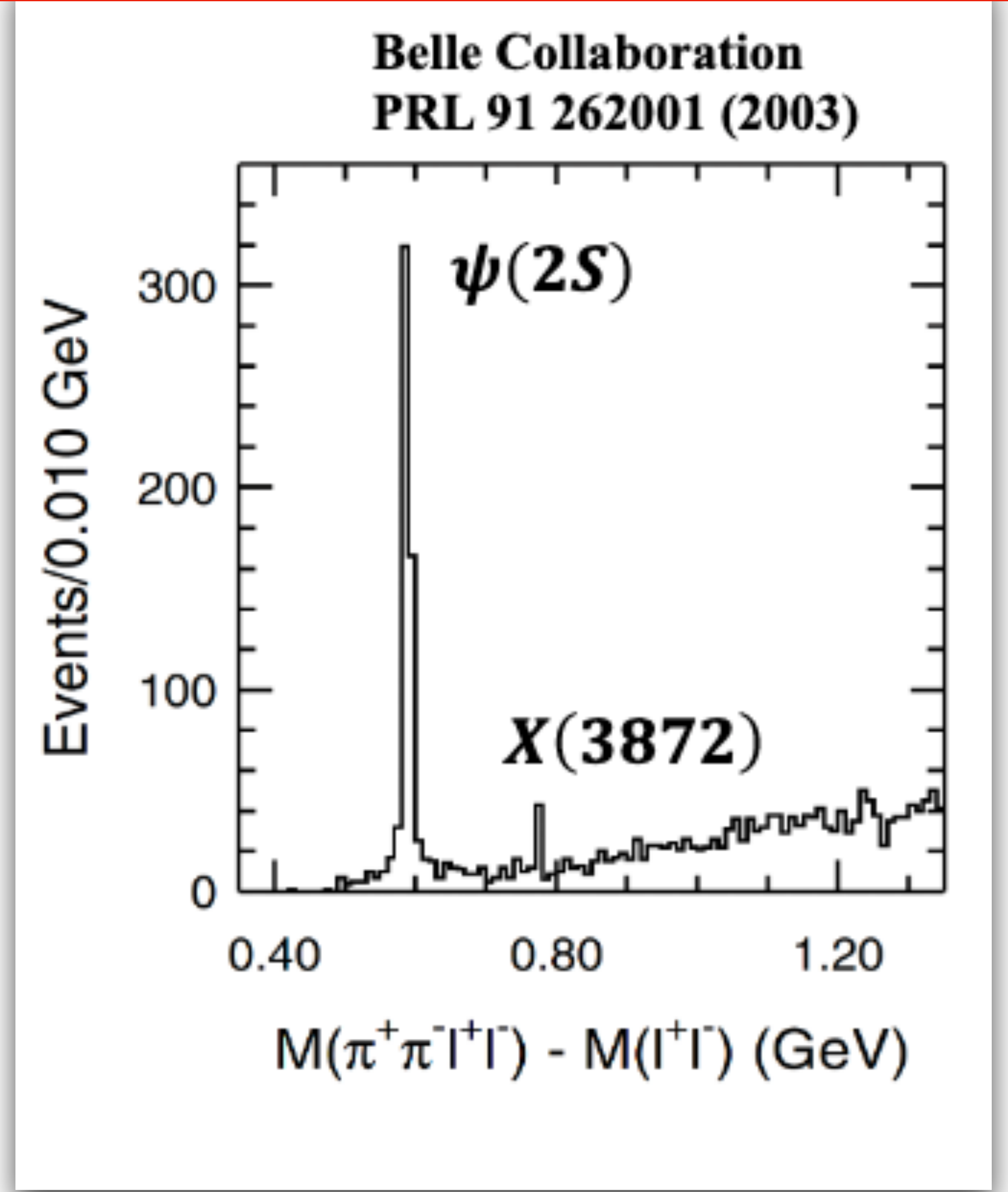
G. Zweig *)
CERN – Geneva

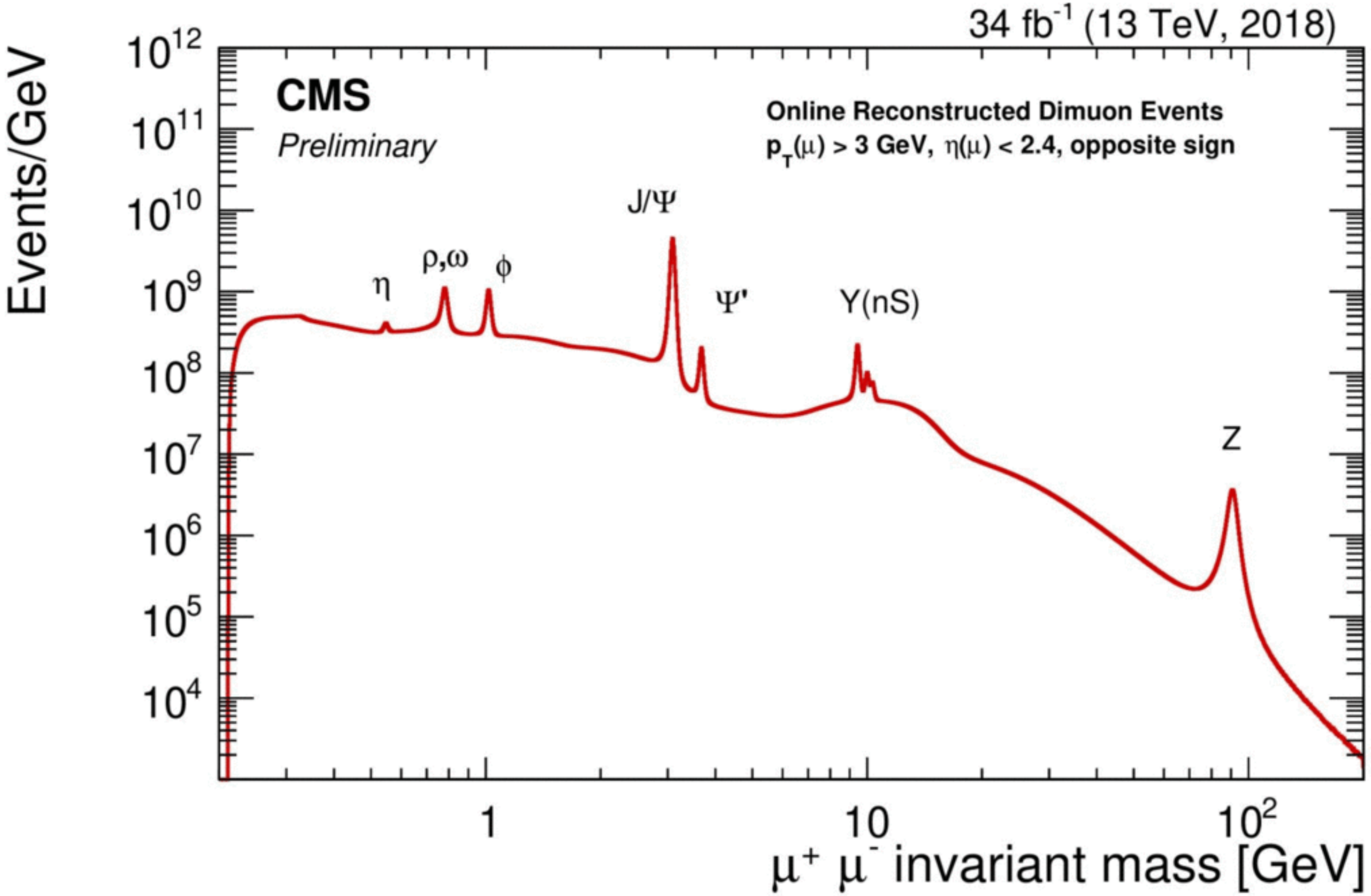
In general, we would expect that baryons are built not only from the product of three aces, AAA, but also from $AAAA\bar{A}$, $AAAAA\bar{A}\bar{A}$, etc., where $\bar{A}$ denotes an anti-ace. Similarly, mesons could be formed from $A\bar{A}$, $AA\bar{A}\bar{A}$ etc. For the low mass mesons and baryons we will assume the simplest possibilities, $A\bar{A}$ and AAA, that is, "deuces and treys".

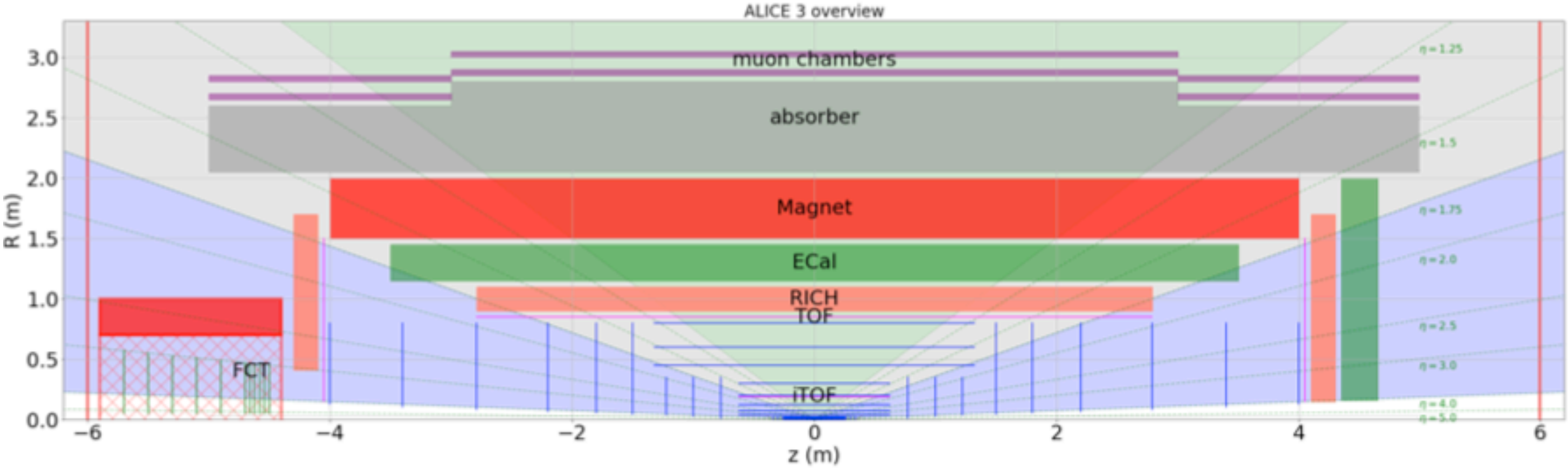
Multiquark hadrons are called exotics:

- "tetraquarks": qqqq
- "pentaquarks": qqqqq

The first heavy quark exotic: X(3872)




34 fb-1 (13 TeV, 2018)
CMS
Preliminary
Online Reconstructed Dimuon Events
pT(μ) > 3 GeV, η(μ) < 2.4, opposite sign
Events/GeV
η
ρ,ω
φ
J/Ψ
Ψ'
Υ(nS)
Z
10^12
10^11
10^10
10^9
10^8
10^7
10^6
10^5
10^4
1
10
10^2
μ+ μ- invariant mass [GeV]


ALICE 3 overview
muon chambers
absorber
Magnet
ECal
RICH
TOF
iTOF
FCT
R (m)
z (m)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−6
−4
−2
0
2
4
6

Contributions to ALICE

- Run 1 and 2: ACORDE and V0 (scintillation detectors)
- Run 3: new FV0 and FDD detectors (scintillator detectors), TPC upgrade
- Data analysis / MC simulations

Example for FDD

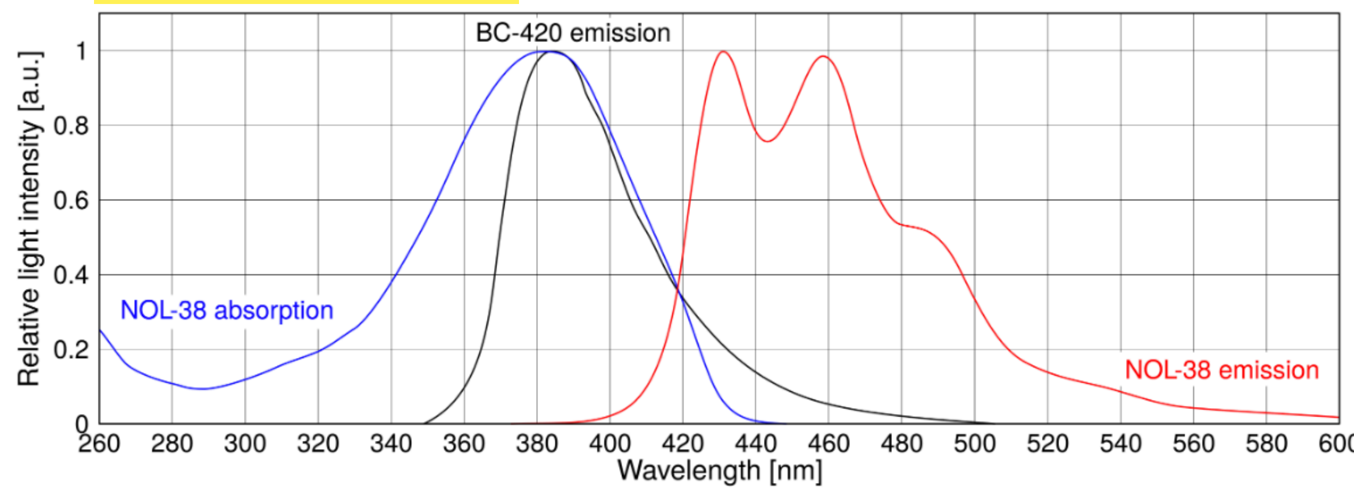
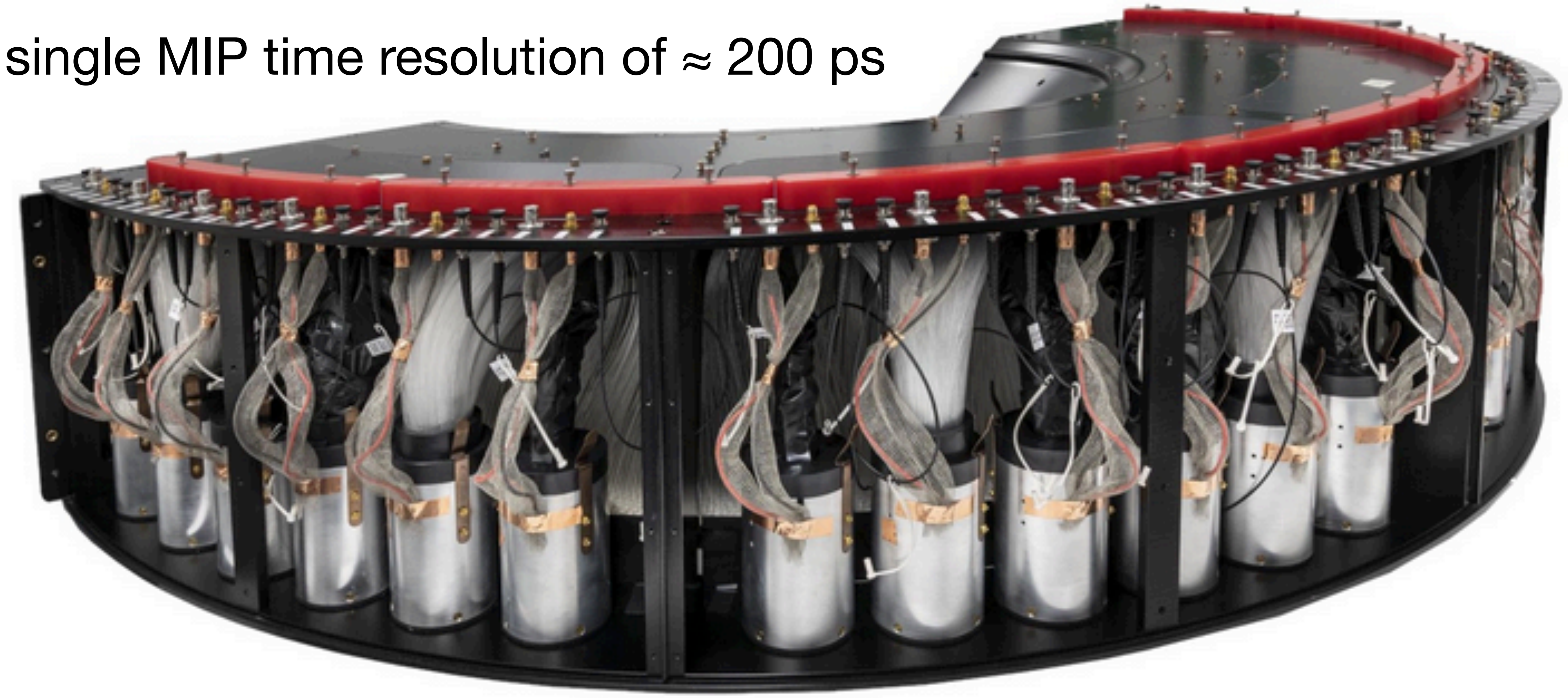
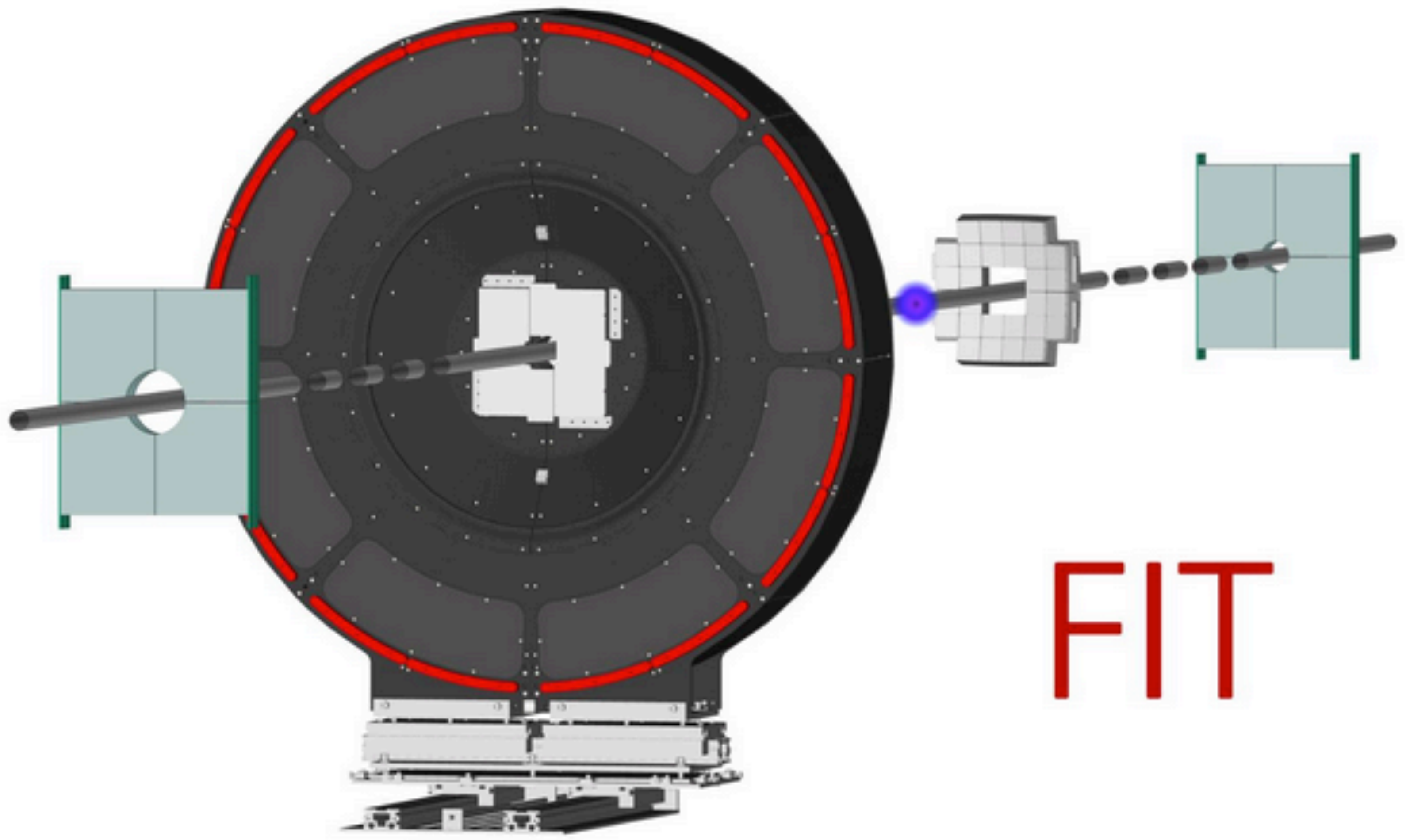


Figure 3.66.: Emission spectrum of the BC-420 scintillator (*black line*), based on figure published by the manufacturer [179]. Emission (*red*) and absorption (*blue*) spectrum of NOL-38 wavelength shifter are also shown

single MIP time resolution of ≈ 200 ps





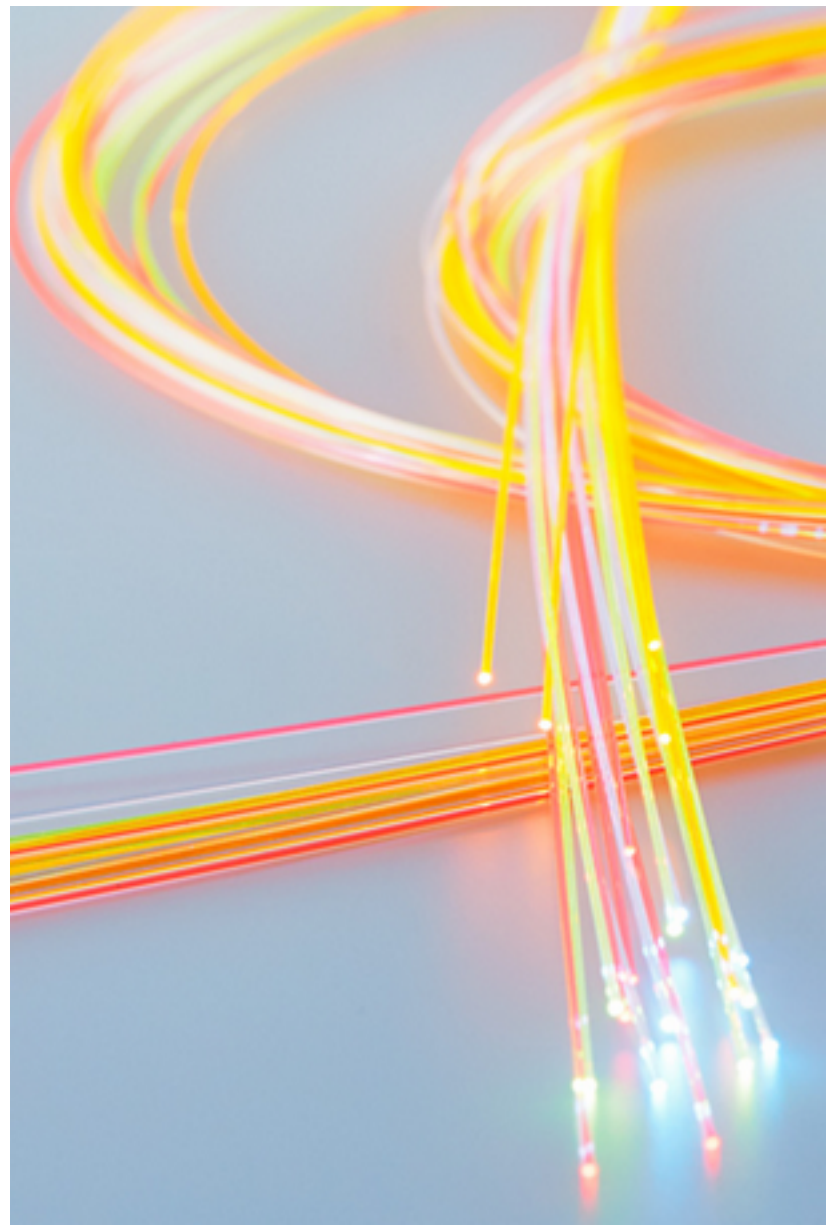
Fibres

The light produced by the particle interaction has to be collected, re-emmited, and transported to the photodetectors efficiently by WLS fibres

Companies: Saint-Gobain and Kuraray factories

- Multiclad fibres with long attenuation length (~2-3 m). Tests with other fibres smaller attenuation lengths

Type	Luminescence			Absorption Peak (nm)	Attenuation length[2] (m)	Characteristics
	Color	Spectra	Peaks (nm)			
Y-7 (100)	Green		490	439	>2.8	Blue to green shifter
Y-8 (100)	Green		511	455	>3.0	Blue to green shifter
Y-11 (200)	Green	Refer to	476	430	>3.5	Blue to green shifter (u K-27 formulation) High luminescence High attenuation length



Existing studies (FNAL-NICADD)

Instituto de Ciencias Nucleares UNAM

- Typical time resolution, ~1 ns

Table 1. Prototypes of extruded scintillator bars from NICADD manufacturer. All the bars were instrumented with fibres Kuraray WLS Y11(200) S-type except the S2 bar that has been instrumented with fibres from the Saint Gobain company (BCF92). The fibres in the L1, L2 and L4 bars were read out at both ends. The fibres in the S1, S2, S5 and S8 bars were read out only at one end. The main parameters of the photosensors are shown in Table 3.

	Bar dimensions (h × w × l) mm^3	number of fibres/bar	fibre diameter [mm]	SiPM model (AdvanSiD company)
L1	(10 × 45 × 3000) mm^3	1 fibre in 1 groove	2	ASD-NUV3S-P
L2	(20 × 40 × 3000) mm^3	1 fibre in 1 groove	2	ASD-NUV3S-P
L4	(20 × 40 × 3000) mm^3	1 fibre in 1 groove	1.2	ASD-NUV1S-P
S1	(10 × 45 × 250) mm^3	2 fibres in 1 groove	1.2	ASD-NUV3S-P
S2	(10 × 45 × 250) mm^3	2 fibres in 1 groove	1.2	ASD-NUV3S-P
S5	(20 × 40 × 250) mm^3	2 fibres in 1 groove	1.2	ASD-NUV3S-P
S8	(20 × 40 × 250) mm^3	1 fibre in 1 hole	2	ASD-NUV3S-P

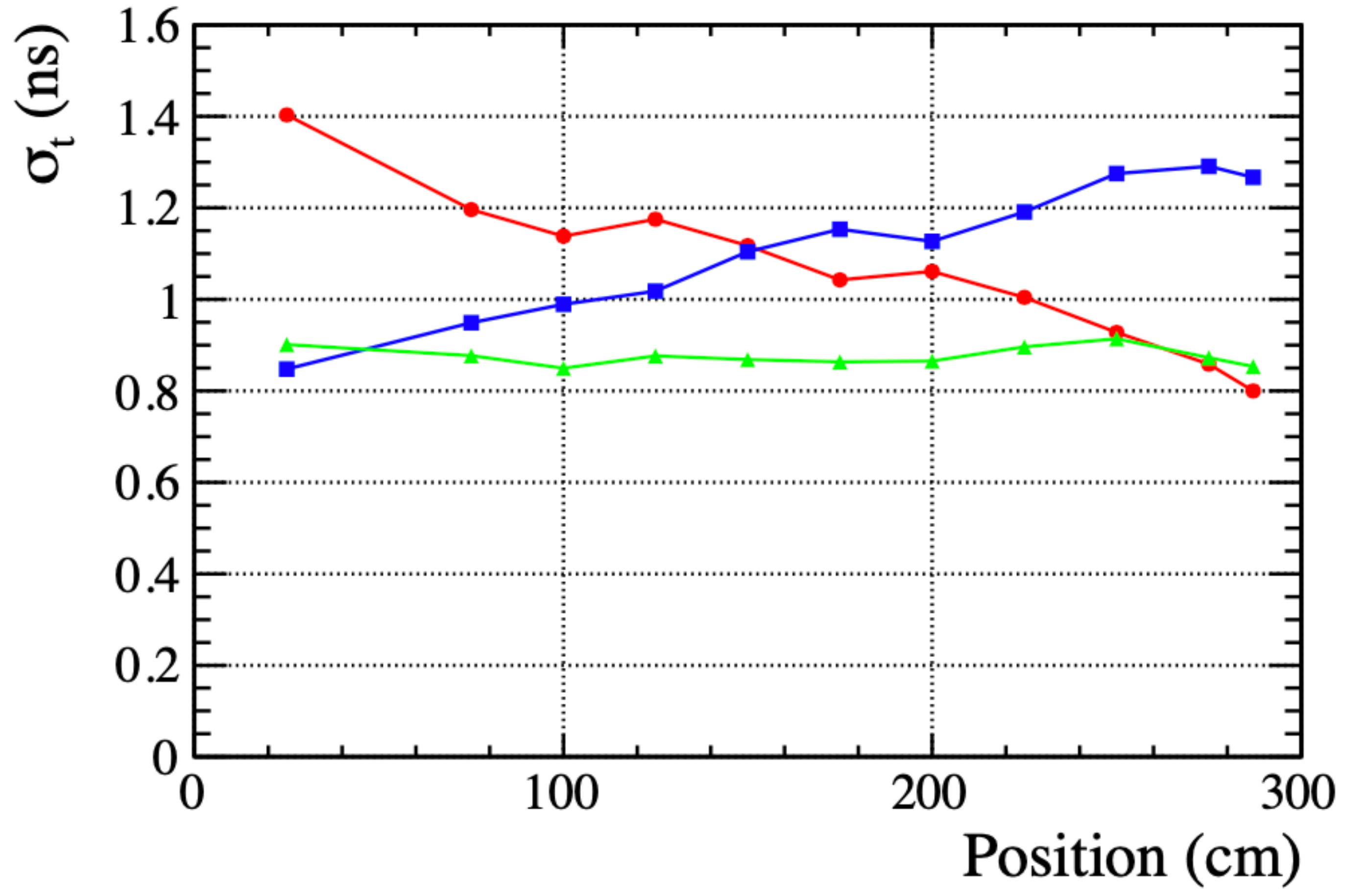


Figure 14. L1 bar time resolution using only SiPM $L(R)$, red circles(blue squares) and both SiPMs (green triangles).

W. Baldini, *JINST* 12 (2017) 03, P03005

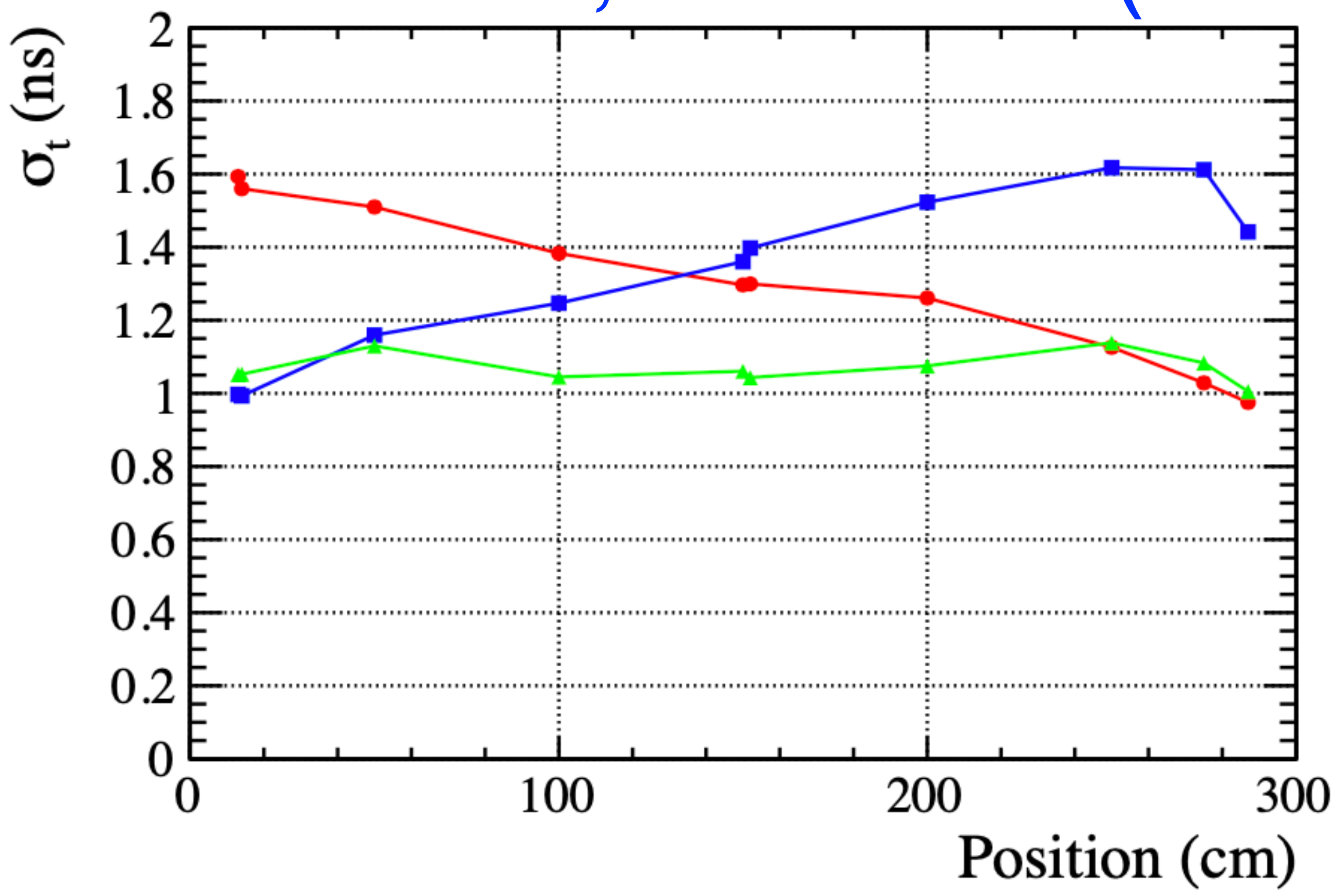


Figure 16. L4 bar time resolution using only SiPM $L(R)$, red circles(blue squares) and both SiPMs (green triangles).

Existing studies (FNAL-NICADD)

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S5	(20 × 40 × 250) mm^3	2 fibres in 1 groove	1.2	ASD-NUV3S-P
S8	(20 × 40 × 250) mm^3	1 fibre in 1 hole	2	ASD-NUV3S-P

With this option, the estimated cost can be reduced to 0.2 MCHF. But different scintillator plastics will be tested (BC-408,)

Component	Comment	Cost (MCHF)
Absorber	non-magnetic steel (3CHF / kg * 1100 t), support	5.0
Scintillators	2 * 175 m^2 extruded scintillators with WLS	0.6
Readout	SiPMs + FEE (10 k channels)	0.2
Power	LV PSUs	0.2
Mechanics	4 * 18 modules * 5000 / module	0.5
Services		0.5
Total		**7.0**

Table 7: Estimated core cost of the muon identifier

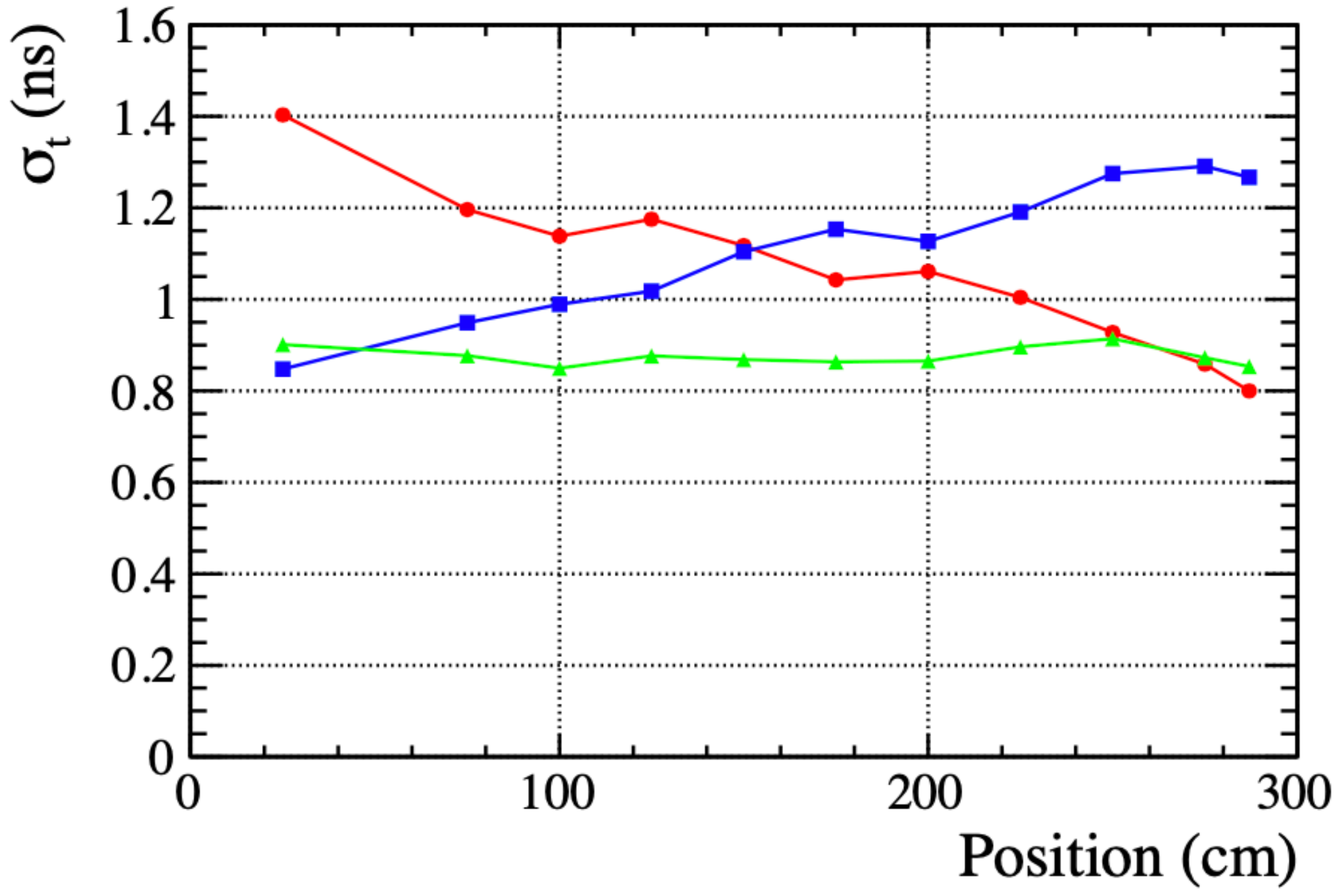


Figure 14. L1 bar time resolution using only SiPM $L(R)$, red circles(blue squares) and both SiPMs (green triangles).

W. Baldini, *JINST* 12 (2017) 03, P03005

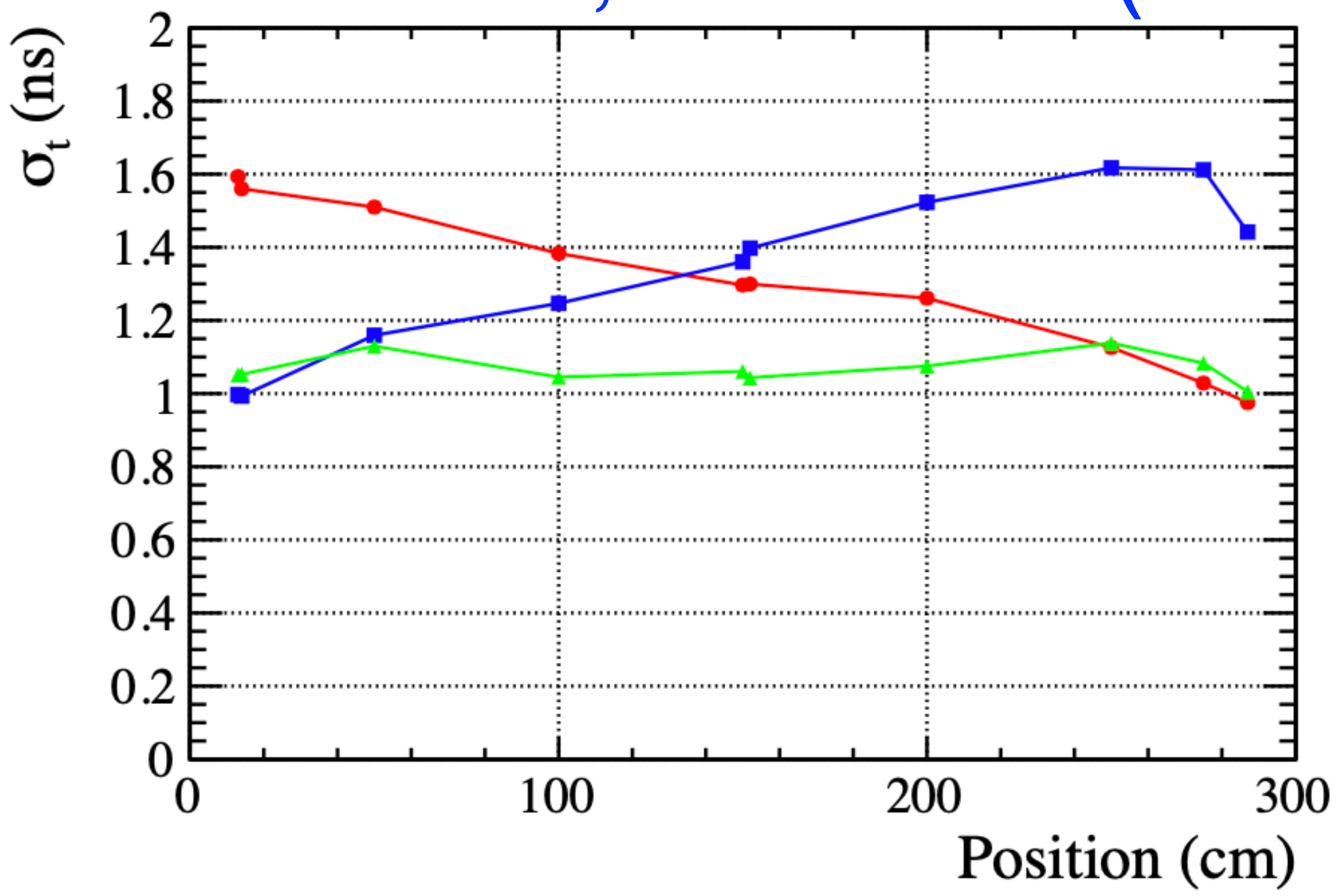
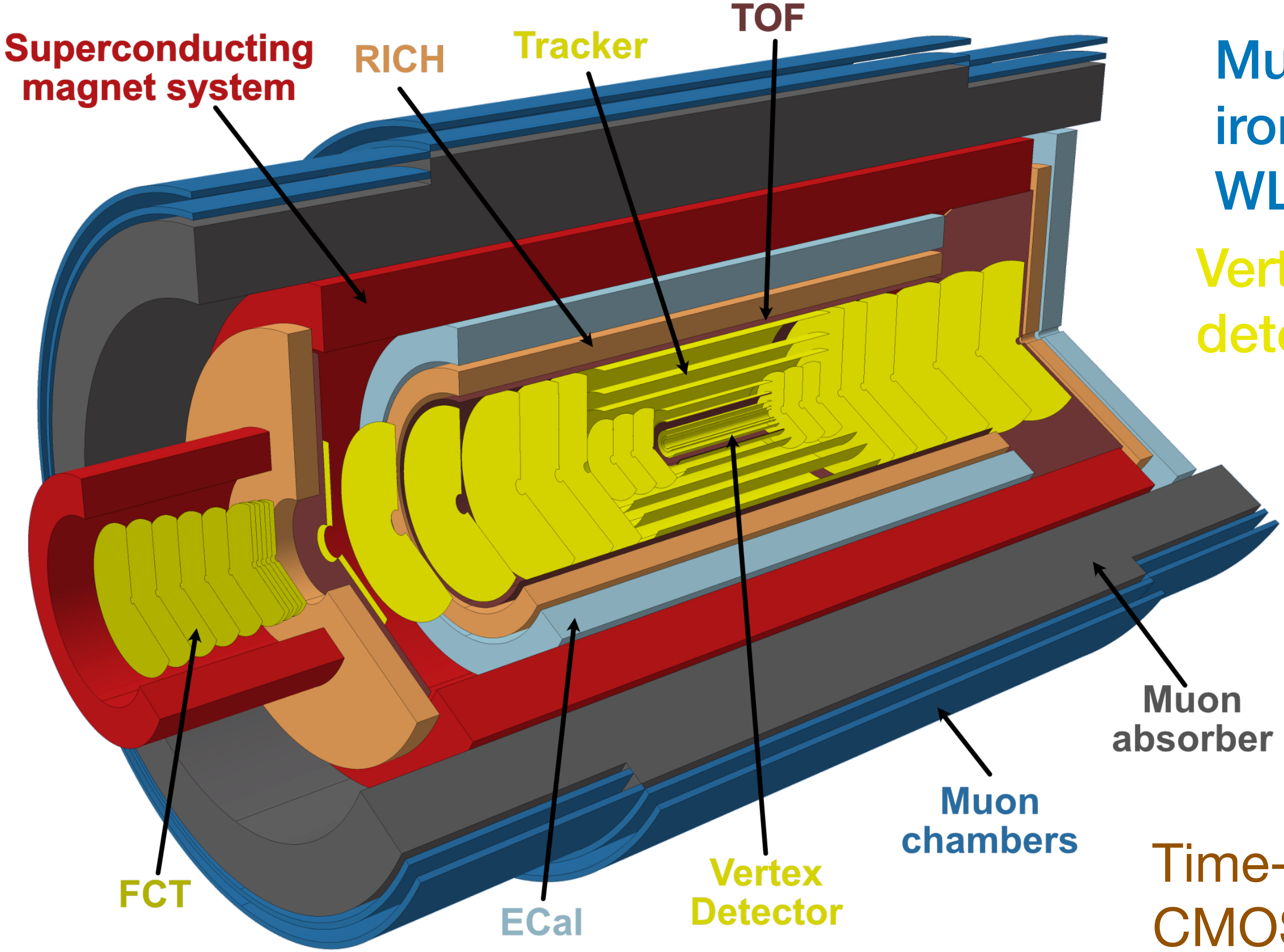


Figure 16. L4 bar time resolution using only SiPM $L(R)$, red circles(blue squares) and both SiPMs (green triangles).

ALICE 3



MuonID:
iron absorber, scintillating bars, WLS, SiPM

Vertexer detector: retractable detector, R_{in}~5mm

RICH: aerogel radiator, SiPM readout

Tracker: monolithic CMOS sensors

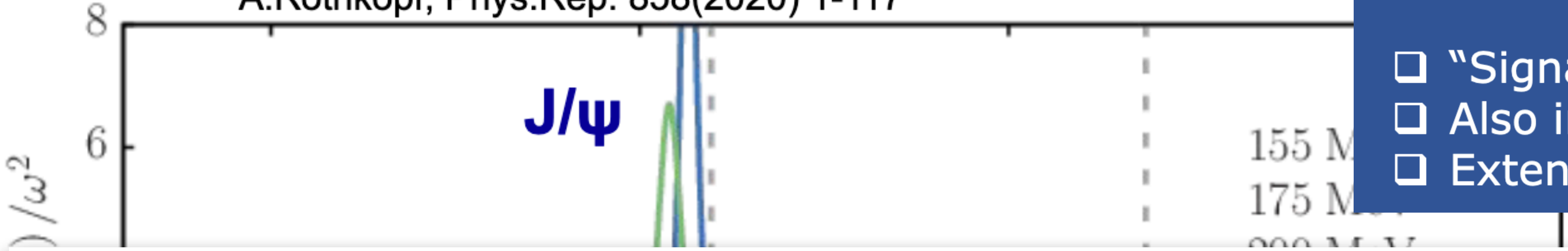
Tracker: monolithic CMOS sensors

Time-of-flight detector monolithic CMOS sensors with gain layer

Charmonium states

Charmonium production as probe of QGP in heavy-ion collisions

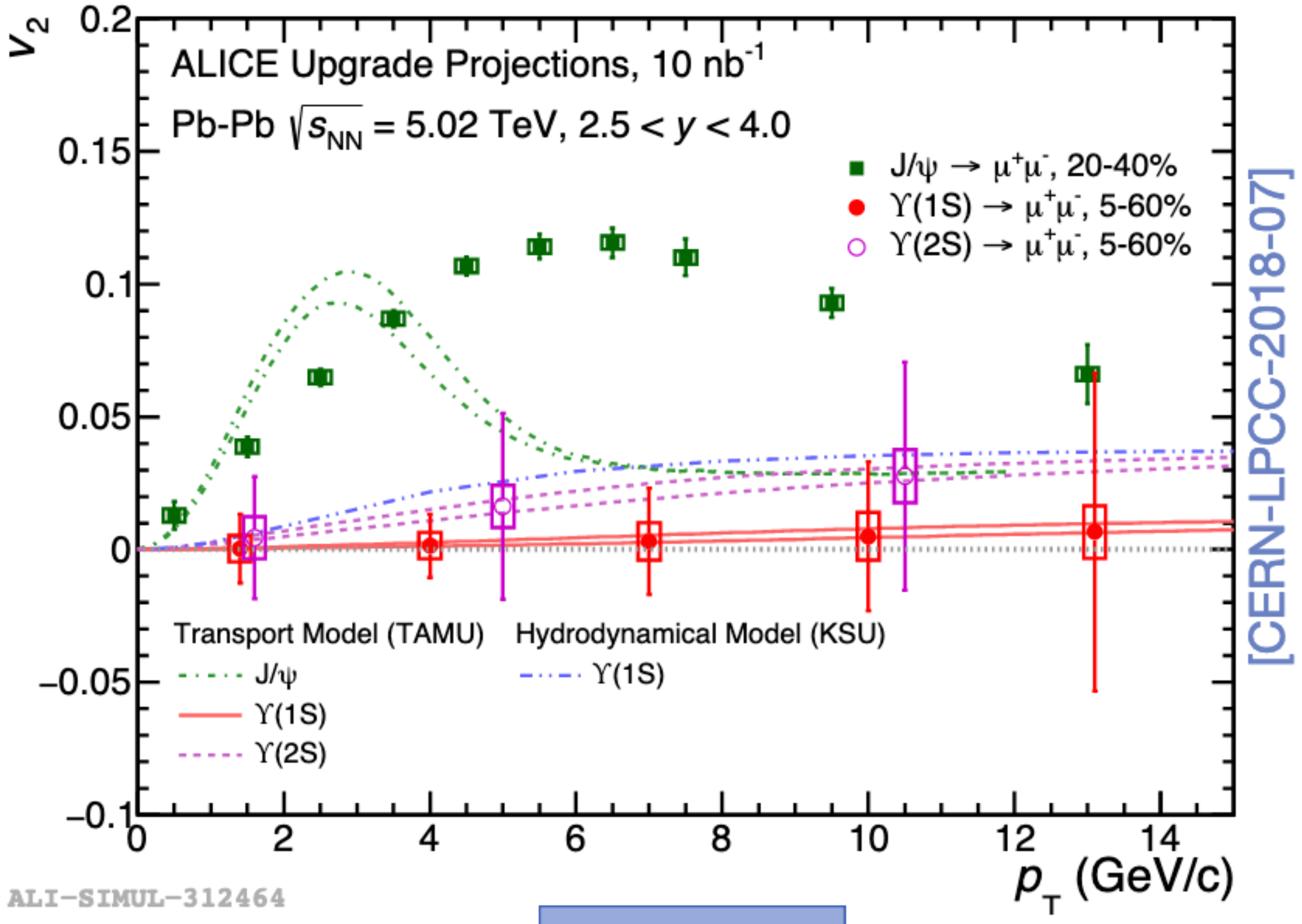
A.Rothkopf, Phys.Rep. 858(2020) 1-117



Measuring quarkonia down to zero p_T

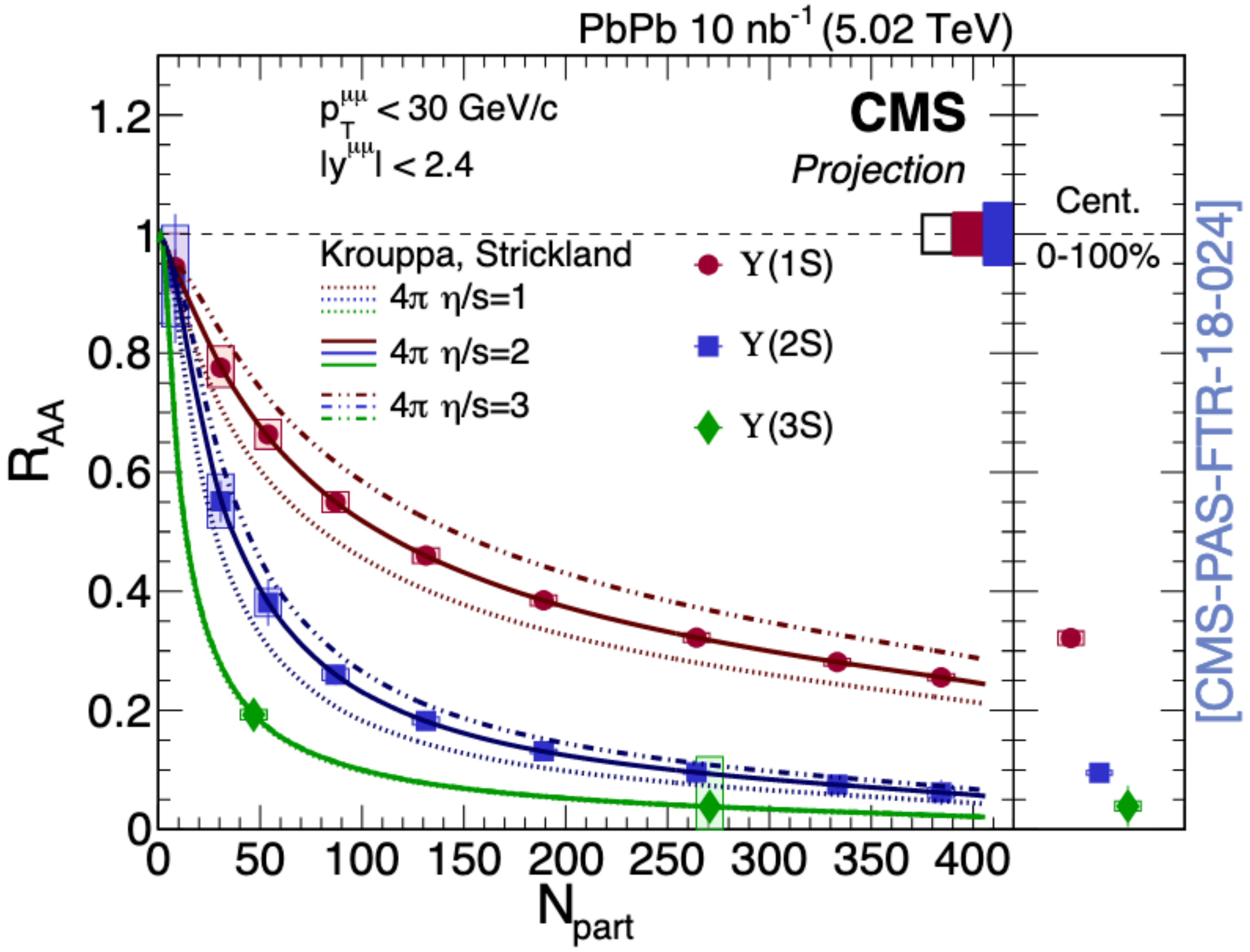
- "Signature" ALICE feature from the beginning
- Also in the future a distinctive factor wrt ATLAS/CMS
- Extend this capability in ALICE3 for the muon decay channel at midrapidity

v_2 for J/ψ, ϒ



Run 3 & 4

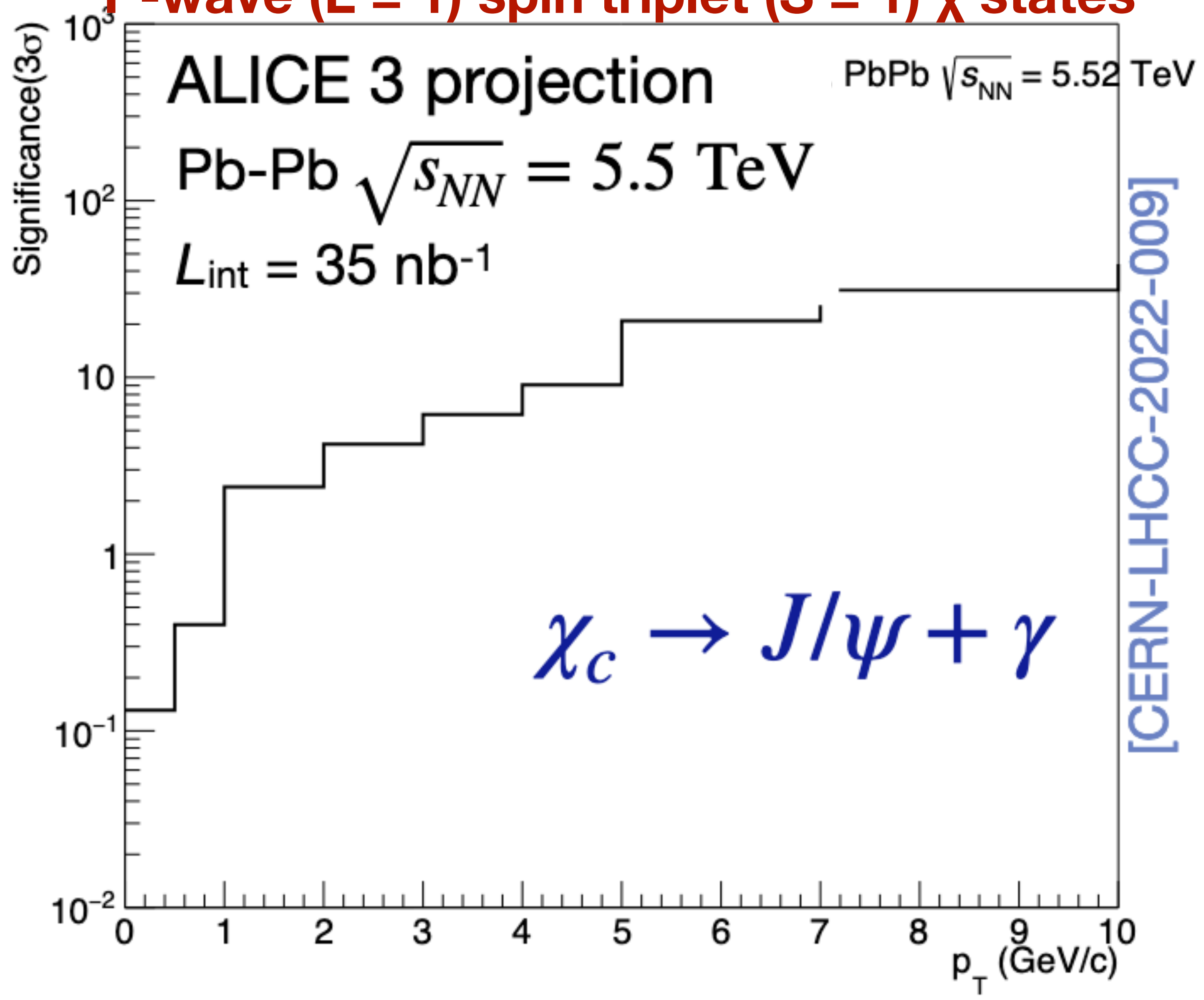
R_{AA} for ϒ states



Run 3 & 4

χ_c in Pb-Pb collisions

P-wave (L = 1) spin triplet (S = 1) χ states



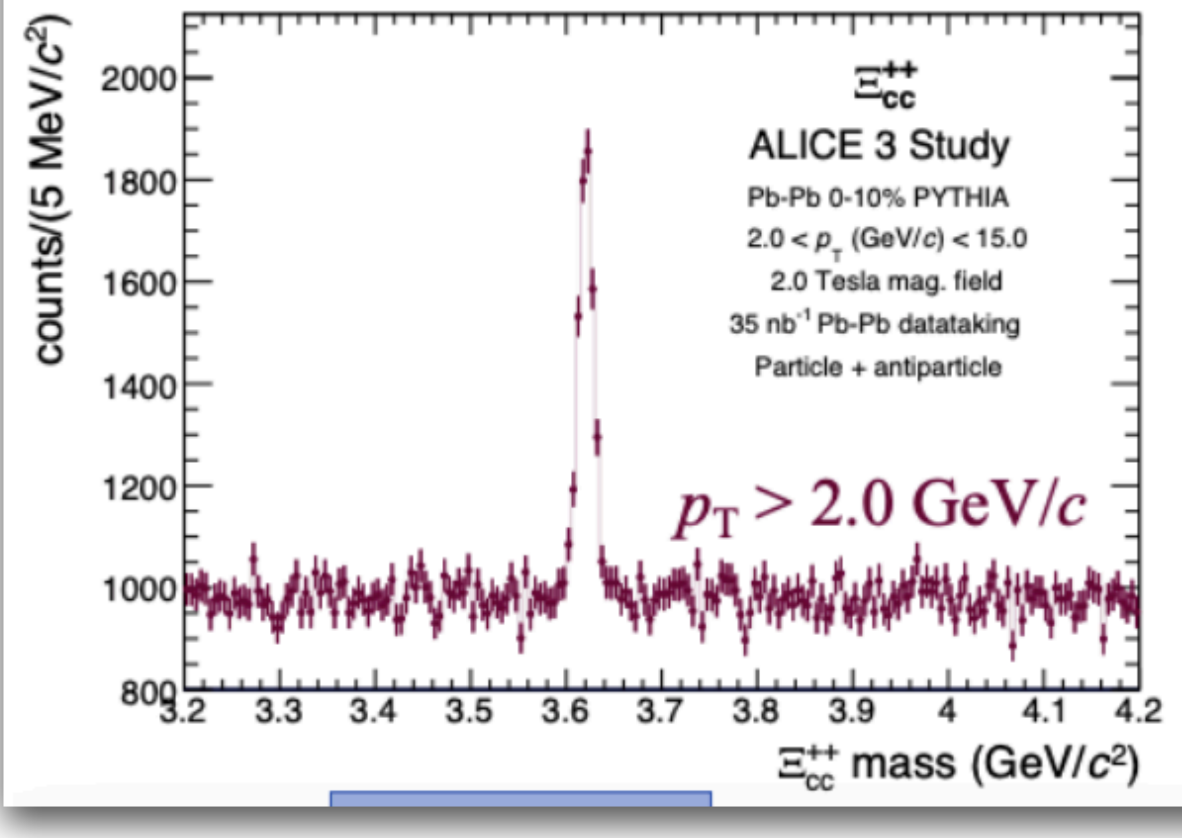
Run 5 & 6

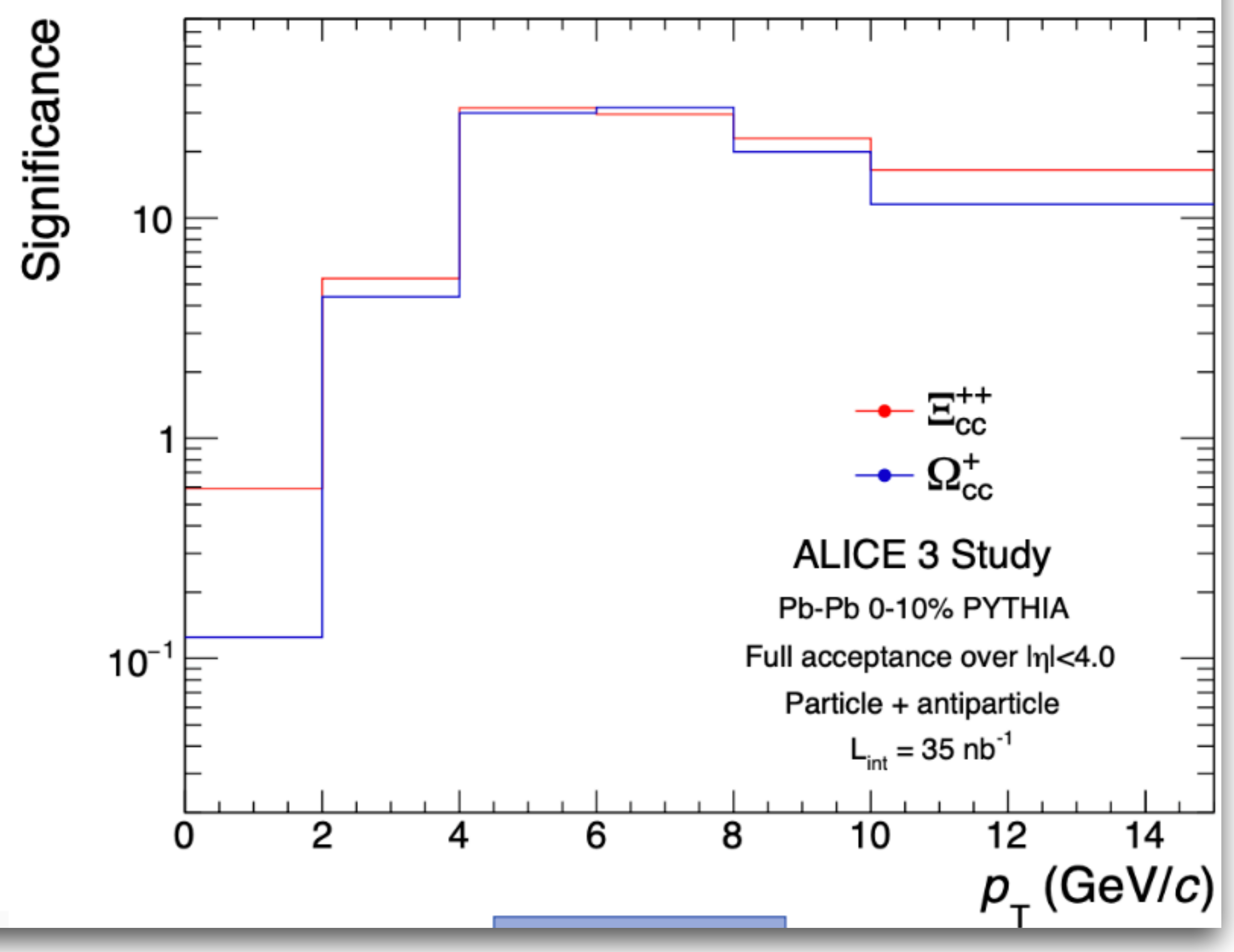
Multi-charm baryons

Expected enhancement of multi-charm states provides high sensitivity to equilibration

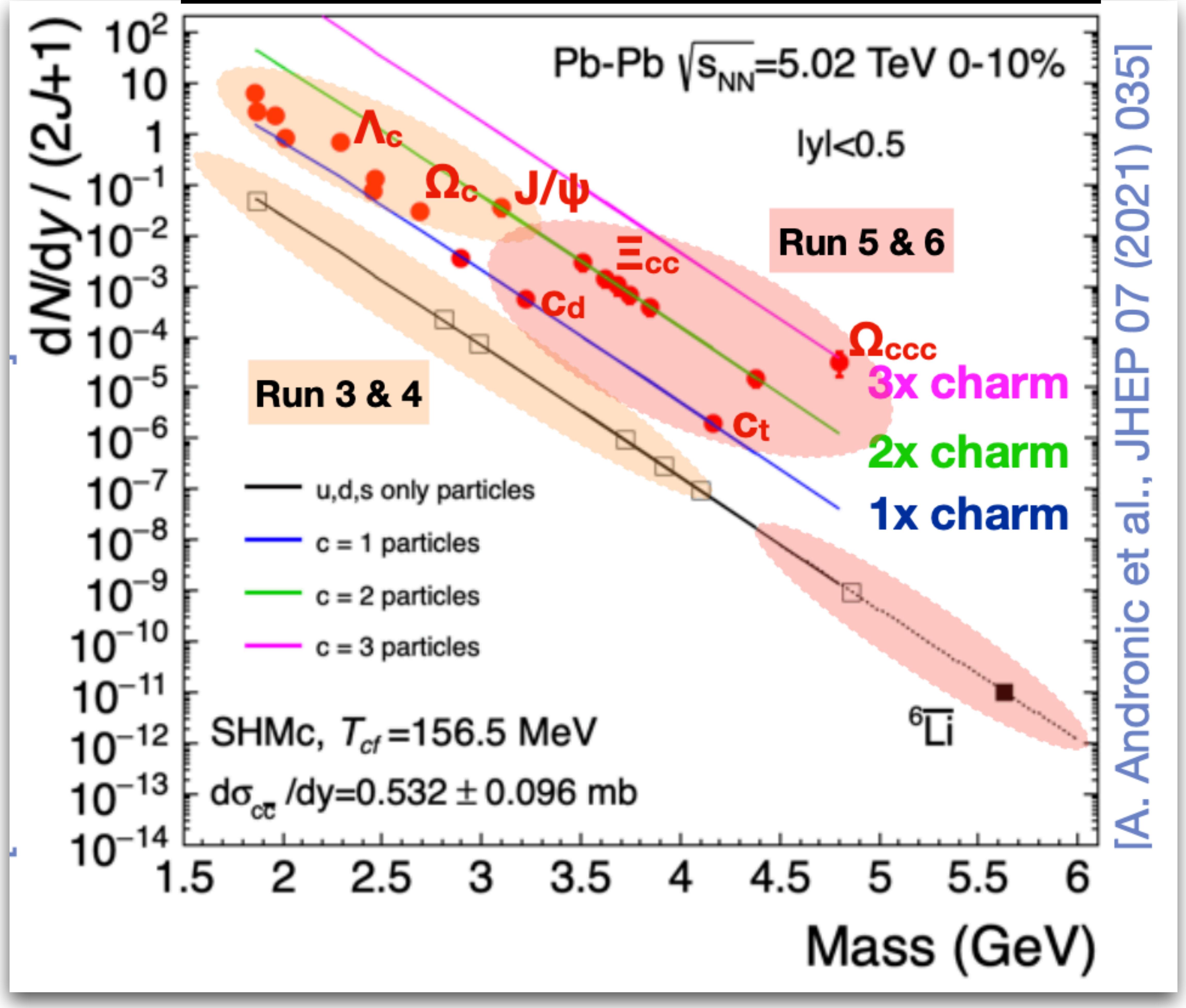
- Systematic measurement of hadron yields
- Luminosity, acceptance, vertexing, PID, strangeness tracking

$$\Xi_{cc}^{+} \rightarrow \Xi_{c}^{+} + \pi^{+}$$
$$\Xi_{c}^{+} \rightarrow \Xi^{-} + 2\pi^{+}$$





Hadron yields in statistical hadronisation model



Low cost extruded scintillator

Low cost (~45 USD/kg), if equipped with WLS fibre ->good optical response

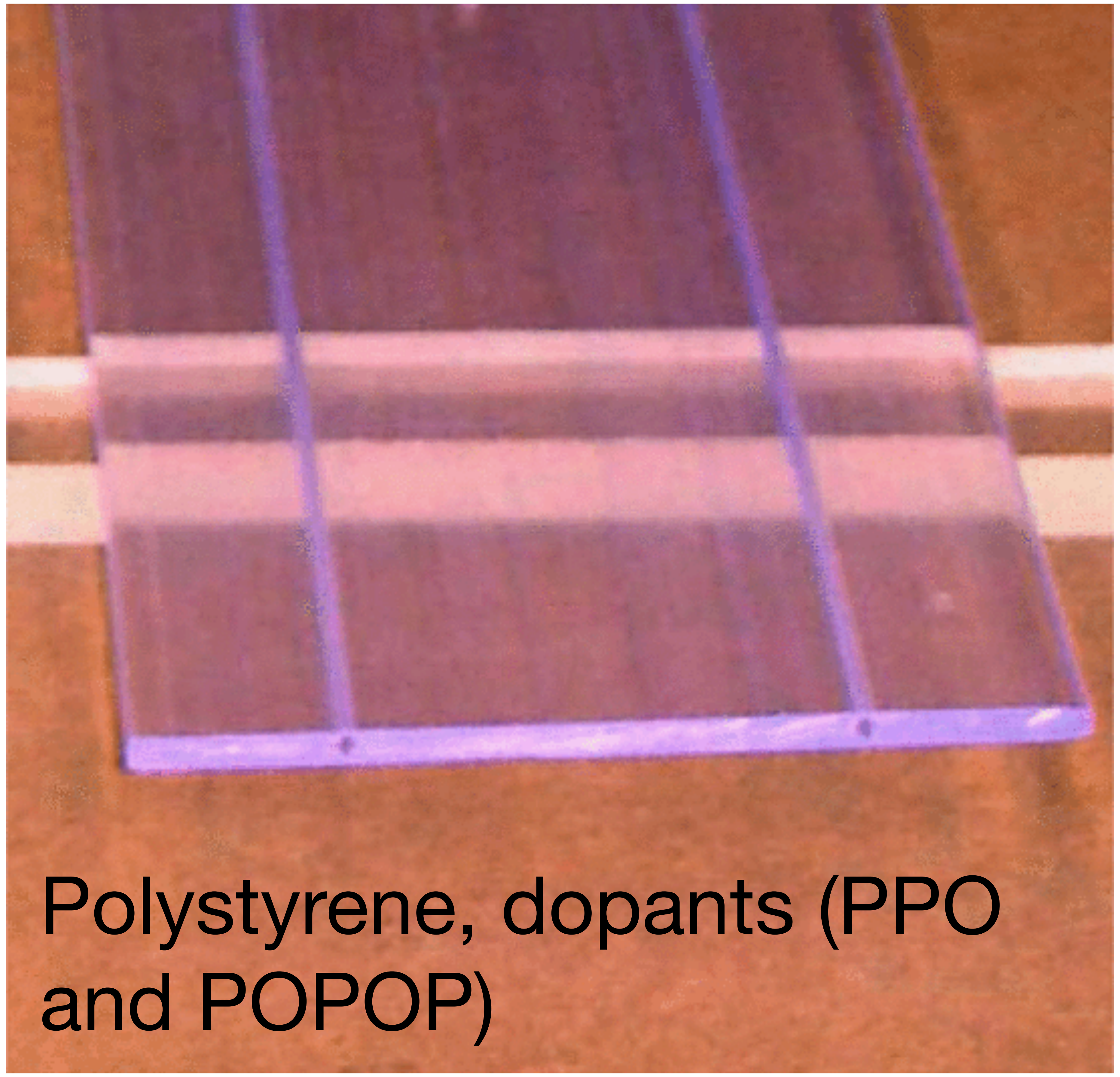
Fermilab extrusion facility (FNAL-NICADD)

- Produced scintillators for MINOS/ SciBar/INGRID/P0D/ECAL/WAGASCI

May need to produce/test new die

We need ~ 4 t of scintillator (0.17 MCHF)

	Bar dimensions (h x w x l)
L1	(1.0X4.5X300) cm^3
L2	(2.0X4.0X300) cm^3



Polystyrene, dopants (PPO and POPOP)

https://ieeexplore.ieee.org/abstract/document/1462328