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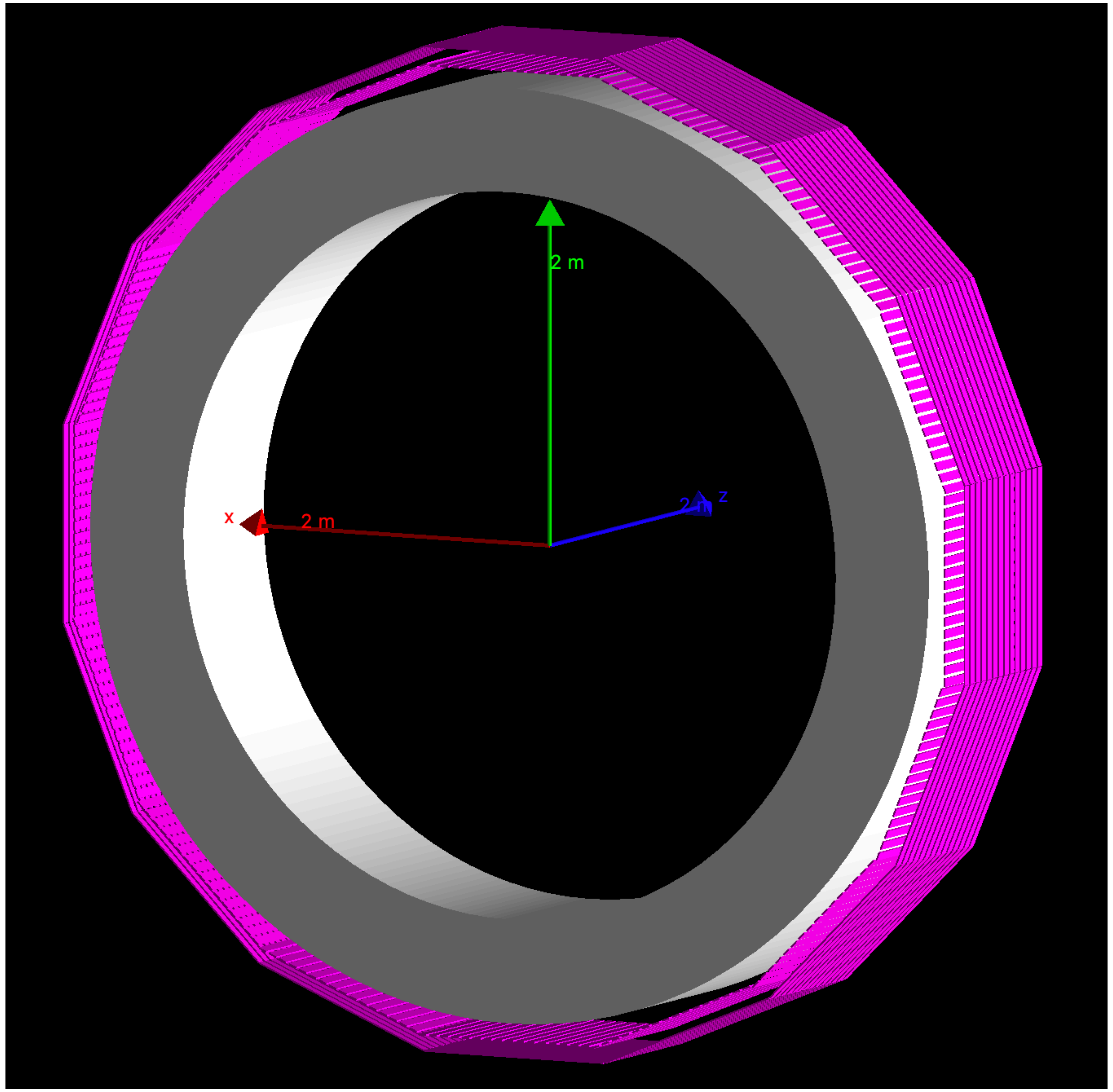


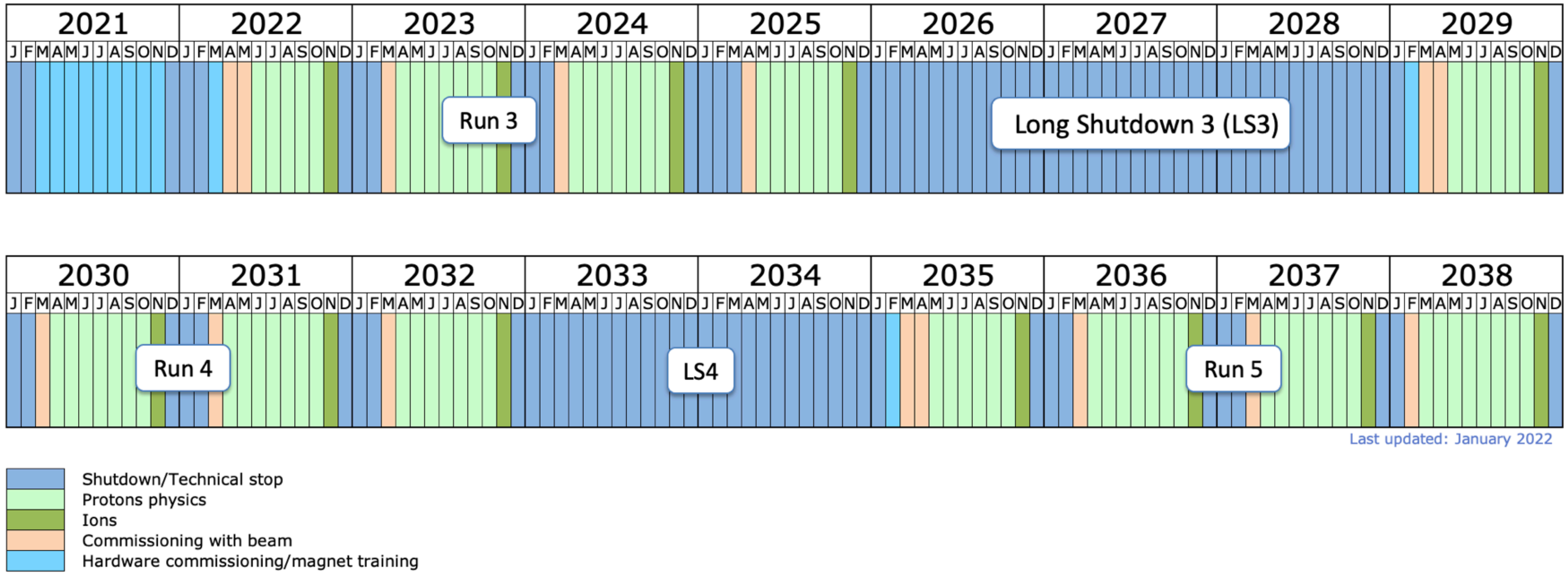
MuonID

Antonio Ortiz

Inspiration from discussions with Marco Van Leeuwen, Jochen Klein, Ildefonso León, Arturo Fernández, Arturo Menchaca, Guillermo Contreras, Gerardo Herrera, Guy Paic

Longer term LHC schedule

In January 2022, the schedule was updated with long shutdown 3 (LS3) to start in 2026 and to last for 3 years.



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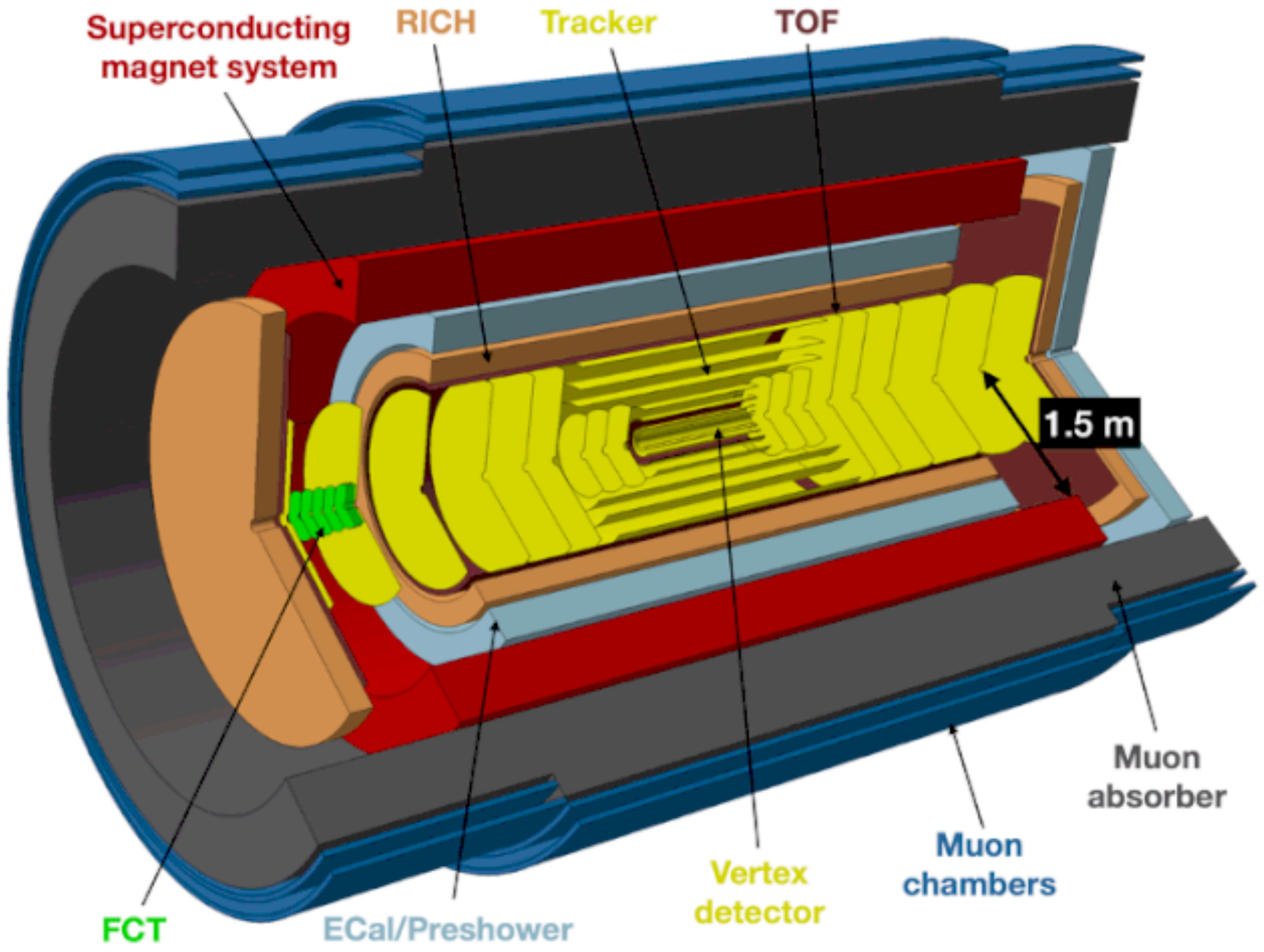

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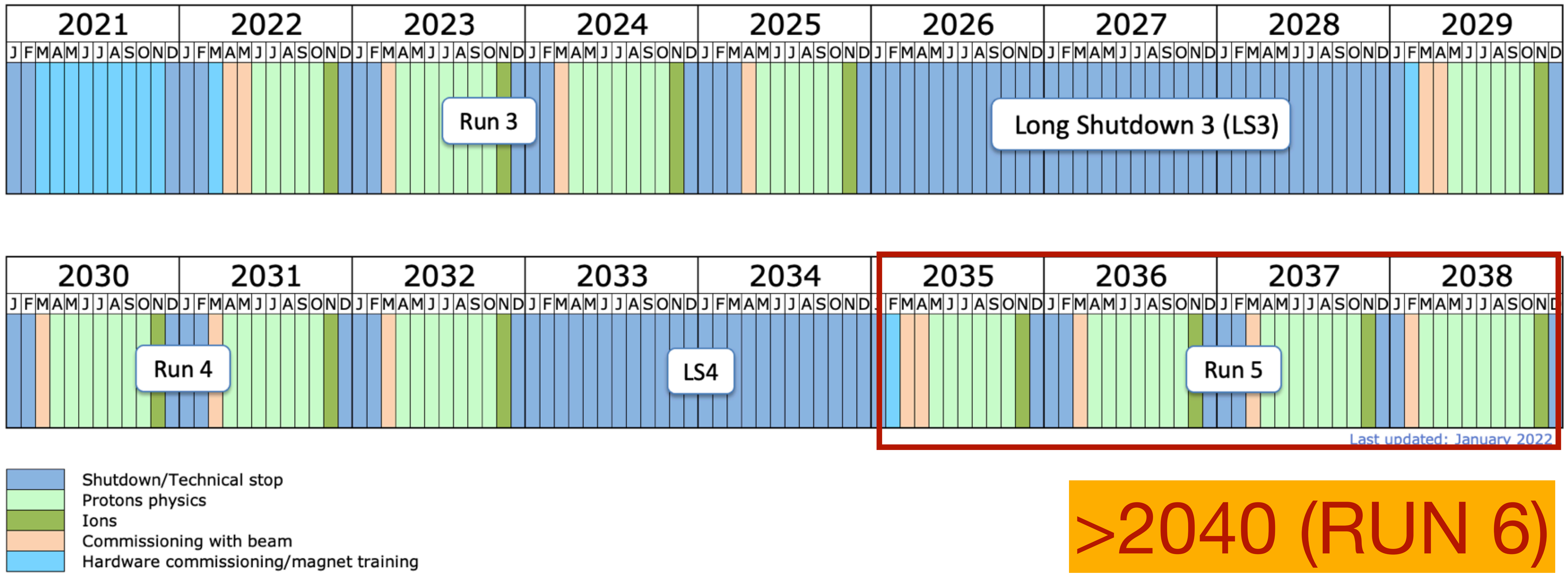
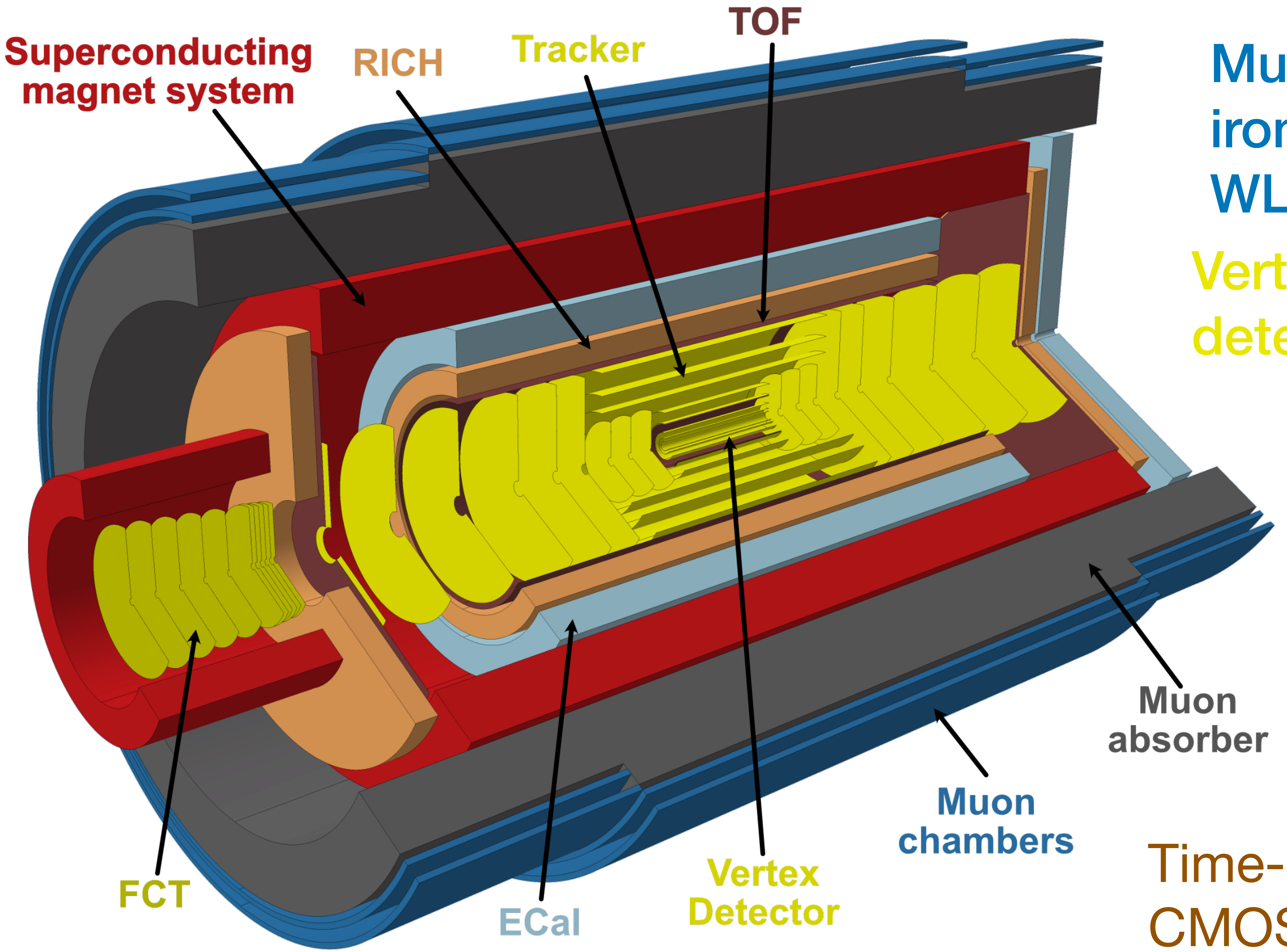


>2040 (RUN 6)

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

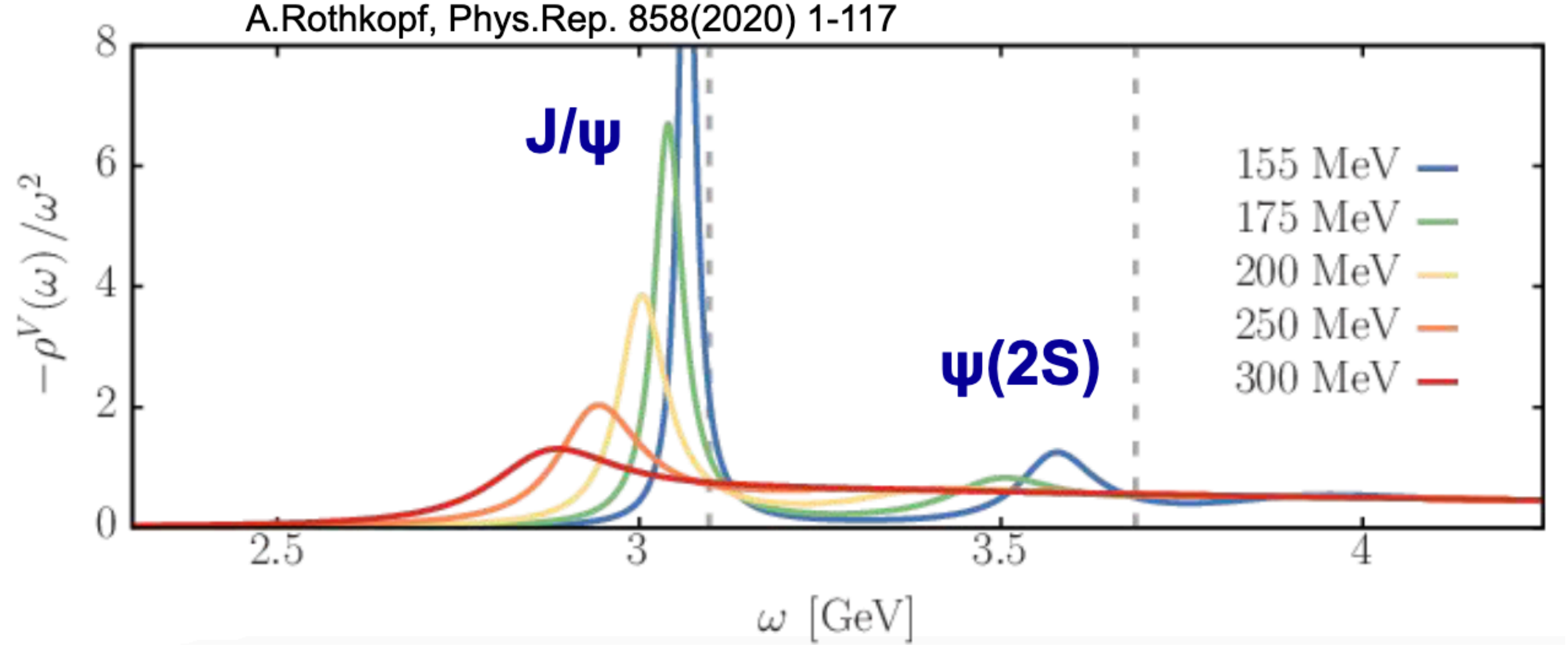
Tracker: monolithic CMOS sensors

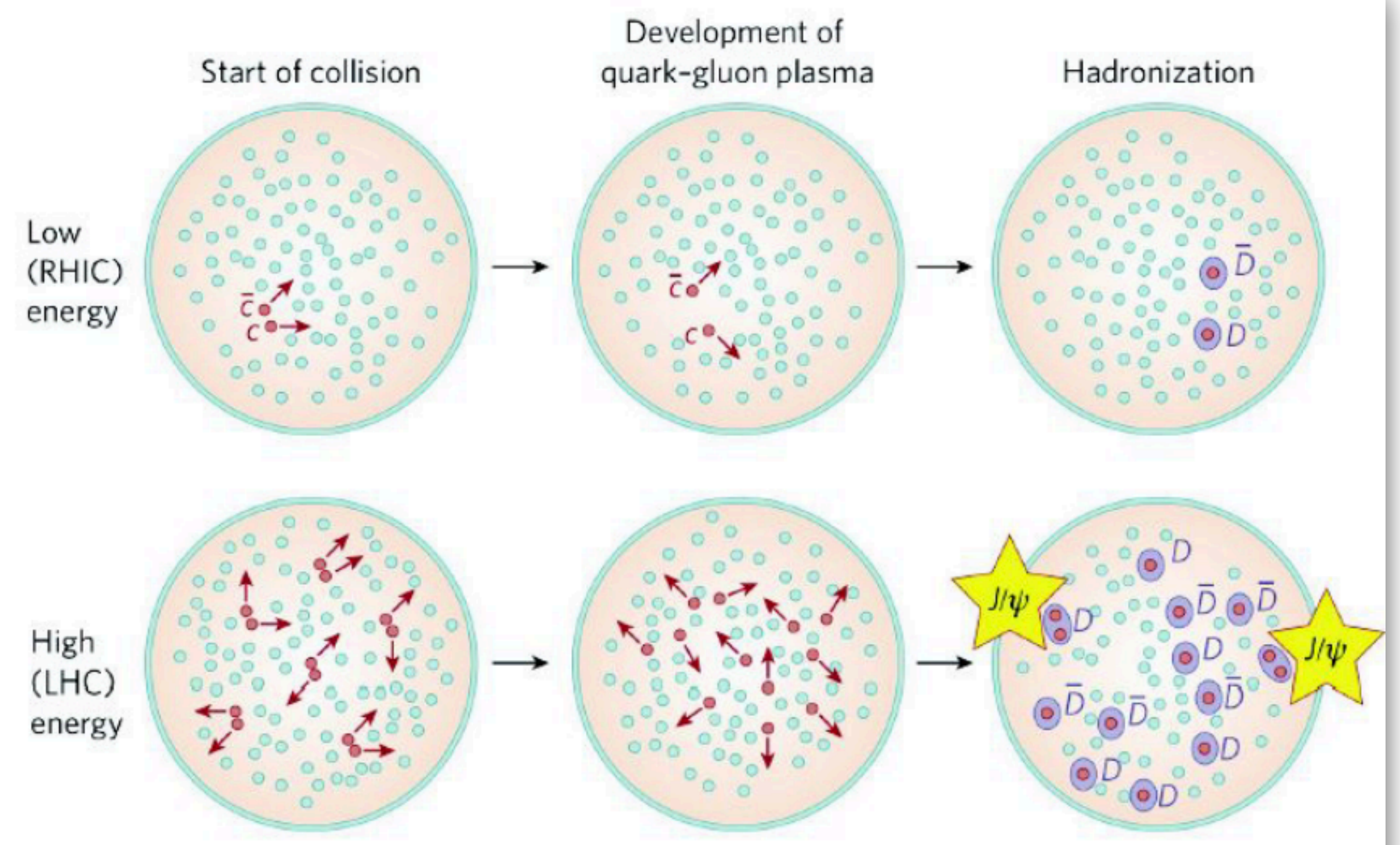
Time-of-flight detector monolithic CMOS sensors with gain layer

Selected topic: charmonium states

Charmonium production as probe of QGP in heavy-ion collisions

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



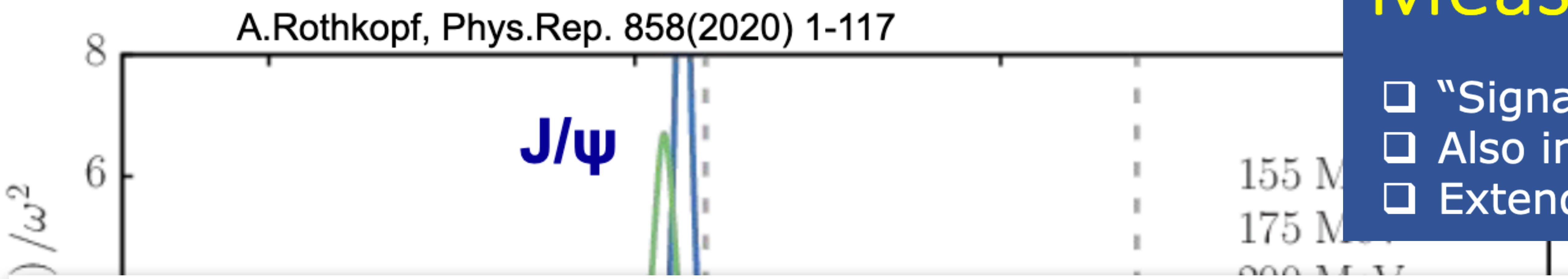


Braun-Munzinger, P., Stachel, J. The quest for the quark–gluon plasma. *Nature* 448, 302–309 (2007)

Sequential dissociation → expectation of stronger suppression for ψ(2S) w.r.t J/ψ

Selected topic: charmonium states

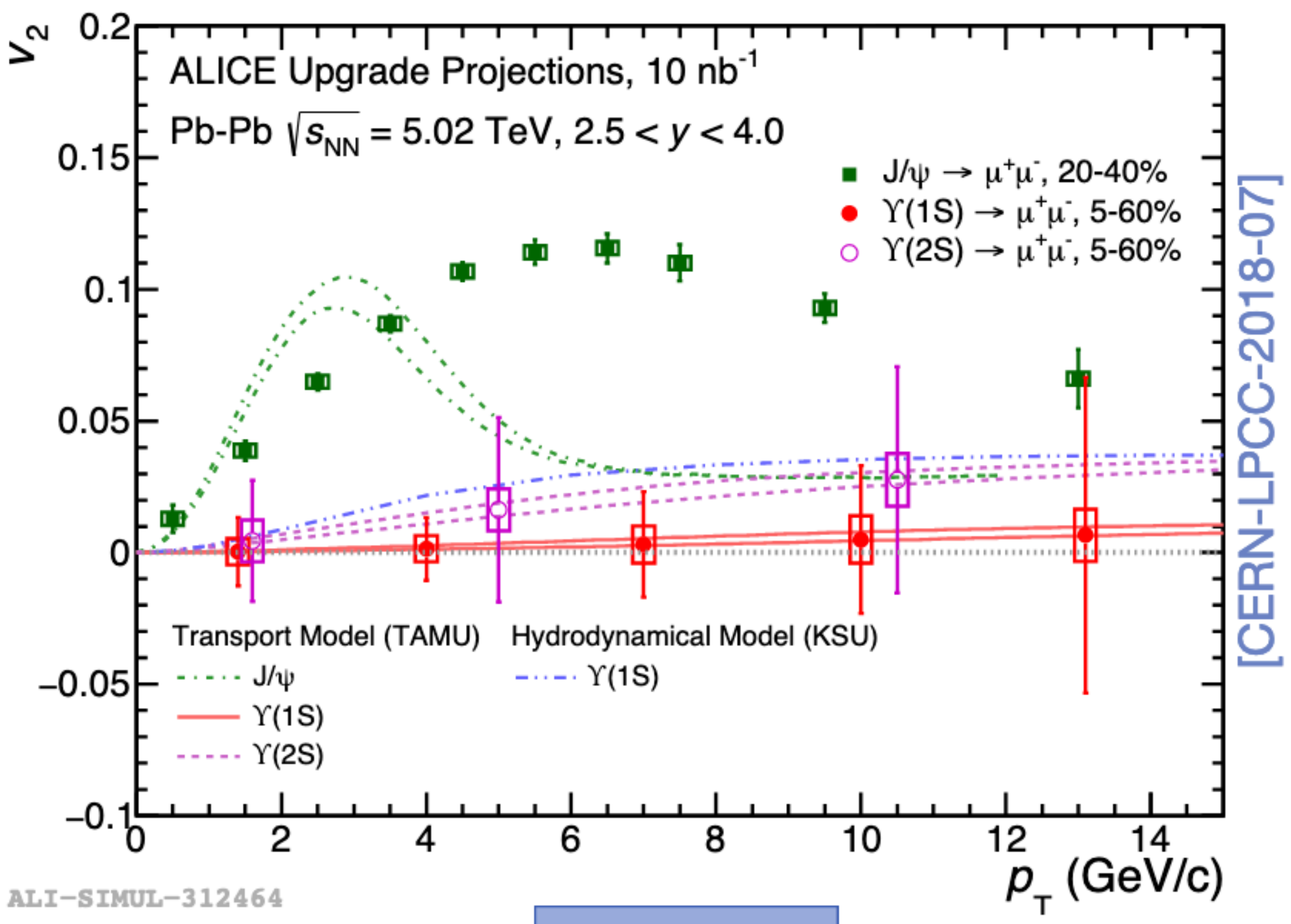
Charmonium production as probe of Q



Measuring quarkonia down to zero p_T

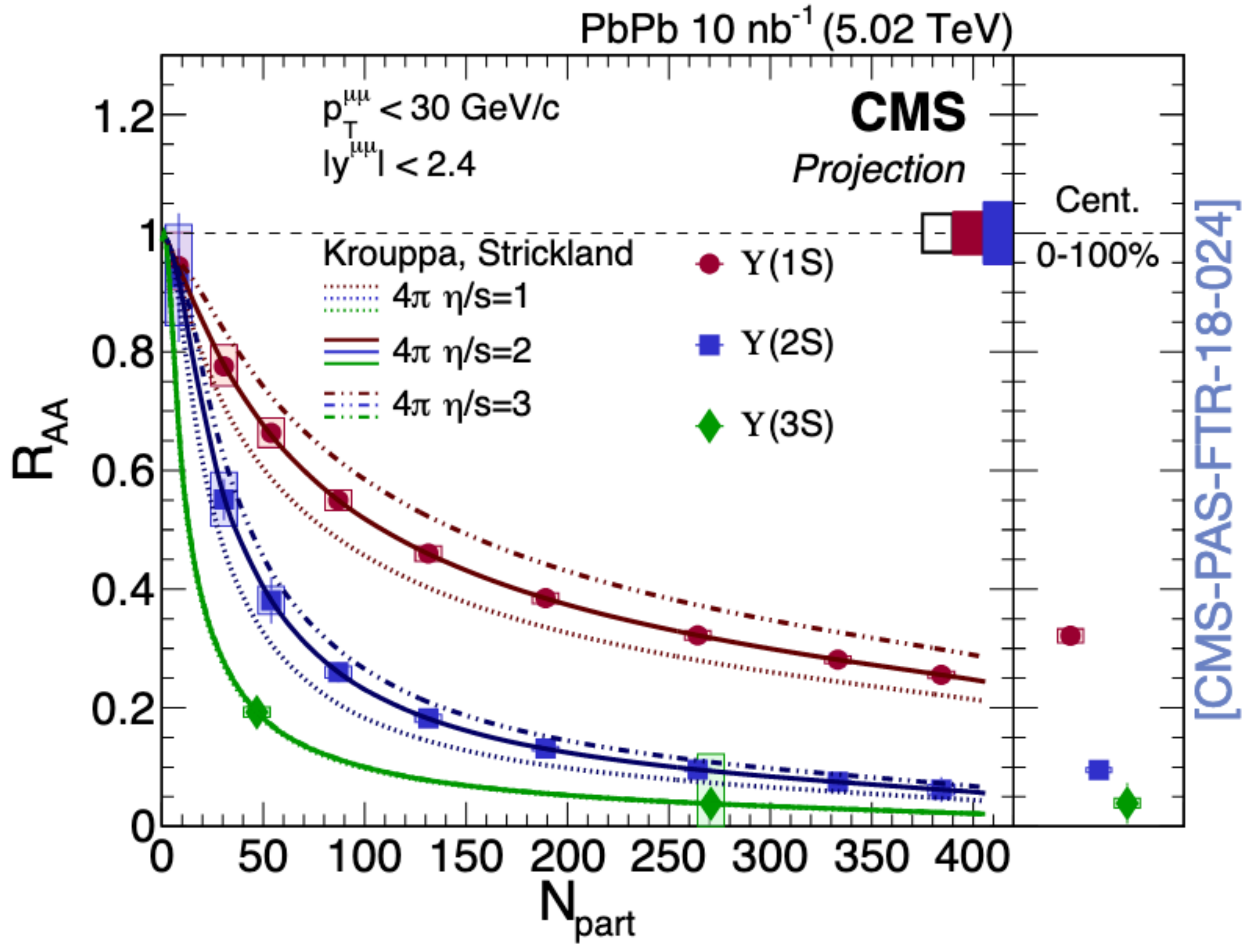
- ❑ “Signature” ALICE feature from the beginning
- ❑ Also in the future a distinctive factor wrt ATLAS/CMS
- ❑ Extend this capability in ALICE3 for the muon decay channel at midrapidity

v_2 for J/ψ, Υ



Run 3 & 4

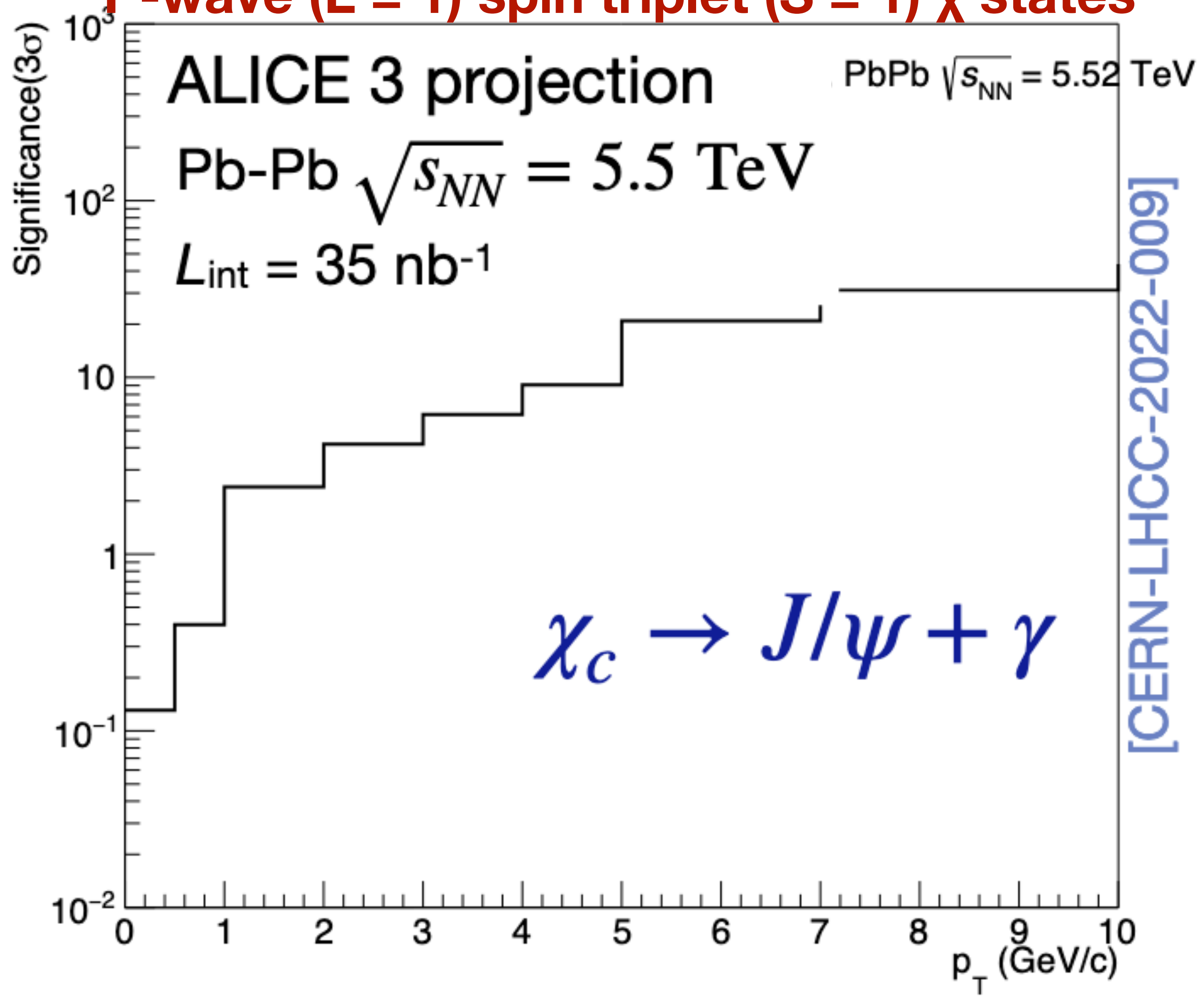
R_{AA} for Υ states



Run 3 & 4

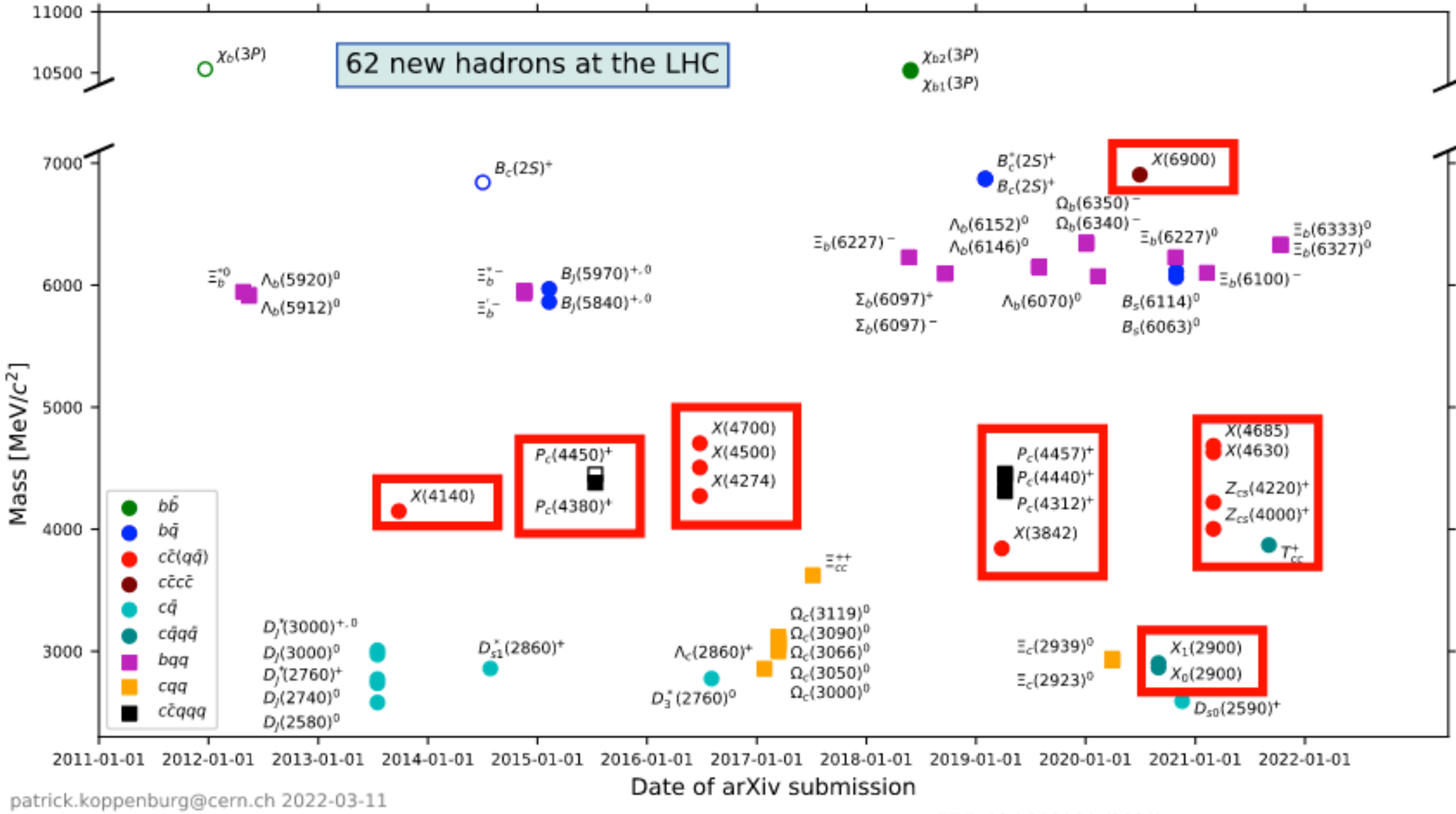
χ_c in Pb-Pb collisions

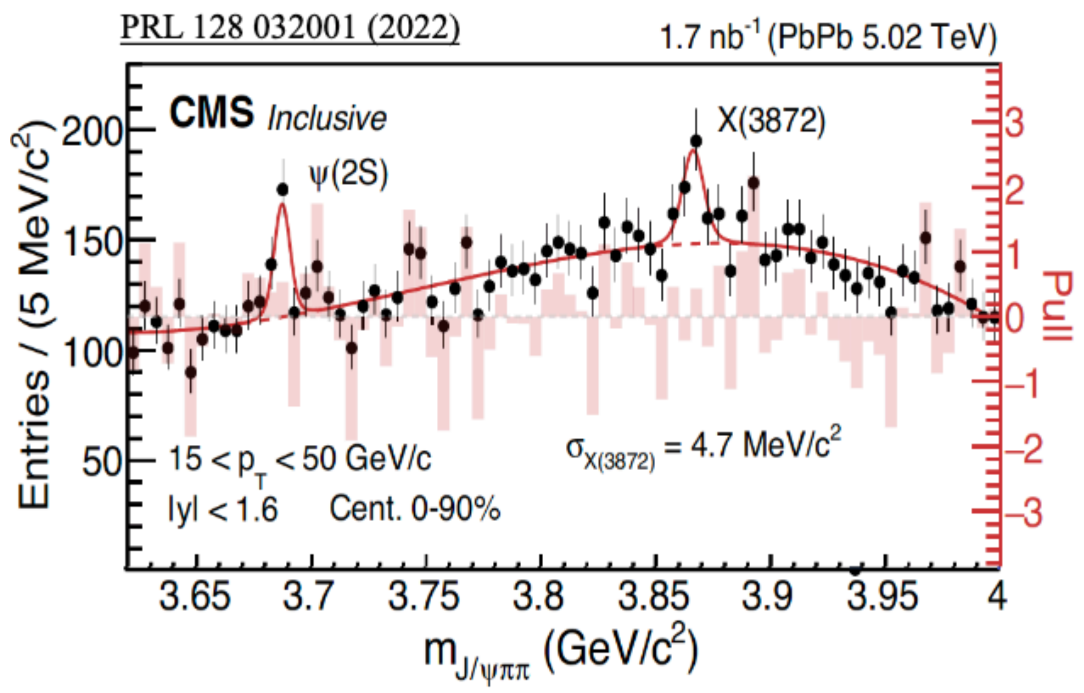
P-wave (L = 1) spin triplet (S = 1) χ states



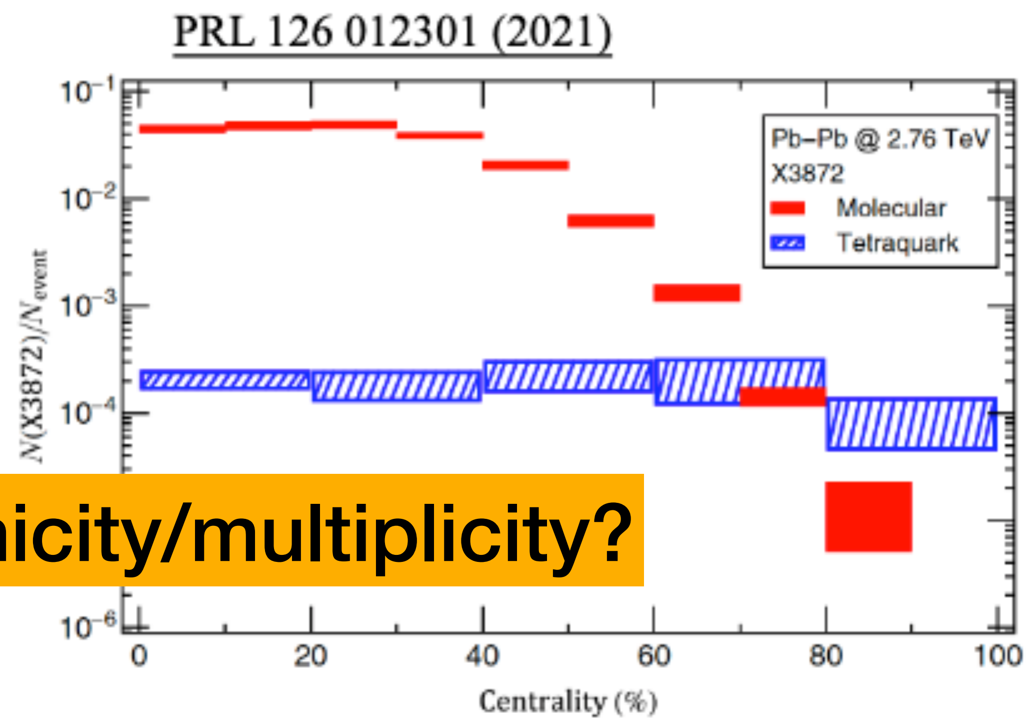
Run 5 & 6

Selected topic: exotica

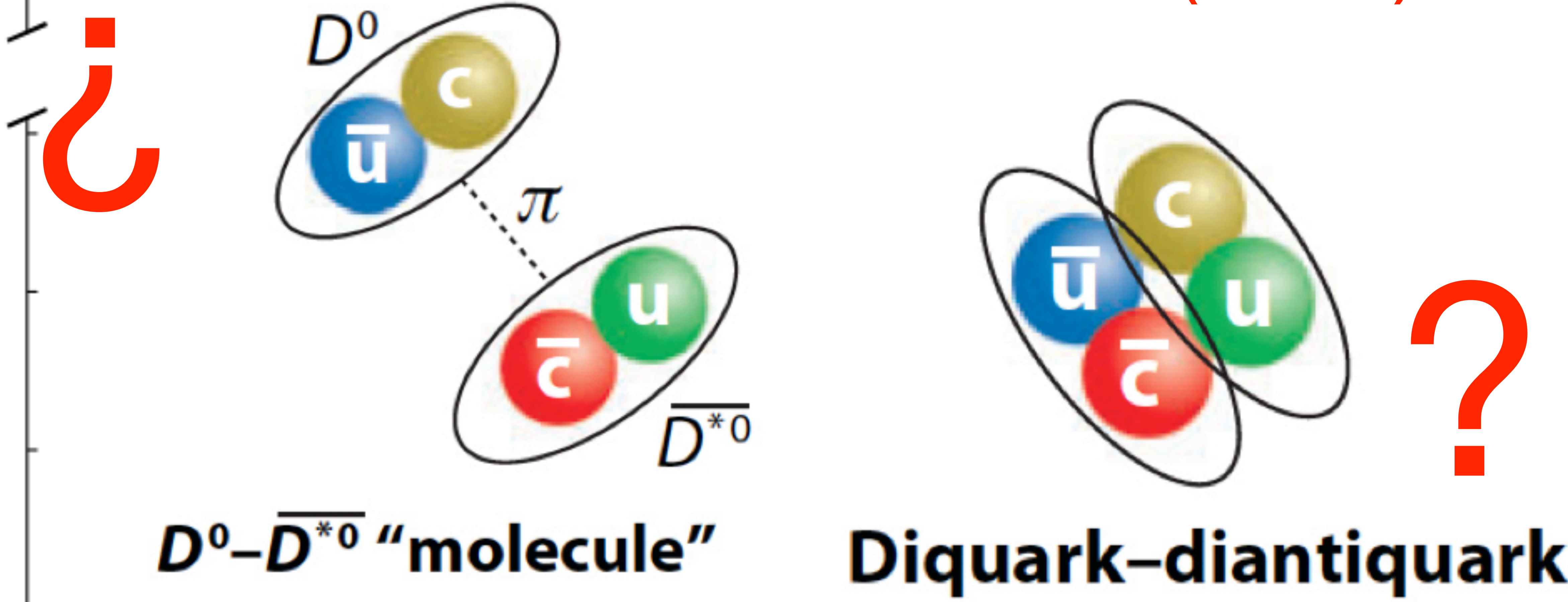




pp vs flatenicity/multiplicity?



X(3872)



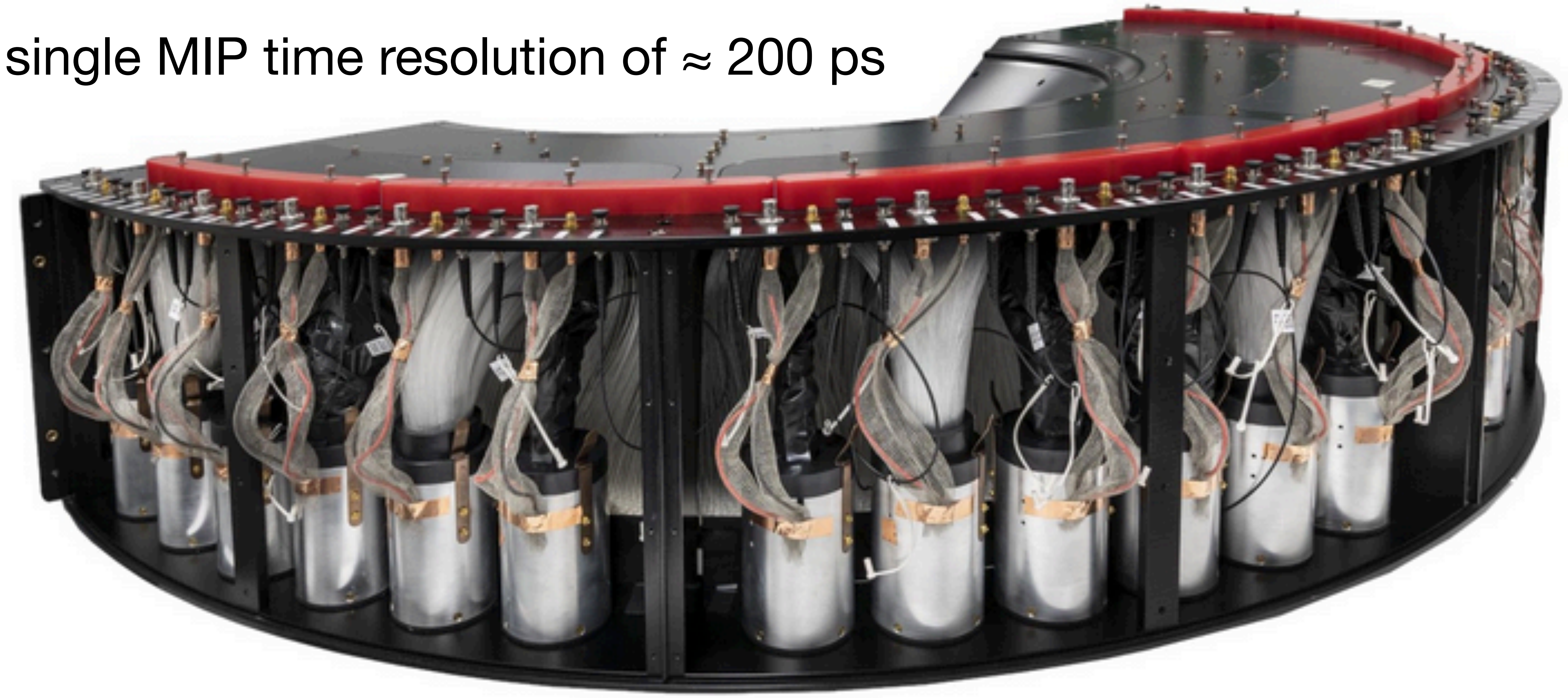
ALICE 3 muonID: muons down to low $p_{\rm T}$ (~1.5 GeV/c at $\eta = 0$) ->unique $p_{\rm T}$ reach to study the formation and dissociation of e.g. X(3872) in HIC at thermal momentum scales.

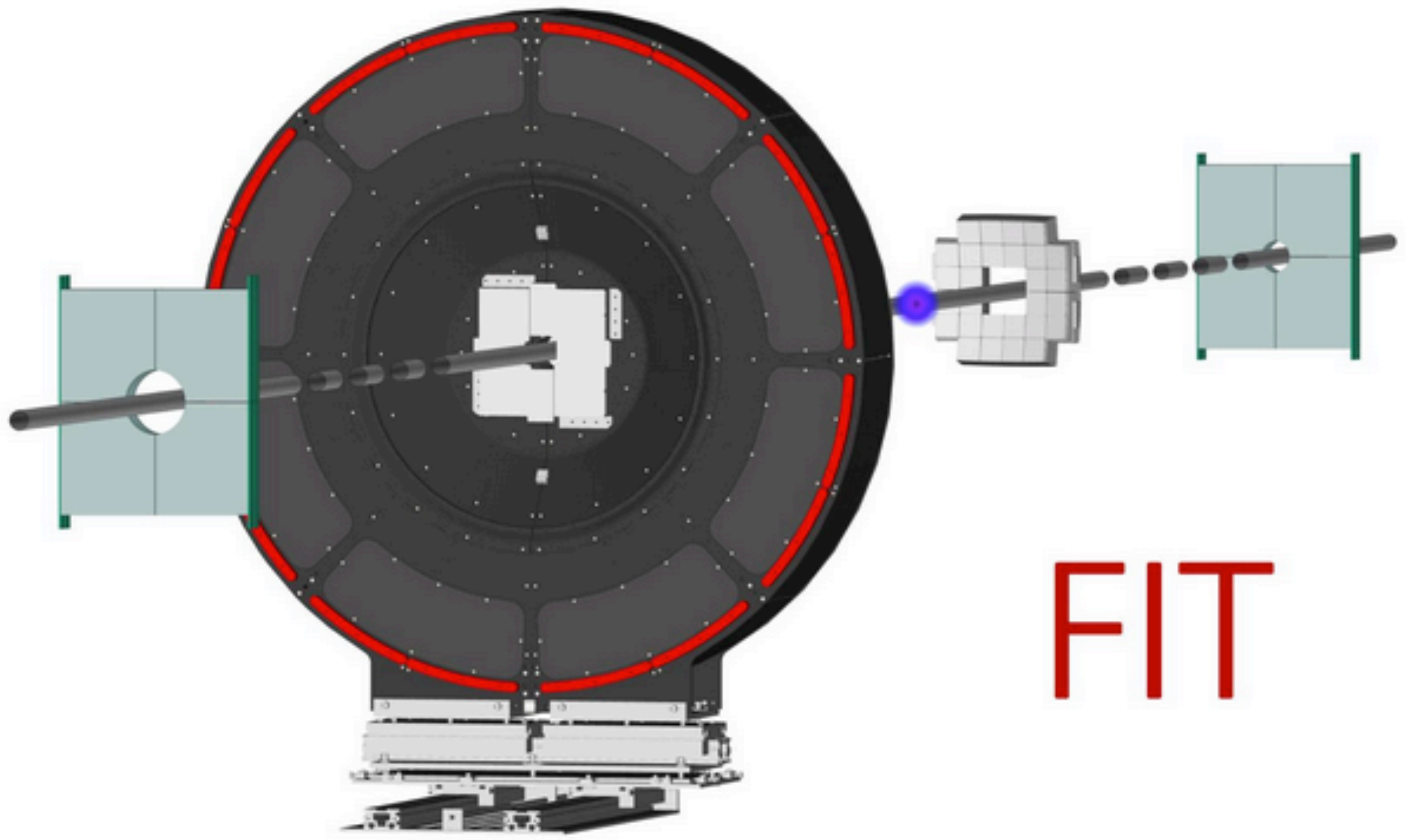
CMS: $p_{\rm T} > 10$ GeV/c.

Expertise of the Mexican team

- Run 1 and 2: ACORDE and V0 detectors (scintillation detectors + readout electronics)
- Run 3: new FV0 and FDD detectors (scintillator detectors), readout of TPC
- RPC and GEM detectors
- Monte Carlo simulations (Geant4, Garfield++)
- Data analysis

single MIP time resolution of ≈ 200 ps





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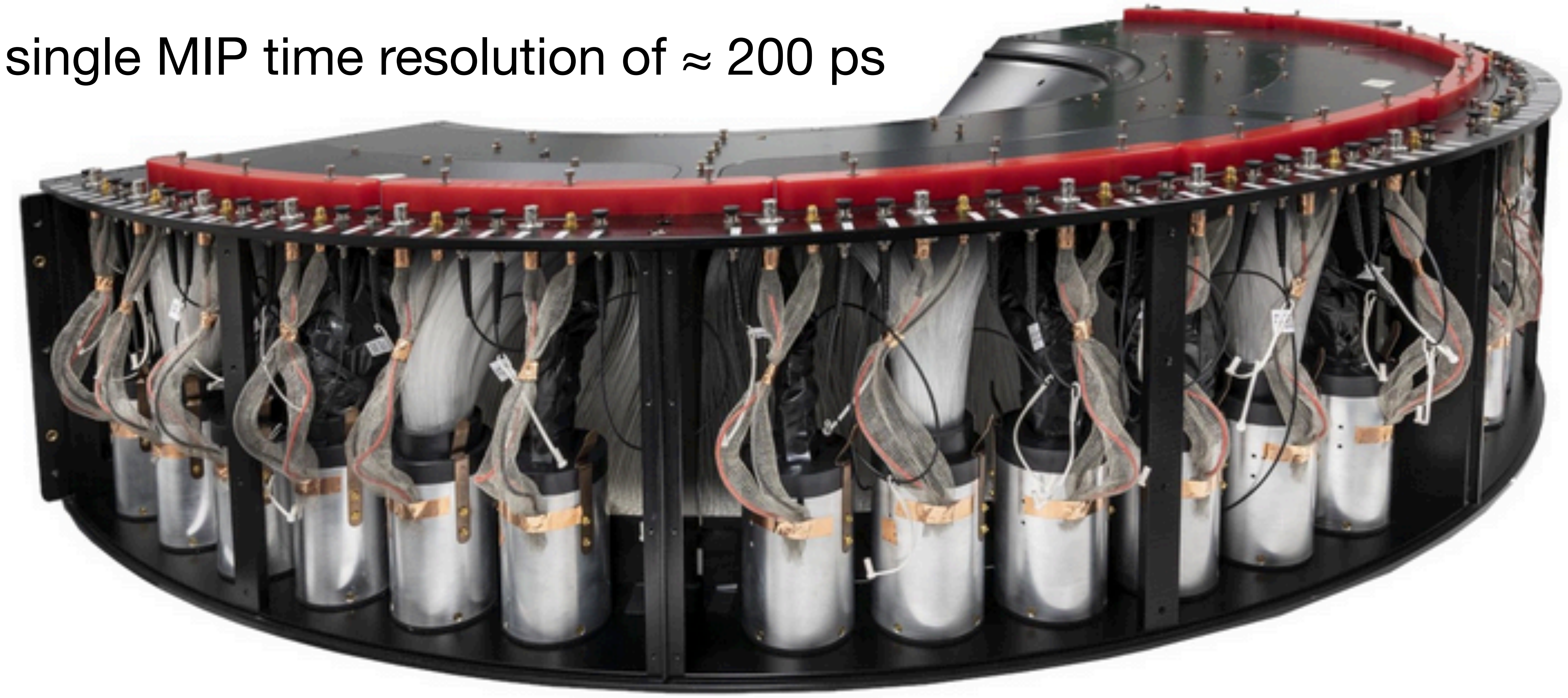
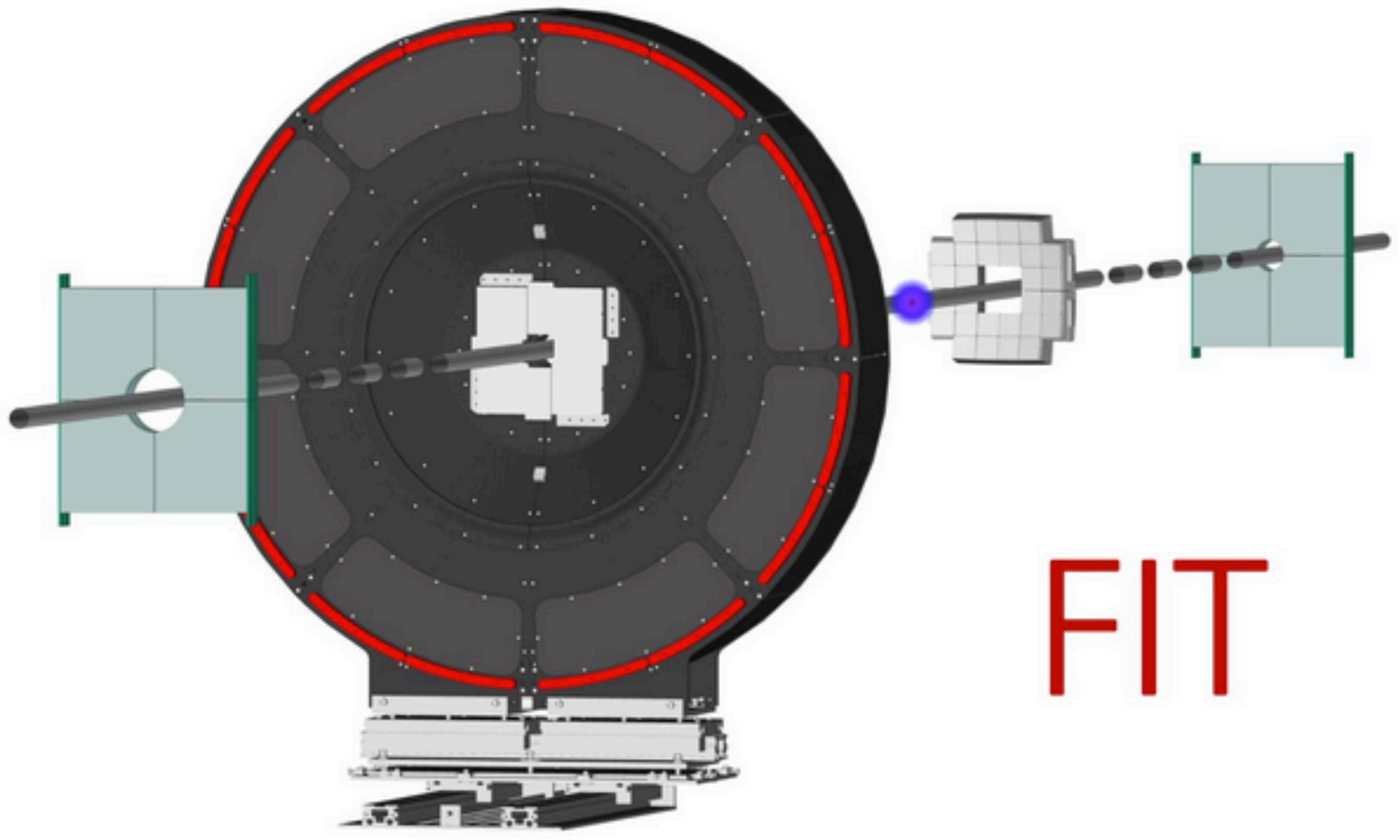
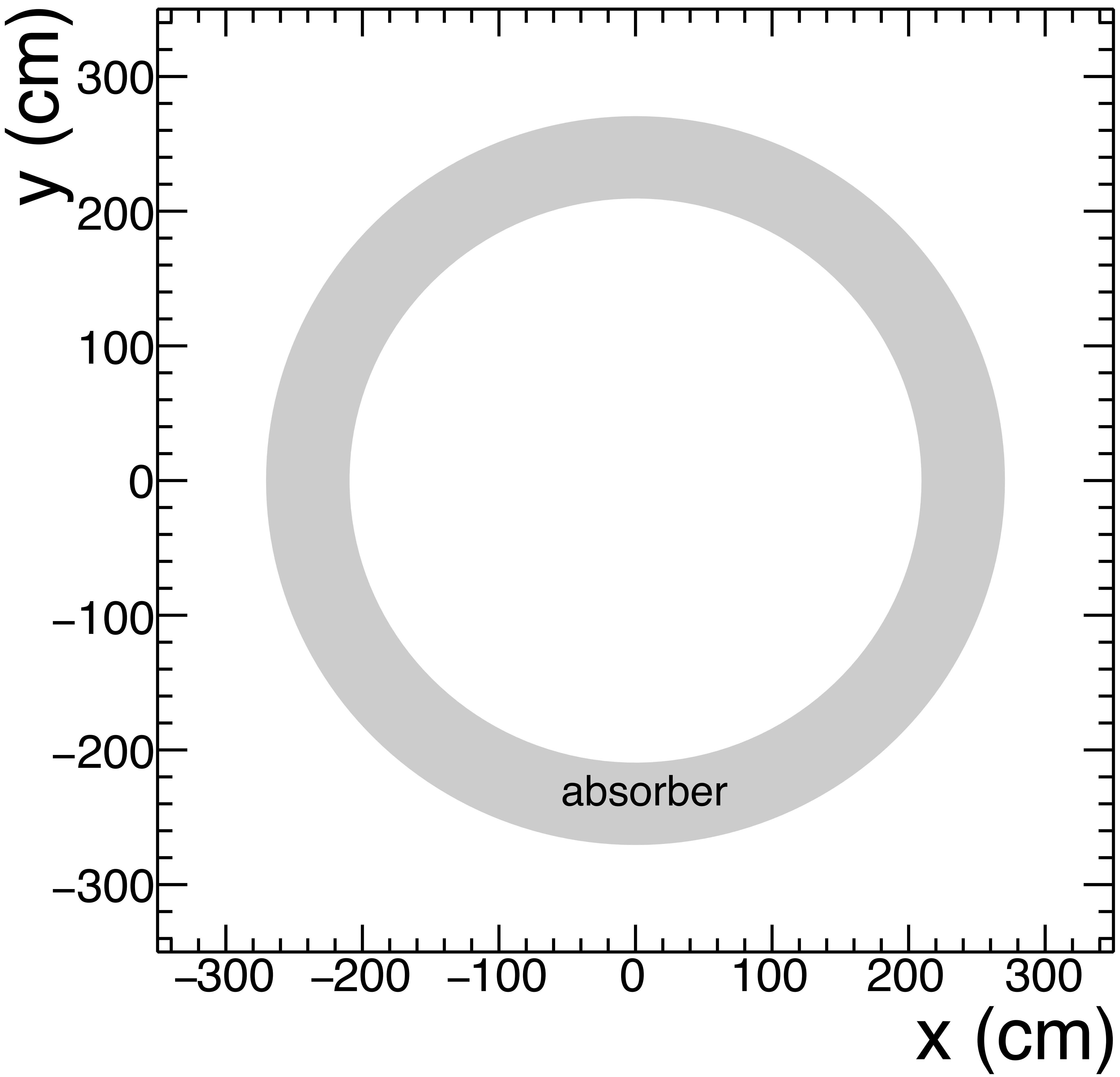




Let us move to the next challenge: muonID looks like a natural option

MuonID (baseline option)

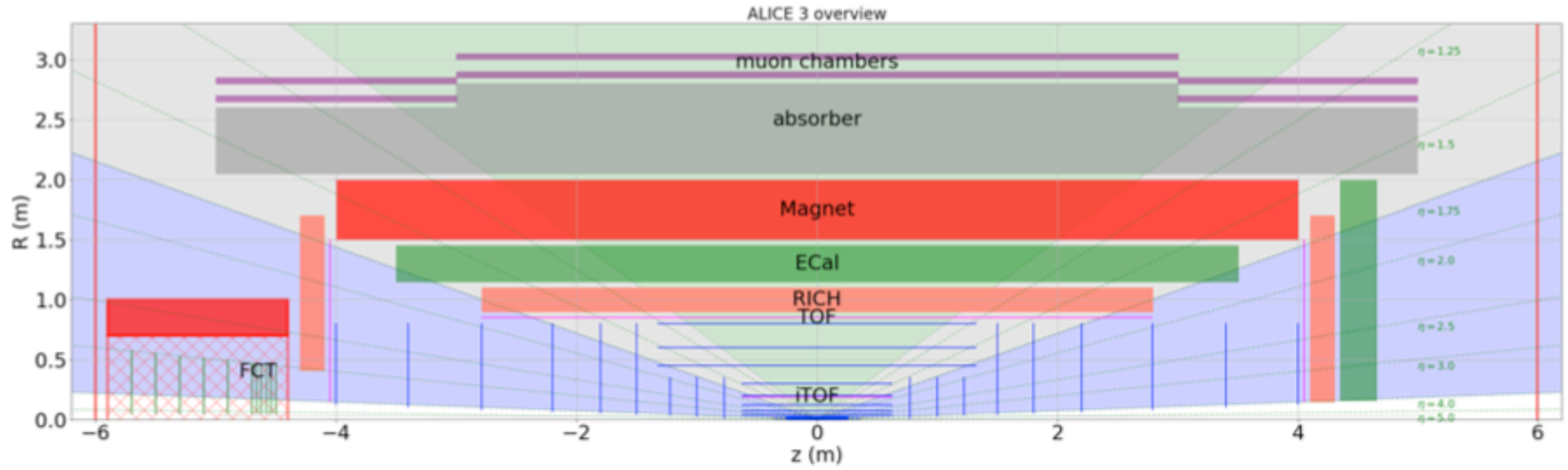


Absorber (iron)

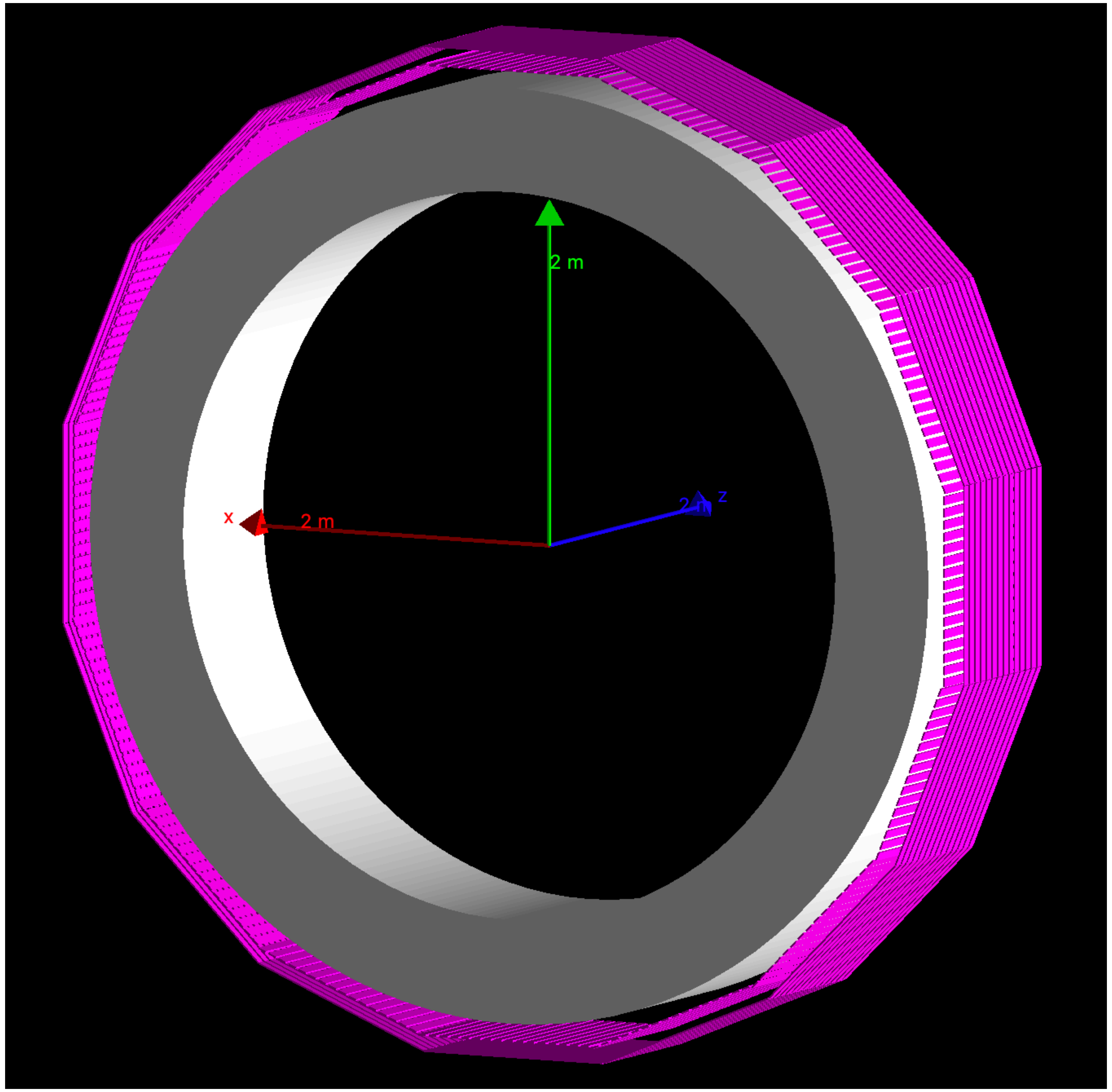
$R_{\mathrm{a,in}} = 2.05\,\mathrm{m},\ R_{\mathrm{a_c,out}} = 2.8\,\mathrm{m},\ R_{\mathrm{a_f,out}} = 2.6\,\mathrm{m}$

$L_{\mathrm{c}} = 6\,\mathrm{m}\ \ L_{\mathrm{f}} = 10\,\mathrm{m}$

The absorber should be optimised to be efficient for the reconstruction of J/ψ at rest (muons down to $p_{\mathrm{T}} \approx 1.5\,\mathrm{GeV}/c$) at $\eta = 0$



Muon chamber (baseline option)



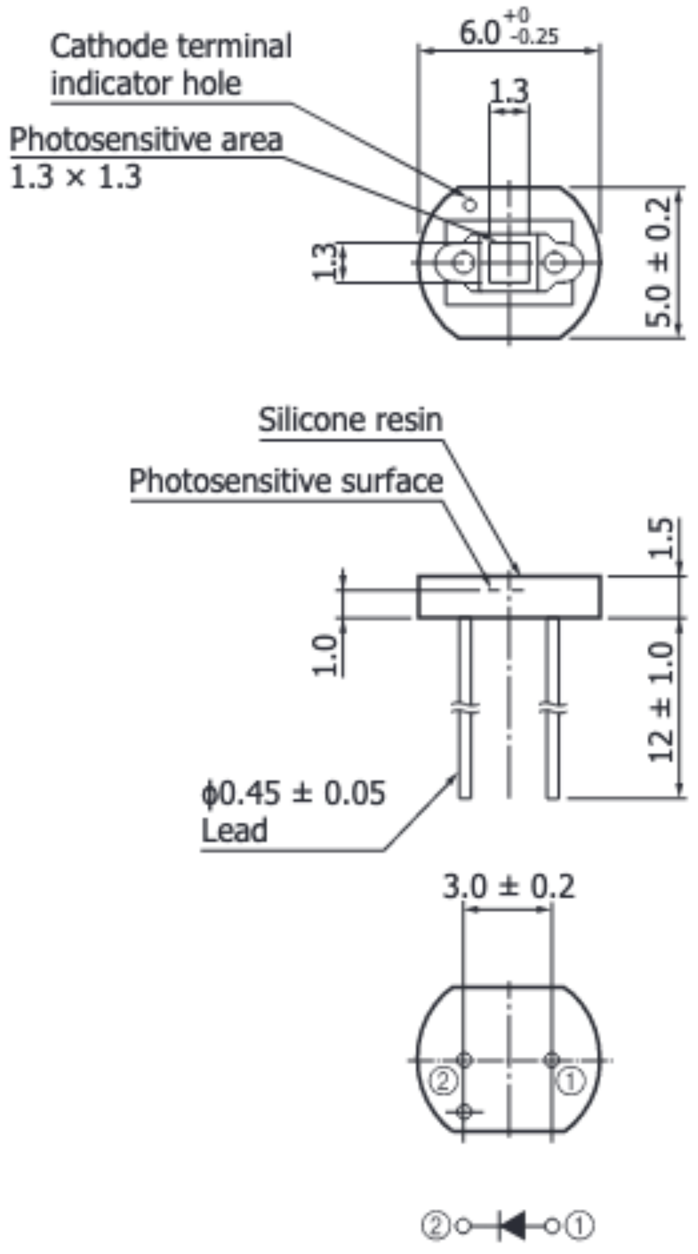
Muon chambers (1x1m²)

Scintillator bars equipped with wave-length shifting fibres (width 5 cm, gap 10 cm)

Readout

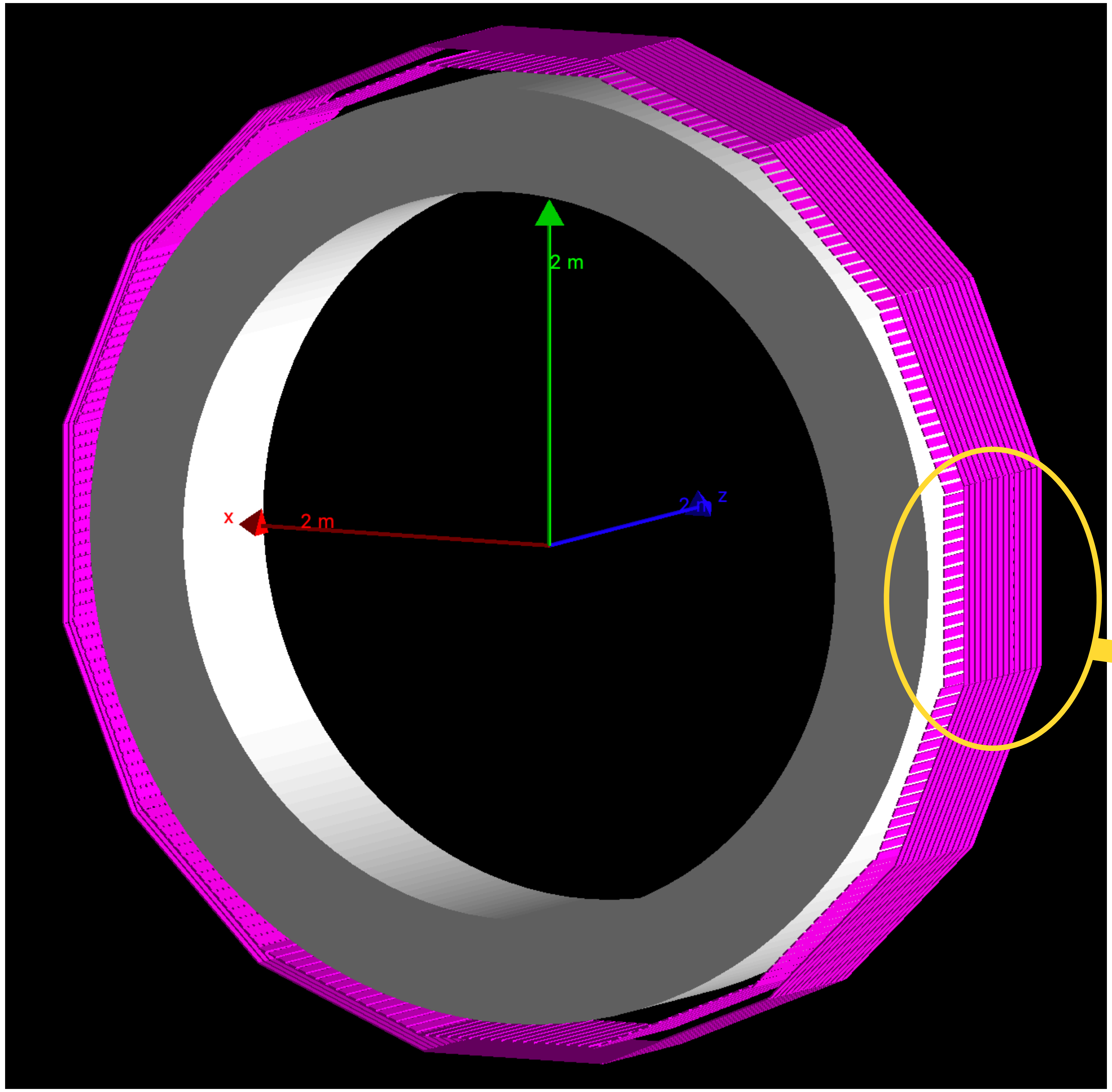
Semiconductor photosensor ("SiPM") by Hamamatsu:

- Compact, high photon detection efficiency, immunity to B-field



Other options: NUV-SiPMs / RGB-SiPMs by AdvanSiD

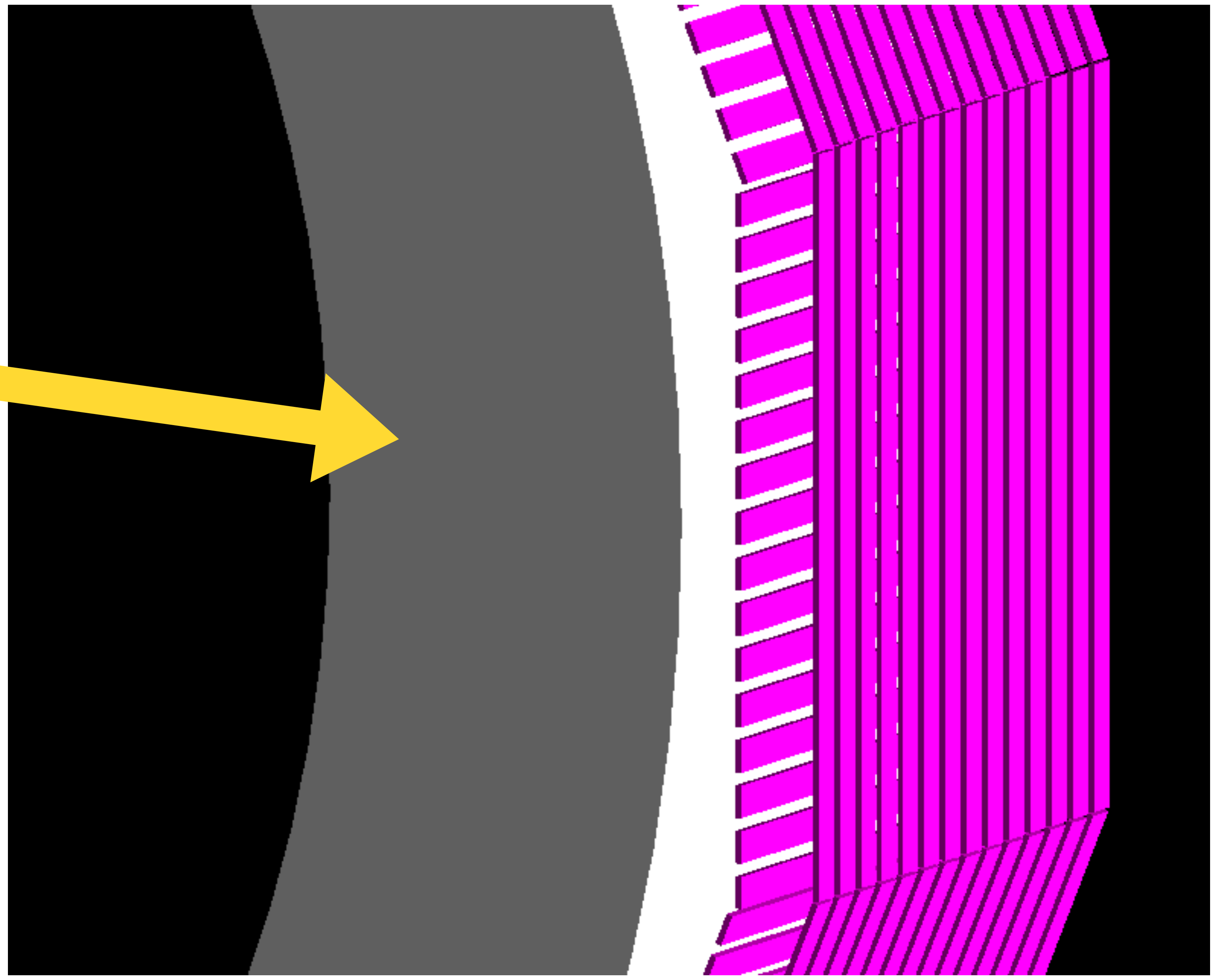
Muon chamber (baseline option)



Muon chambers (1x1m²)

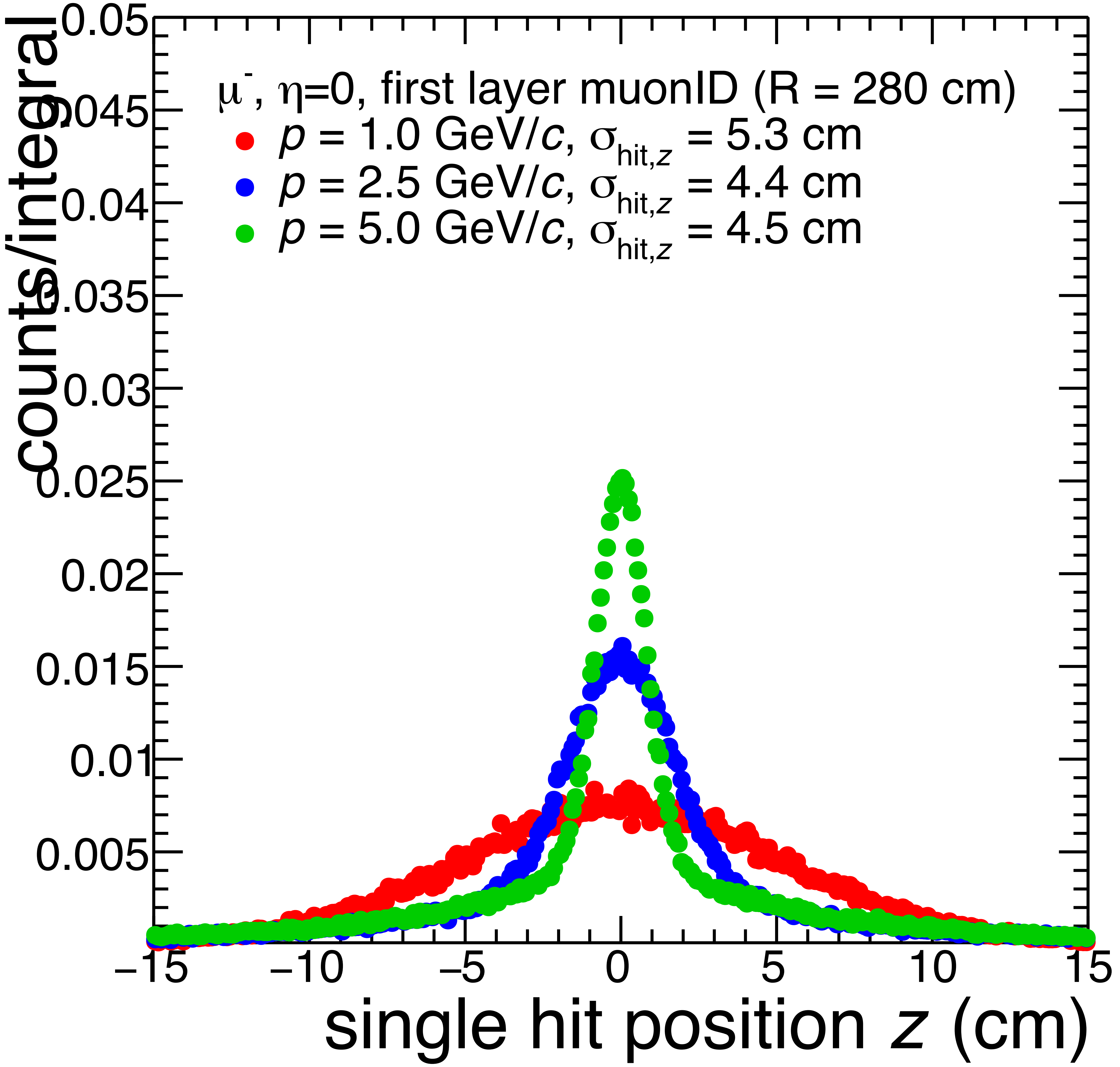
Scintillator bars equipped with wave-length shifting fibres (width 5 cm, gap 10 cm)

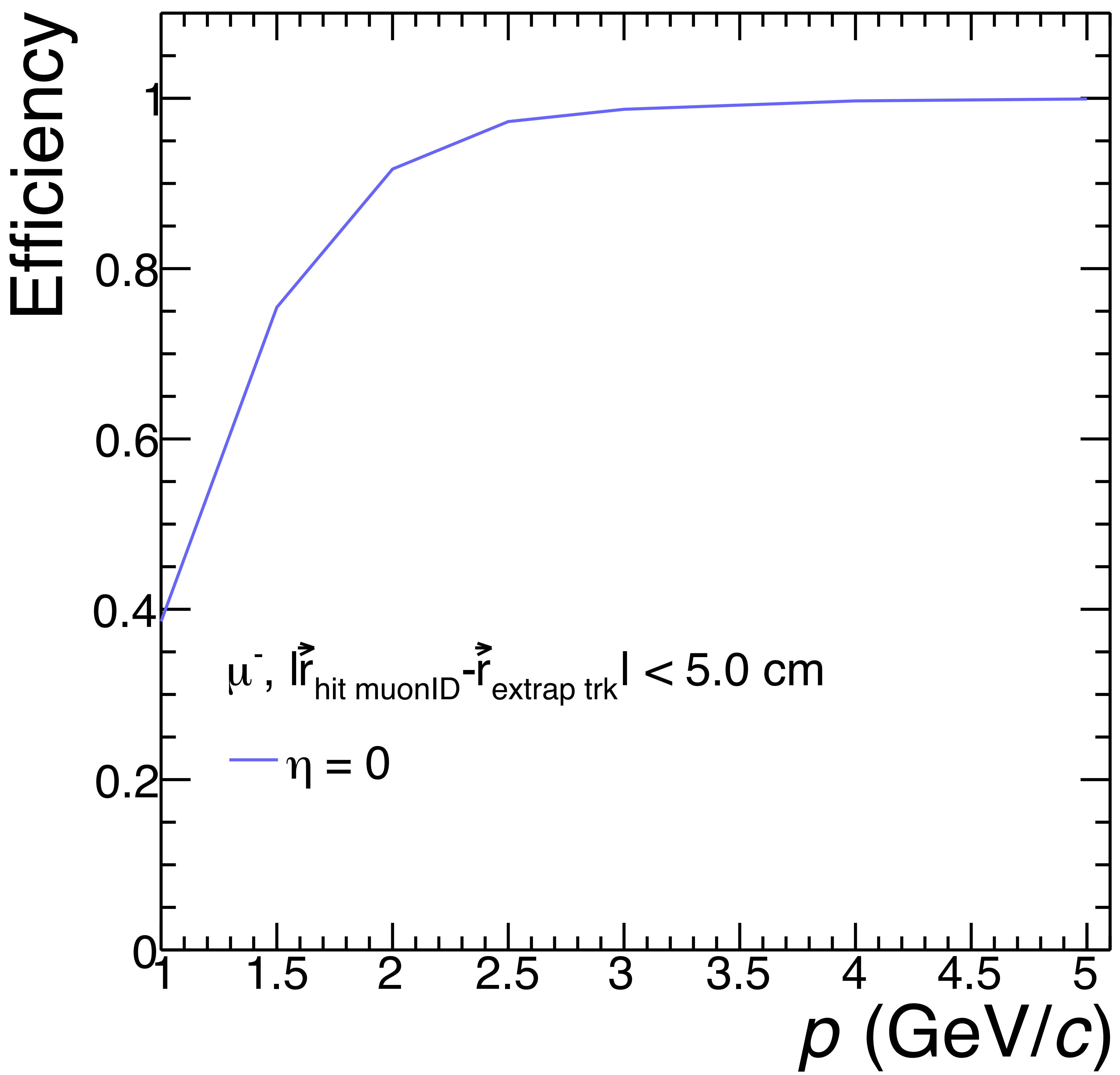
*To allow a good visibility of the geometry I exaggerated the gap between scintillation bars



We need to cover ~400m² of area

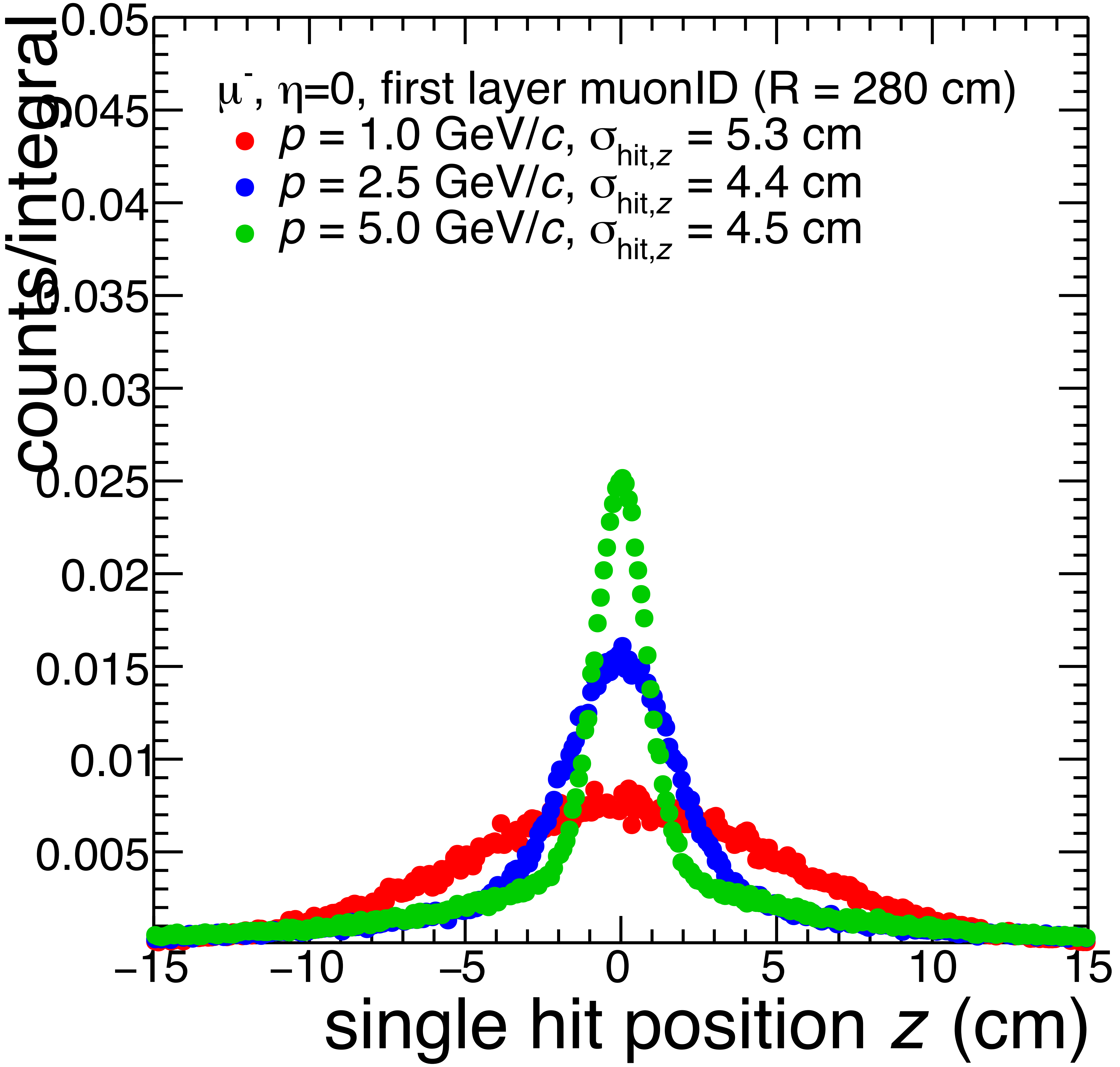
Geant4 simulations

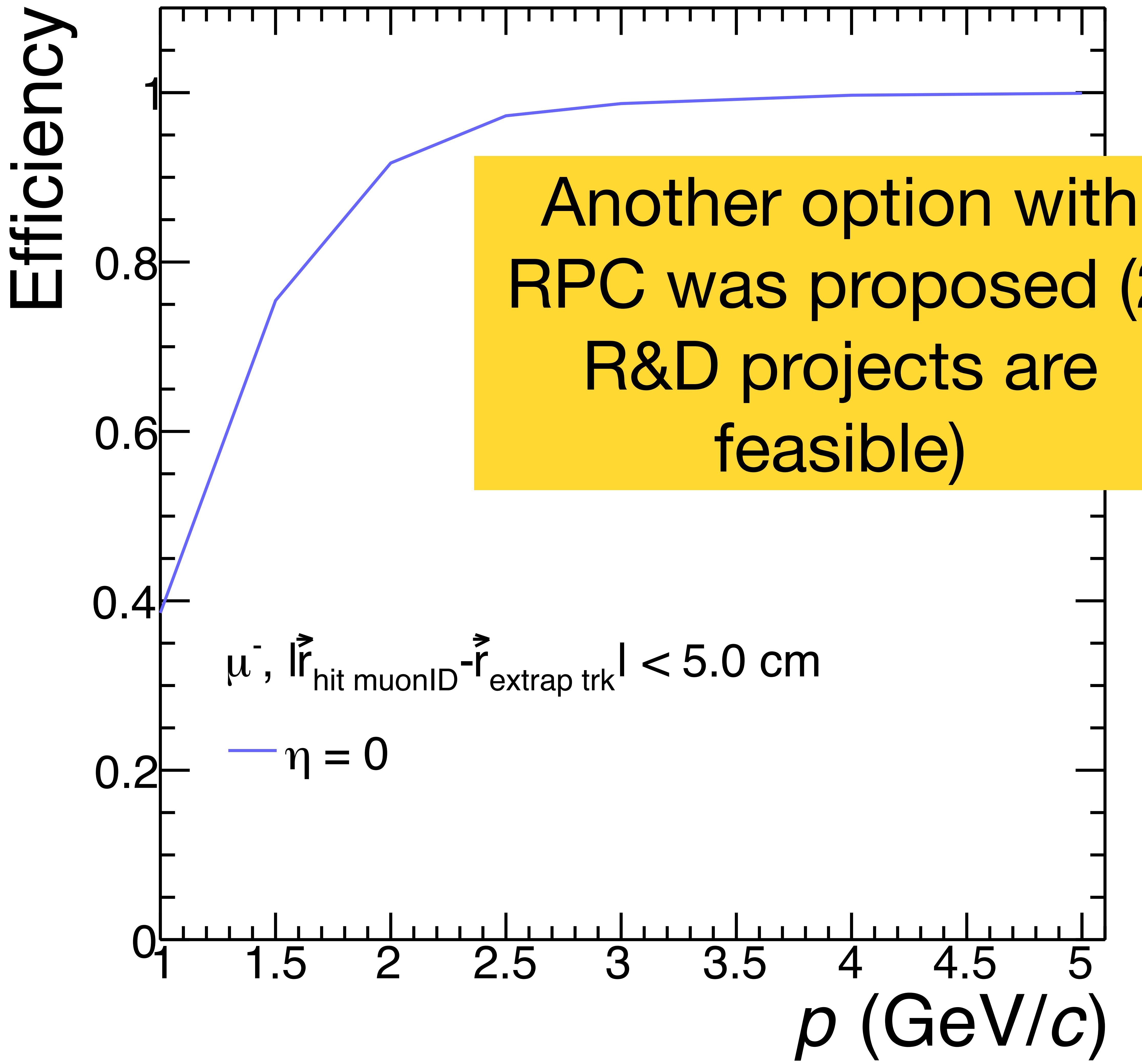




Scintillator: vinyltoluene, gap between scintillator bars: 2mm

Geant4 simulations





Another option with RPC was proposed (2 R&D projects are feasible)

Scintillator: vinyltoluene, gap between scintillator bars: 2mm

Extruded scintillator?

Low cost, if equipped with WLS fibre ->good optical response

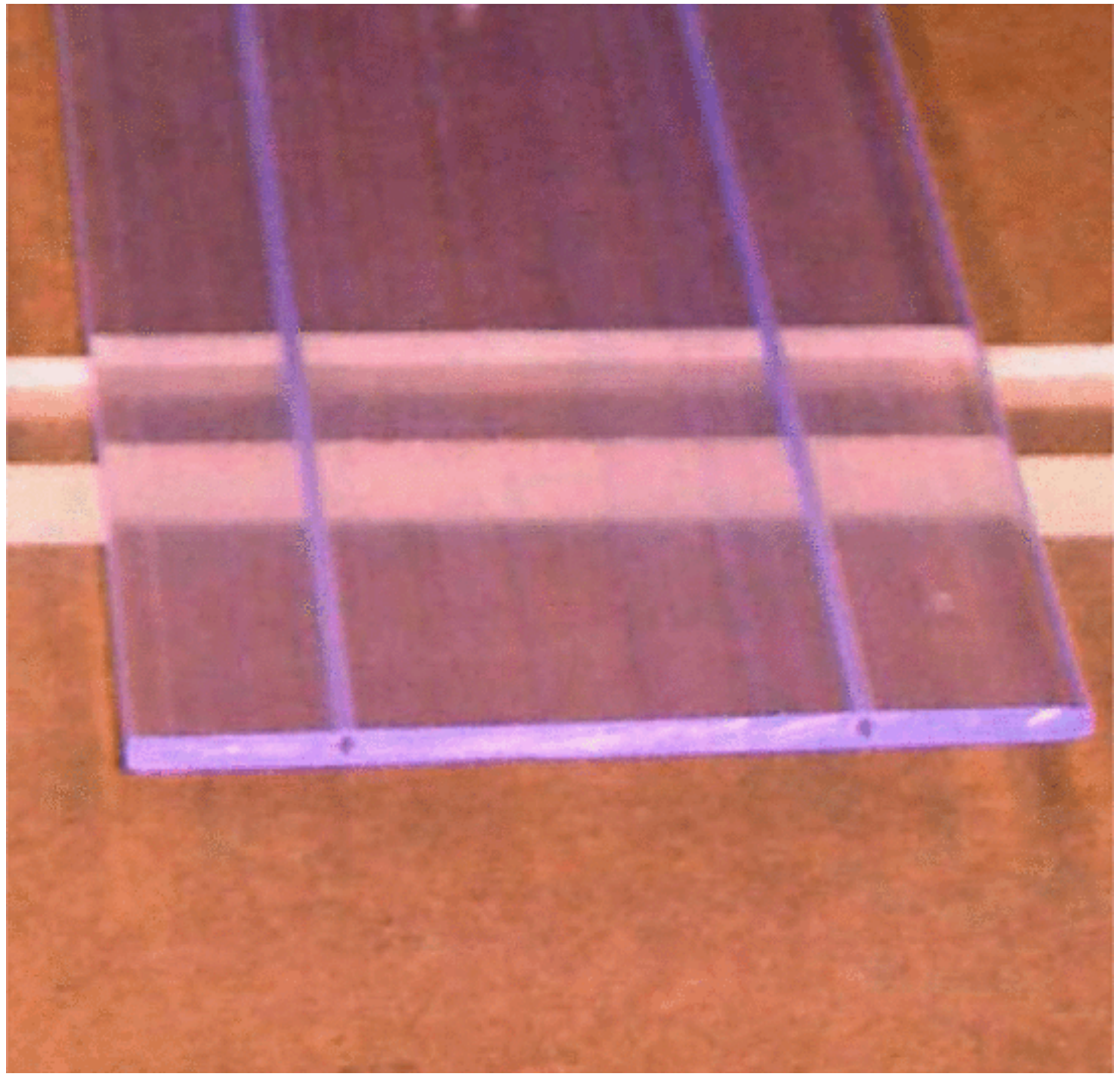
Fermilab extrusion facility (FNAL-NICADD)

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

May need to produce/test new die

Other suppliers?

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



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

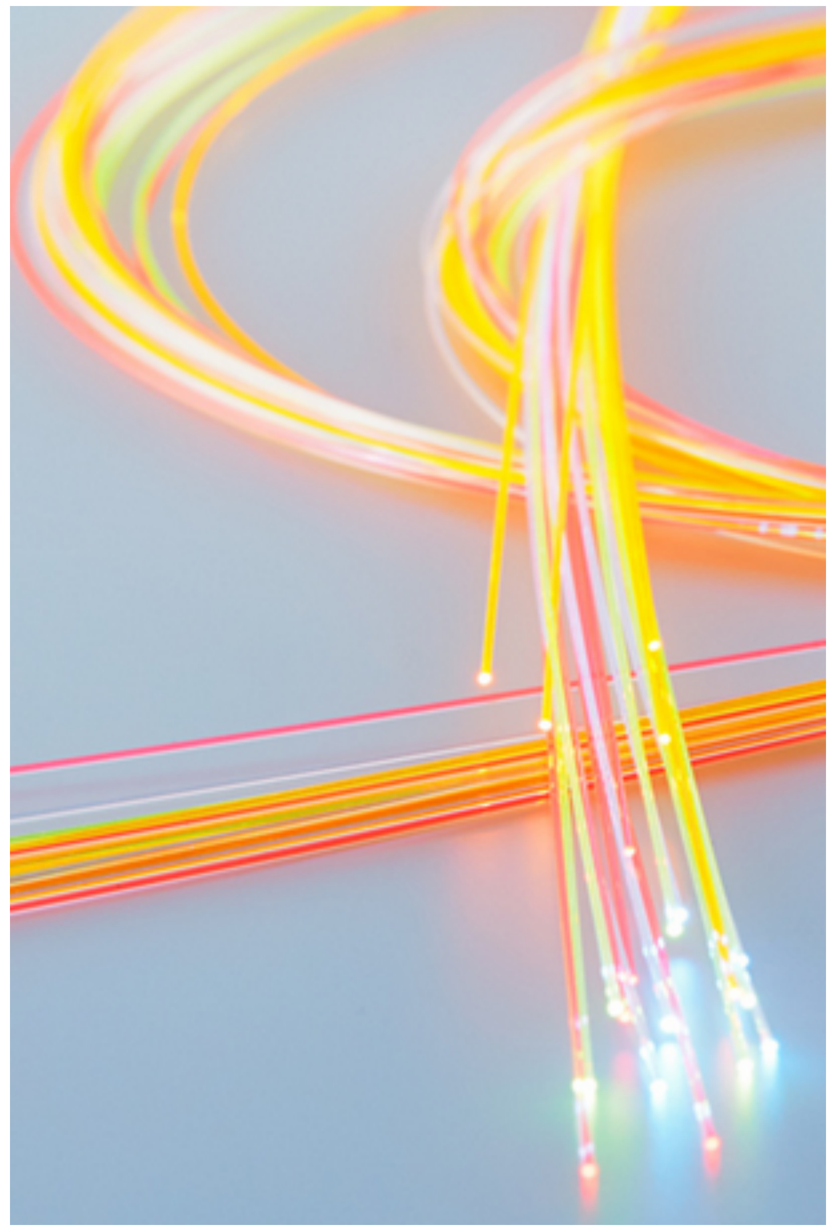
Fibres

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

Companies: Saint-Bobain and Kuraray factories

- Multiclad fibres with long attenuation length (~2-3 m) and good trapping efficiency (~5%). Tests with other fibres smaller attenuation lengths

Type	Luminescence			Absorption Peak (nm)	Attenuation length² (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



Preliminary timeline

2022-2023

- Optimisation of the detector (MC simulations), background rejection, occupancy, …

2024-2026 (application for a CONACyT grant)

- R&D and test of components
  - 1) scintillation bars, fibre, SiPM, electronics, mechanical components
  - 2) RPC, gas mixtures, electronics, mechanical components
- Prototypes and beam test

2027

- Technical design report

2028 (application for a CONACyT grant)

- Mass production testing

2029-2031

- Start mass production/Construction of detector

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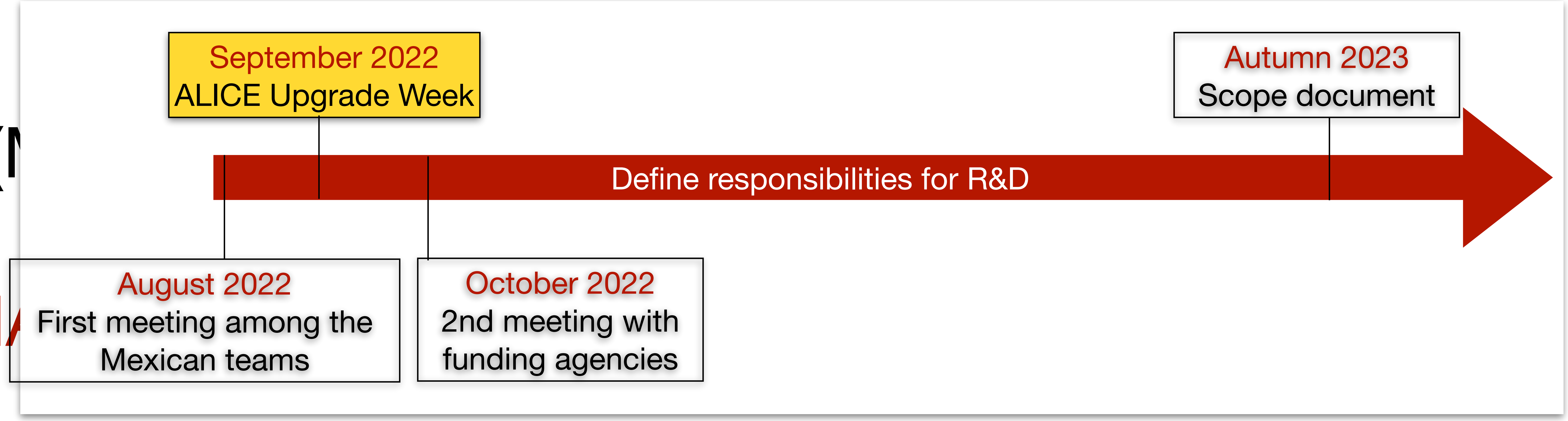

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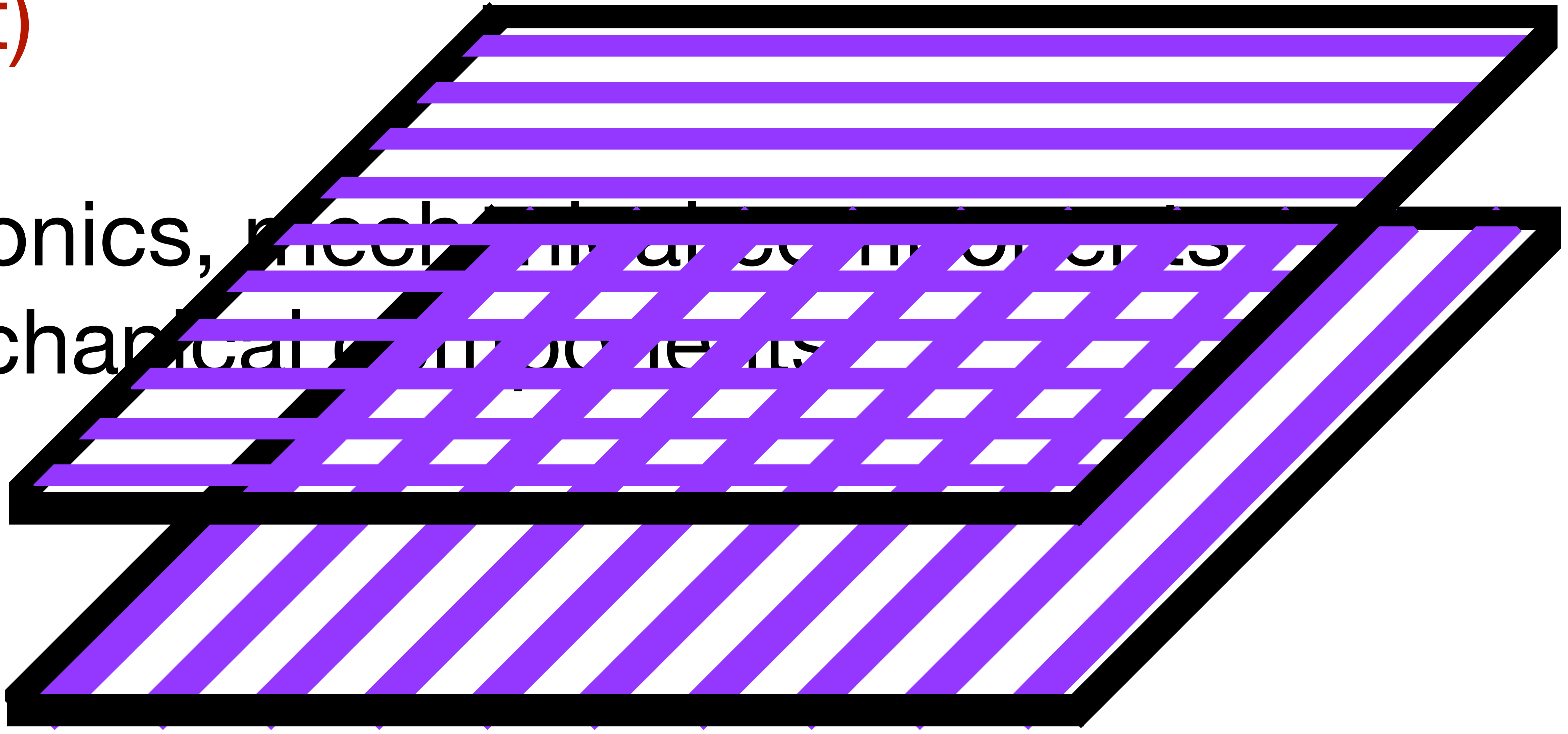

Install a small prototype for Run 4 (2029-2032) ?

Proposal for the organisation

Detector optimisation

- MC simulations (detector + physics performance)

Plastic scintillator and WLS fibres

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

RPCs (eco gases)

Mechanical structure

Electronics

- FEE, DAQ

Weekly meetings

Production of extruded plastic in Mexico? collaboration with Chemical Departments ? Partnership with industry ?

Questions to be addressed

What is the required time resolution ?

What would be the level of background ?

Will we need some cooling ?

Radiation Hardness/Tolerance of Si Sensors ?

Magnetic field effects ?

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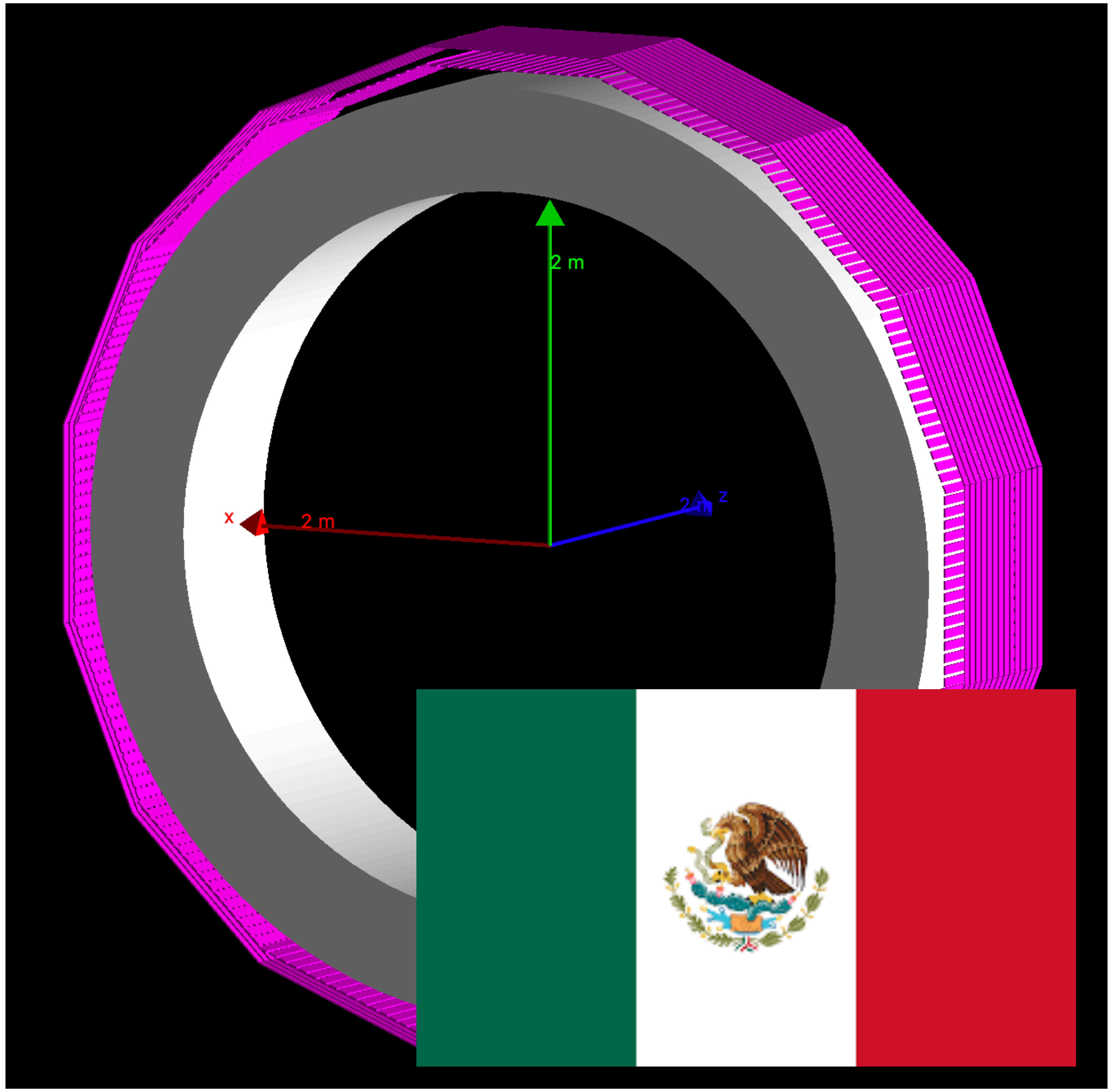

Summary: MuonID is a system which may exploit in an optimal way the human and economic resources of the Mexican team. A good opportunity to contribute to a system which will be important for the CERN program, allowing for a more visible impact of the Mexican community in CERN

Longer term LHC schedule

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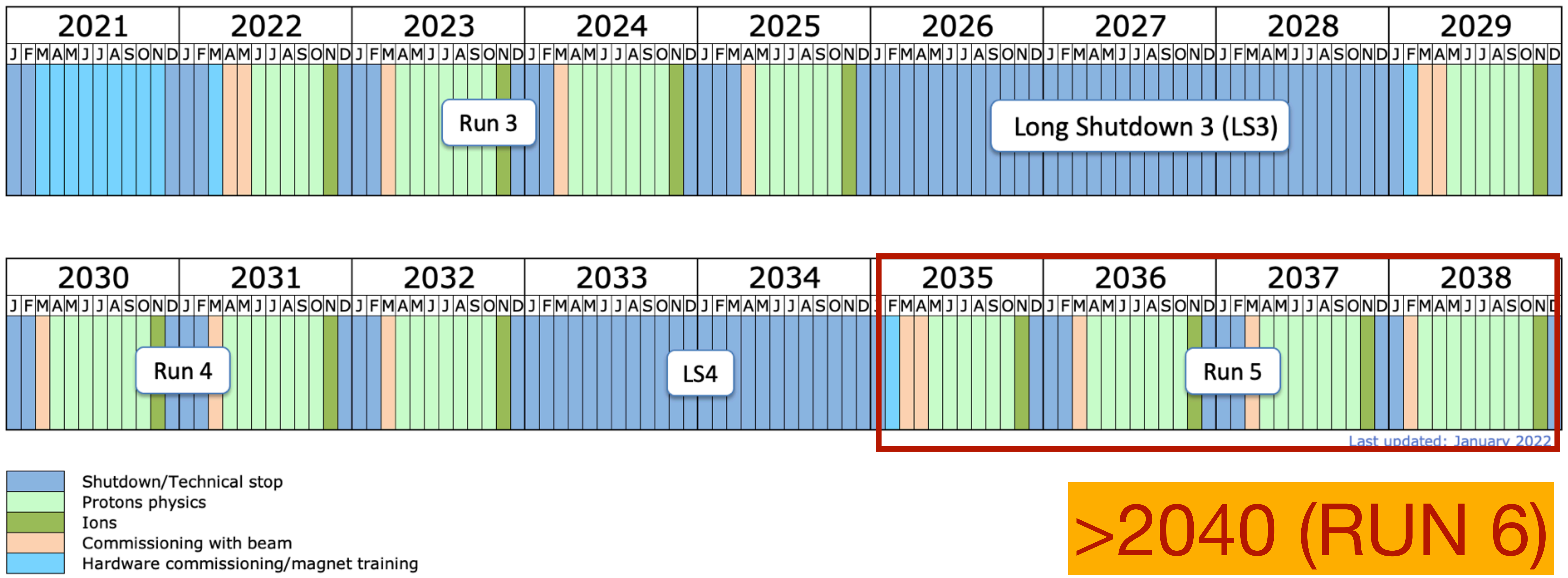


>2040 (RUN 6)

Backup

Charmonius states

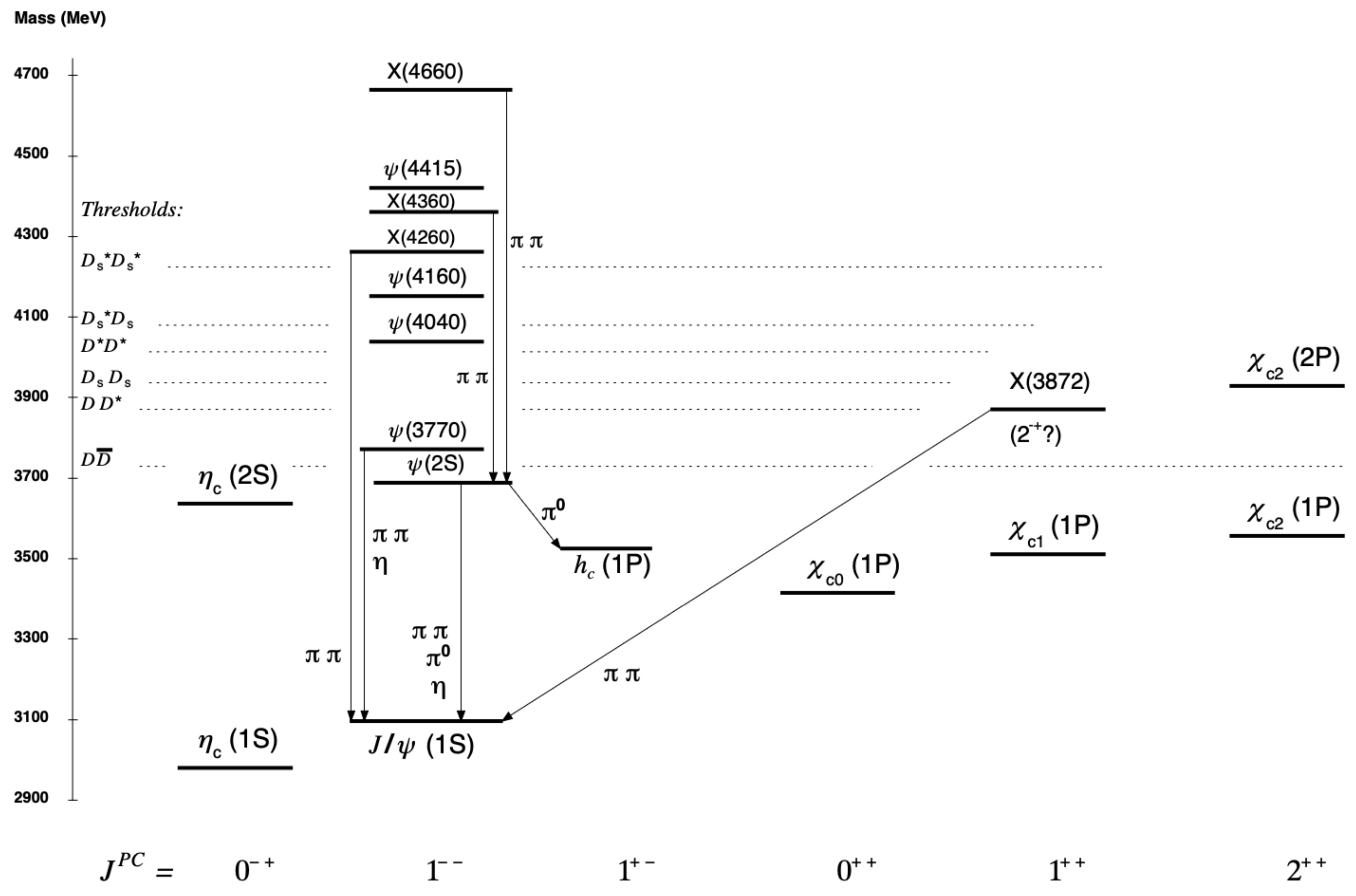


Figure 3.1: The experimentally observed charmonium states. The states labelled X, the nature of which is unknown, are not thought to be conventional charmonium states. Figure from Ref. [3].

Exotic anti-, hyper- and super-nuclei

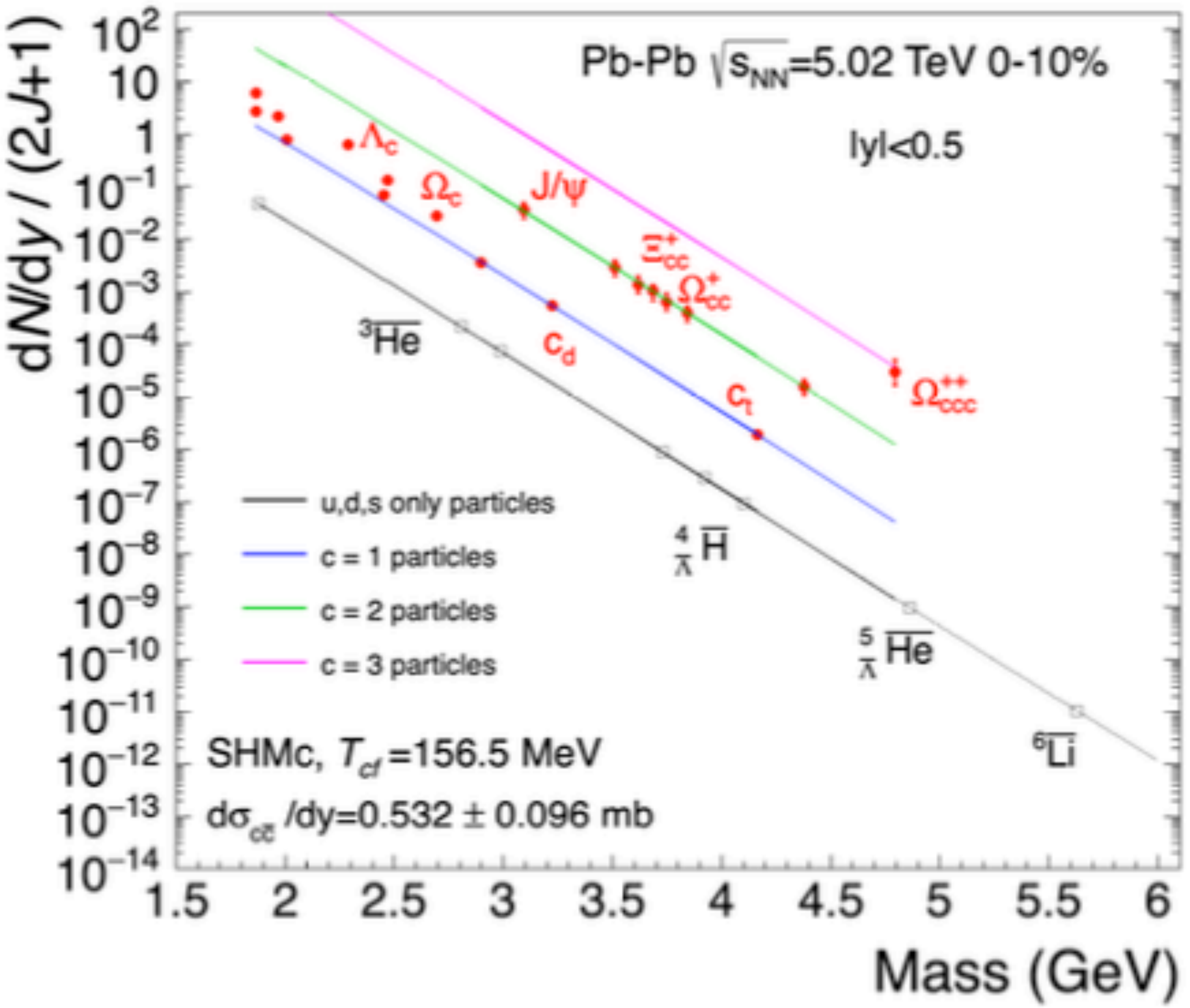


Figure 9: Statistical-thermal model predictions for (anti-)(hyper-)nuclei in black and (multi-)charm states in red. For each additional charm quark an enhancement in the yield by the charm fugacity factor g_c appears at the same hadron mass. All states depicted here are potentially in reach of ALICE 3. Figure taken from [56] with slight adaptations.

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	

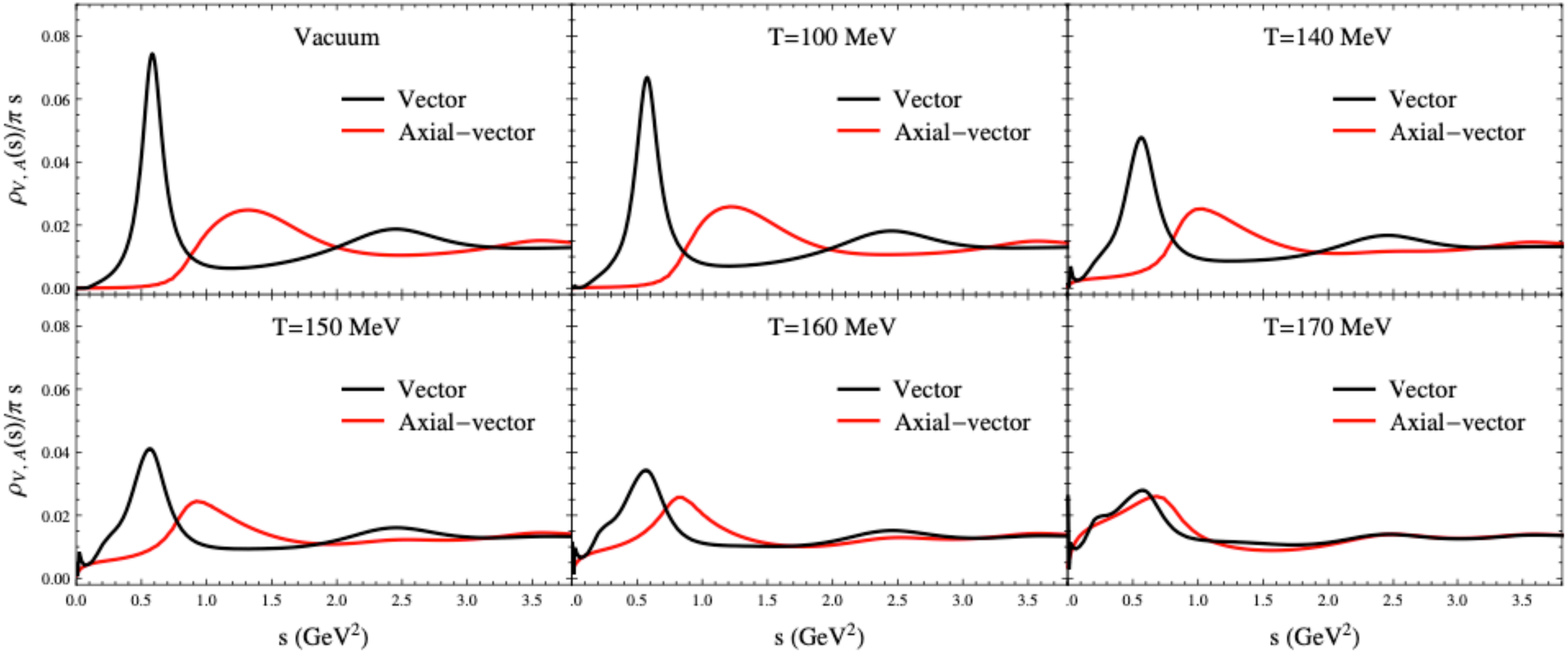


Figure 5: Temperature evolution of vector and axial-vector spectral functions (non-linear realization) [132].

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

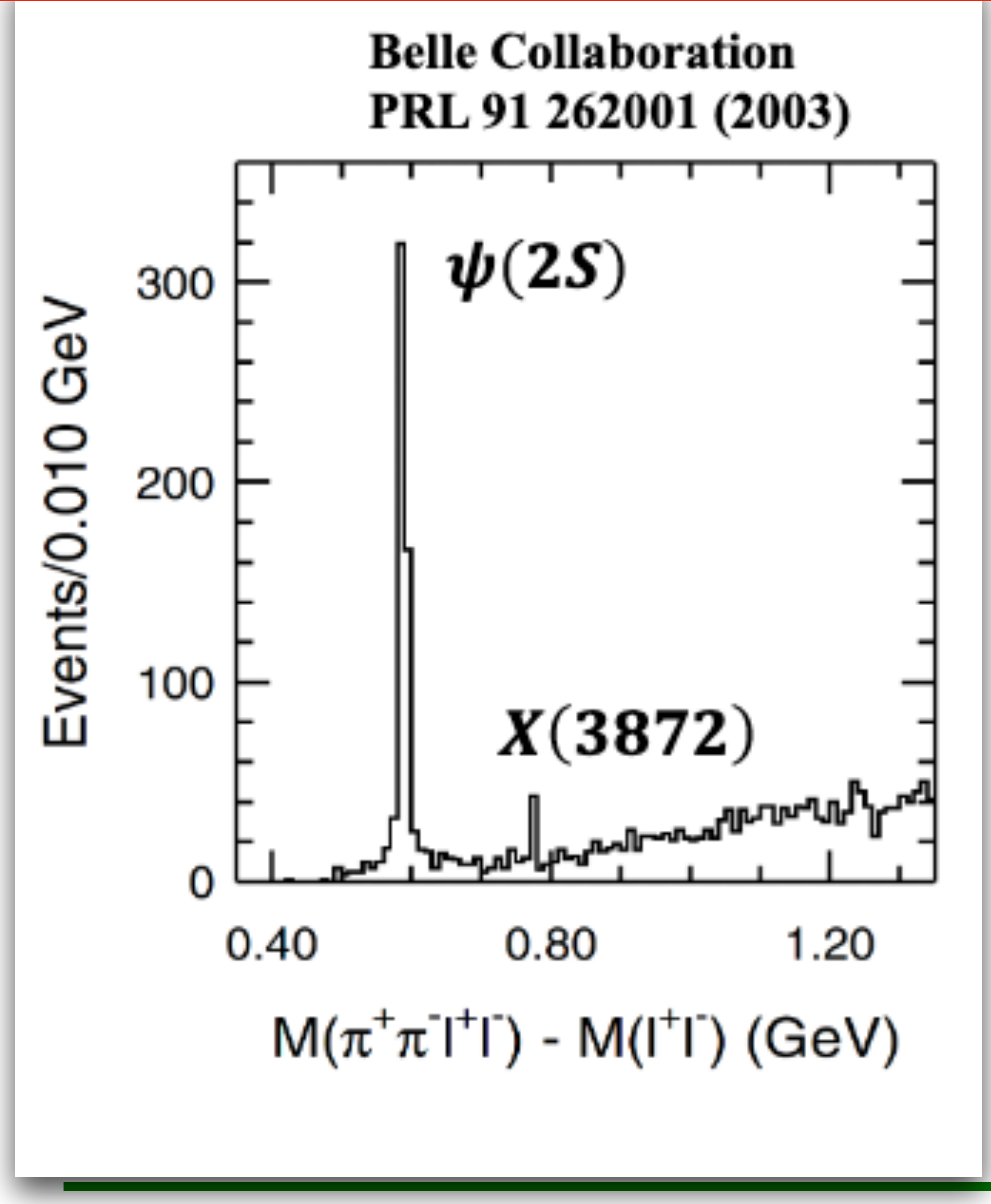
G. Zweig *)
CERN – Geneva

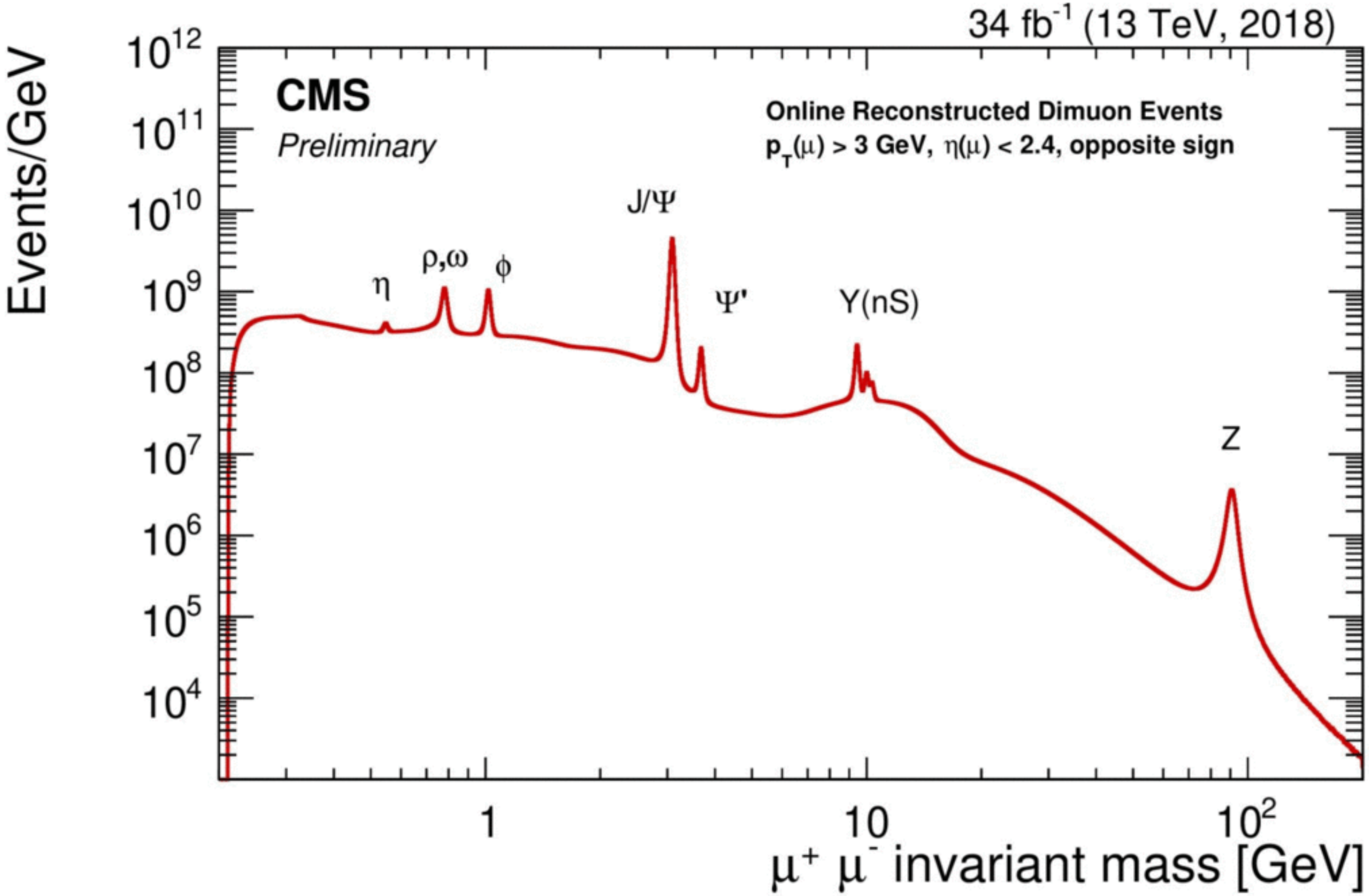
In general, we would expect that baryons are built not only from the product of three aces, AAA, but also from $\bar{A}$AAAA, $\bar{A}\bar{A}$AAAAA, etc., where $\bar{A}$ denotes an anti-ace. Similarly, mesons could be formed from $\bar{A}$A, $\bar{A}\bar{A}$AA etc. For the low mass mesons and baryons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

Multiquark hadrons are called exotics:

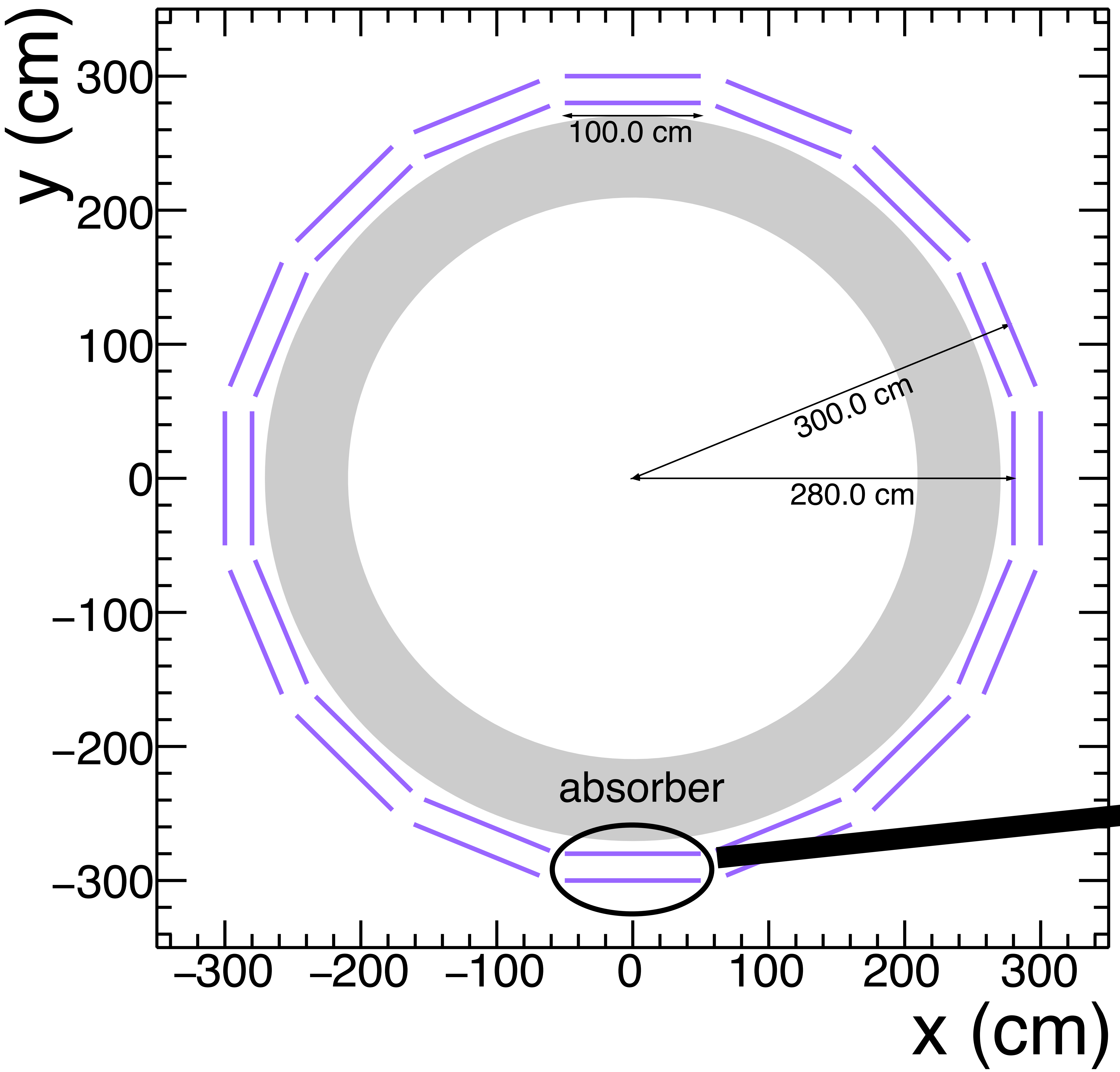
- "tetraquarks": qqqq
- "pentaquarks": qqqqq

The first heavy quark exotic: X(3872)



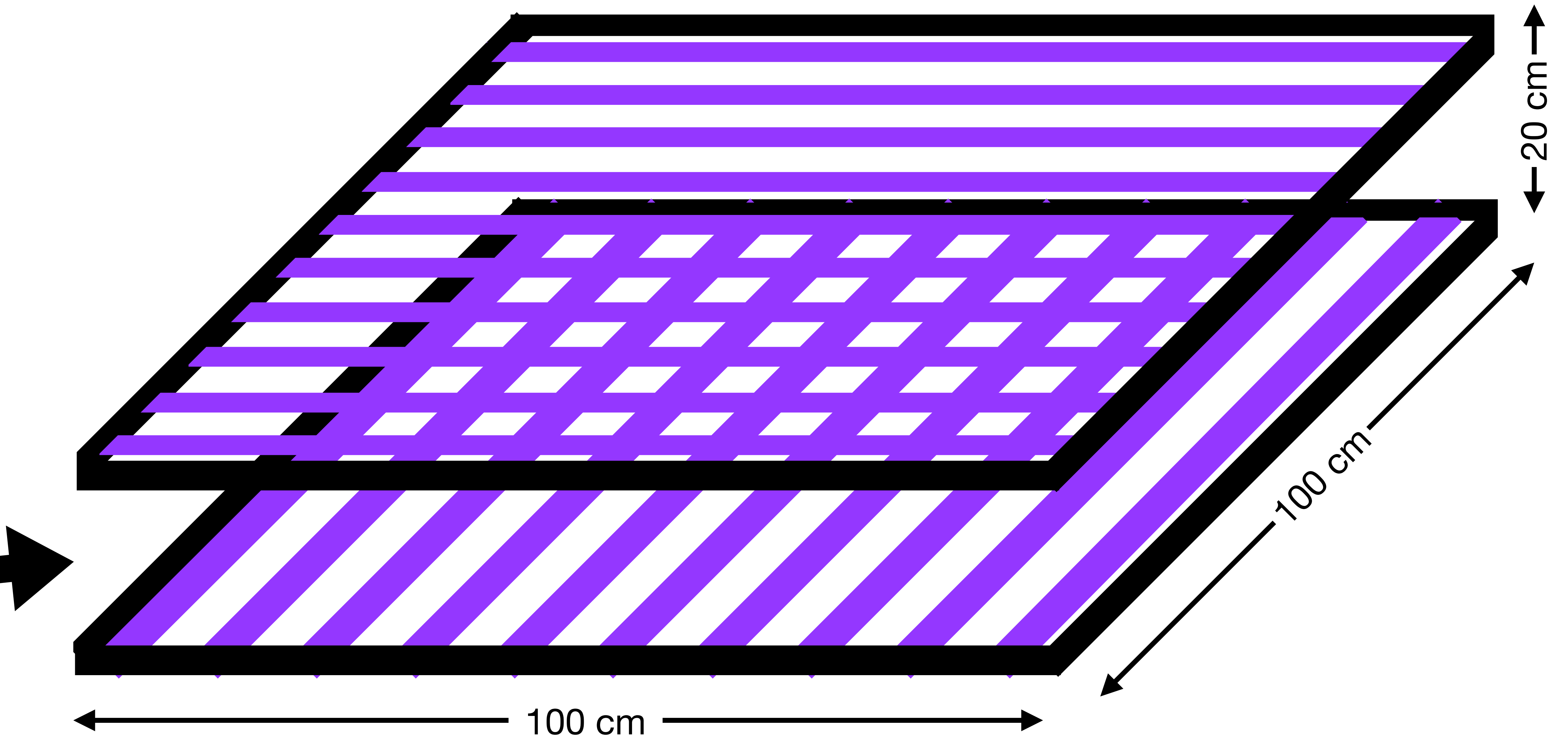

34 fb-1 (13 TeV, 2018)
CMS
Preliminary
Online Reconstructed Dimuon Events
pT(μ) > 3 GeV, η(μ) < 2.4, opposite sign
Events/GeV
η
ρ,ω
ϕ
J/Ψ
Ψ'
Υ(nS)
Z
μ+ μ- invariant mass [GeV]

Muon chamber (baseline option)



Muon chambers

Scintillator bars equipped with wave-length shifting fibres (width 5 cm, gap 20 cm)



Key measurements

- Accurate measurements of charm and beauty hadrons and their correlation over a wide rapidity range: interactions of heavy quarks of different mass in sQGP down to the thermal scale
- Multi heavy-flavoured hadrons (e.g. as the yet undiscovered Ω_{ccc}) for which the production from sQGP is expected to be enhanced by orders of magnitude: sensitivity to how quarks combine into hadrons depending on their degree of thermalisation
- Production and behaviour of the charmed exotic states in the sQGP and their structure, e.g. strong interaction potential between hadrons from measurements of their momentum correlations
- High-precision, multi differential measurements of electromagnetic radiation from the sQGP to probe its early evolution and the restoration of chiral symmetry through the coupling of vector and axial-vector mesons
- Onset of collective behaviour: HM pp collisions

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- Multi heavy-flavoured hadrons (e.g. as the yet undiscovered Ω_{ccc}) for which the production from sQGP is expected to be enhanced by orders of magnitude: sensitivity to how quarks combine into hadrons depending on their degree of thermalisation
- Production and behaviour of the charmed exotic states in the sQGP and their structure, e.g. strong interaction potential between hadrons from measurements of their momentum correlations $X(3872) \rightarrow J/\psi + \pi^+\pi^-$ muonID!
- High-precision, multi differential measurements of electromagnetic radiation from the sQGP to probe its early evolution and the restoration of chiral symmetry through the coupling of vector and axial-vector mesons
- Onset of collective behaviour: HM pp collisions