



Heavy flavour production with SMOG2

Aleksandra Petković
on behalf of the LHCb collaboration

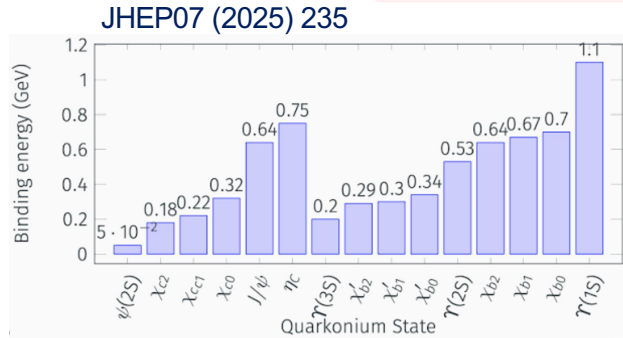


QCD@LHC 2026
University of Oxford
October 1st 2026



Quarkonium formation and dissociation in nuclear matter

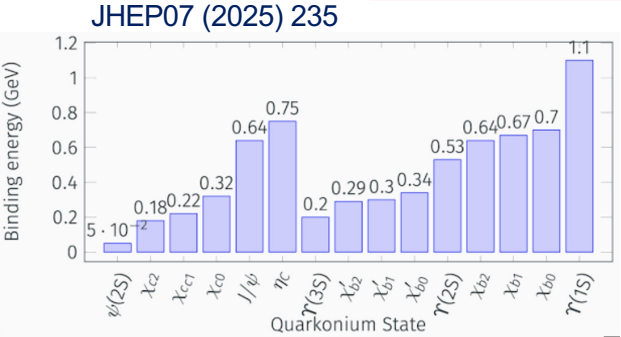
Heavy quarkonium ($c\bar{c}$ or $b\bar{b}$) is a particularly good tool for understanding the evolution and different stages of a heavy-ion collision



Produced almost exclusively in the initial stages of a collision

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10% of J/ψ production comes from $\psi(2S)$, 30% from χ_c

[Phys.Lett.B 178 \(1986\) 416-422](#)

Static picture: Debye-like **colour screening** (medium temperature, binding energy of the state)



Suppression should be **sequential**, each state has a defined melting temperature

[Phys. Rept. 858 \(2020\) 1-117](#)

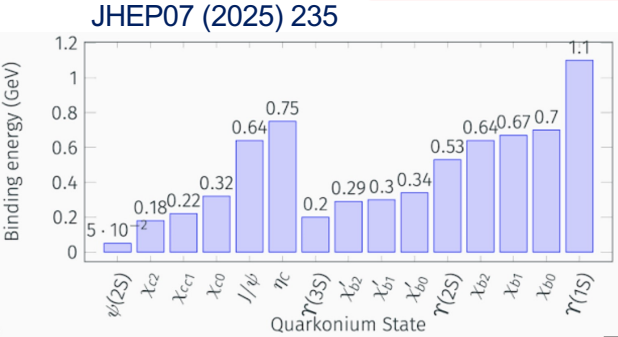
Dynamic picture: **how long a state is exposed to extreme conditions of the medium also matters**



Suppression is sequential, **melting temperature not exact**

Quarkonium formation and dissociation in nuclear matter

Heavy quarkonium ($c\bar{c}$ or $b\bar{b}$) is a particularly good tool for understanding the evolution and different stages of a heavy-ion collision



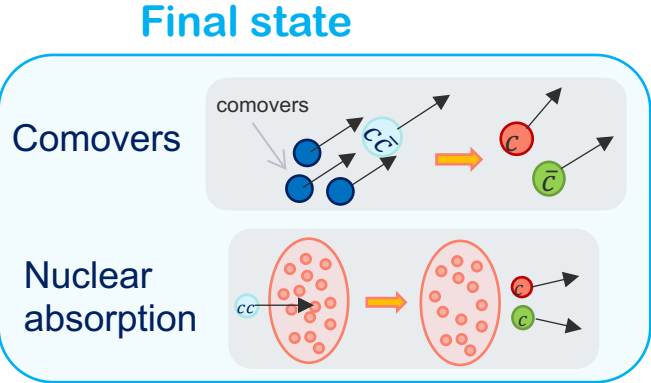
Produced almost exclusively in the initial stages of a collision

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Cold Nuclear Matter (CNM) effects

Initial state

Nuclear PDFs modification
Parton energy loss
(gluon radiation, scattering)



[Phys.Lett.B 178 \(1986\) 416-422](#)

Static picture: Debye-like **colour screening** (medium temperature, binding energy of the state)

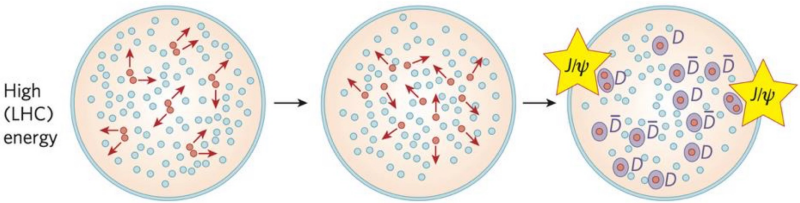
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[Phys. Rept. 858 \(2020\) 1-117](#)

Dynamic picture: **how long a state is exposed to extreme conditions of the medium also matters**

➡ Suppression is sequential, **melting temperature not exact**

Recombination and regeneration



[Nature 448 \(2007\) 302](#)

Charmonium production measurements: Bridging the gap

CNM effects depend on the collision energy, transverse momentum, rapidity, size of the nucleus...

QGP-induced suppression depends on the energy density

➔ Charmonium production needs to be measured in different kinematic regions and collision systems

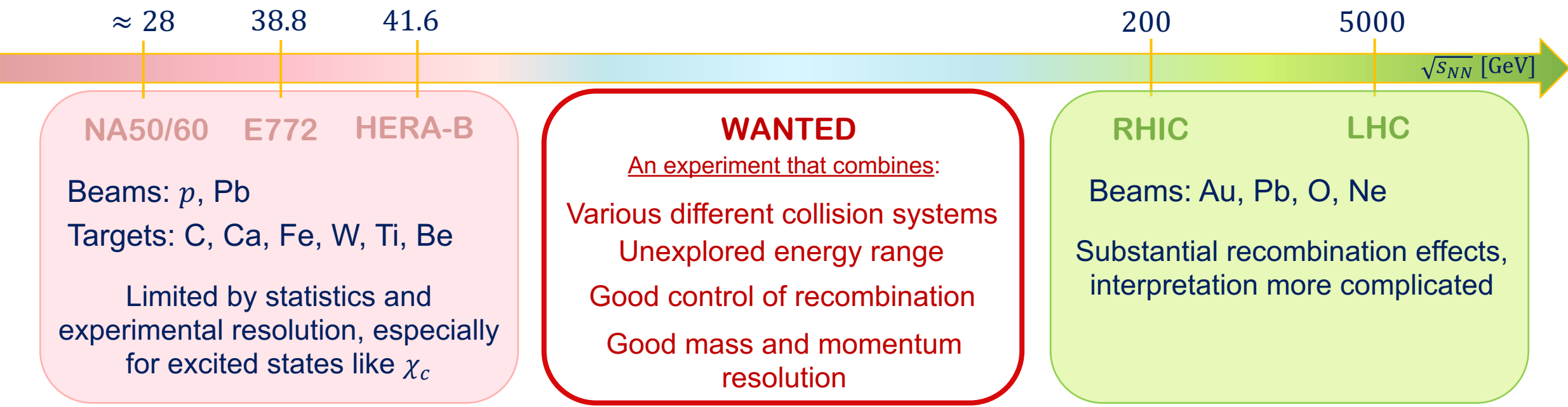


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[PhysRevLett.64.2479](#)
[Eur.Phys.J.C\(2009\) 60:525–542](#)
[Eur. Phys. J. C 49, 559–567 \(2007\)](#)

[PLB 797 \(2019\) 134917](#)
[PRL 98 \(2007\) 232301](#)
[PLB 849 \(2024\) 138451](#)

Charmonium production measurements: Bridging the gap

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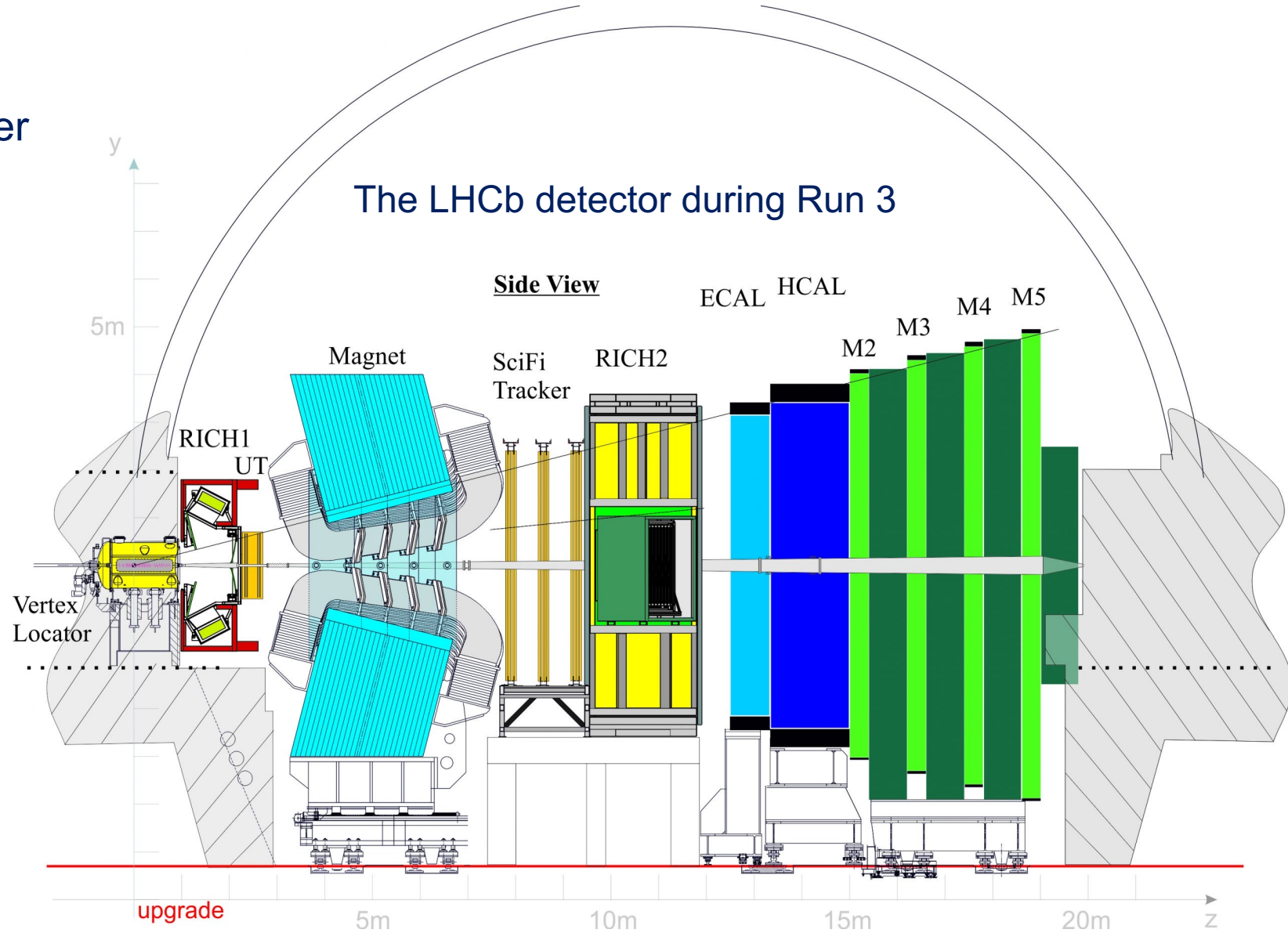
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The LHCb detector

Single-arm **forward** spectrometer

$$2 < \eta < 5$$



JINST 19 (2024) P05065

The LHCb detector

Single-arm **forward** spectrometer

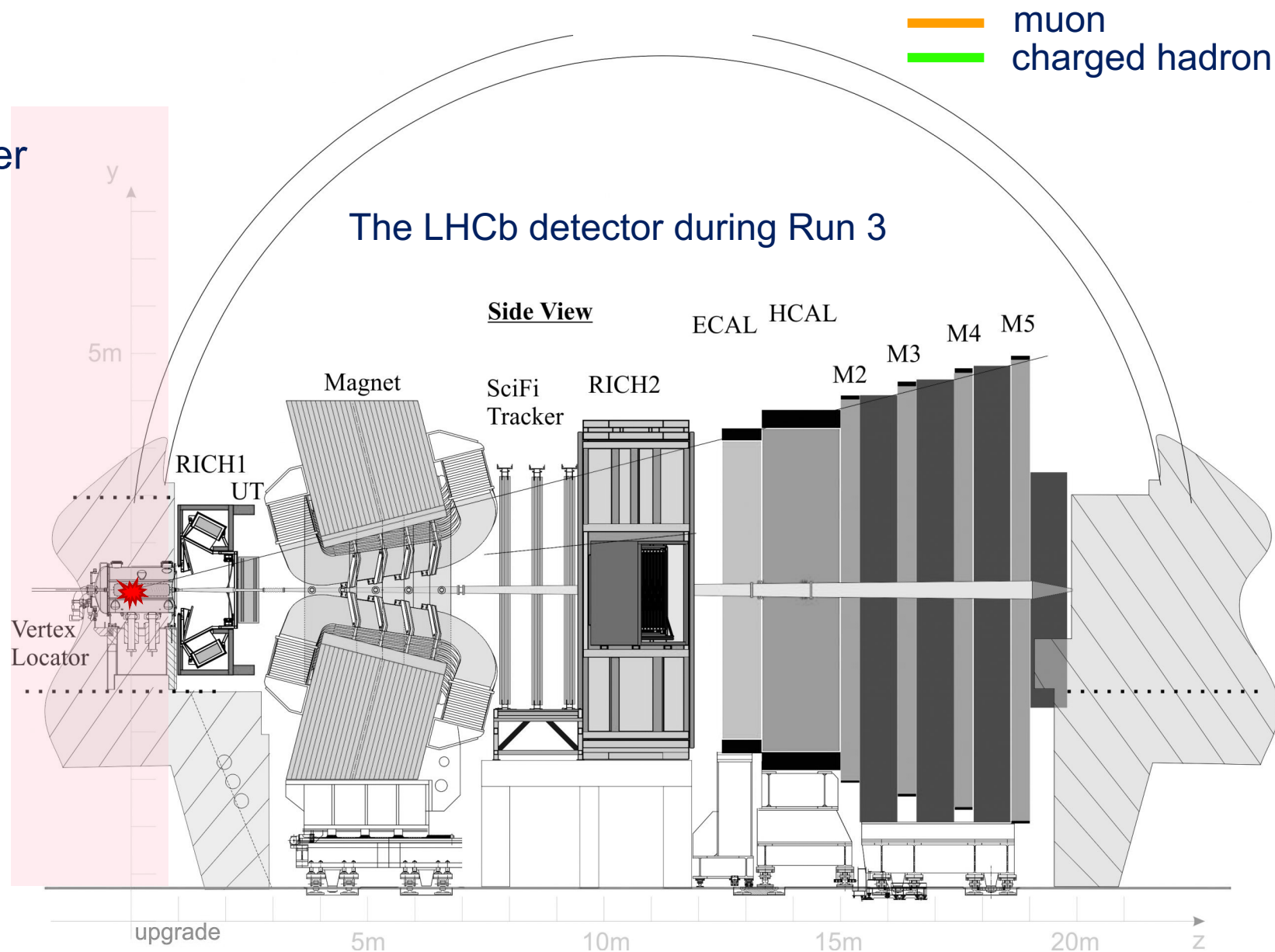
$$2 < \eta < 5$$

VERtex LOcator (VELO)

IP resolution $\sim 20 \mu\text{m}$

Decay time resolution $\sim 45 \text{ fs}$

Prompt/non-prompt separation



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The LHCb detector

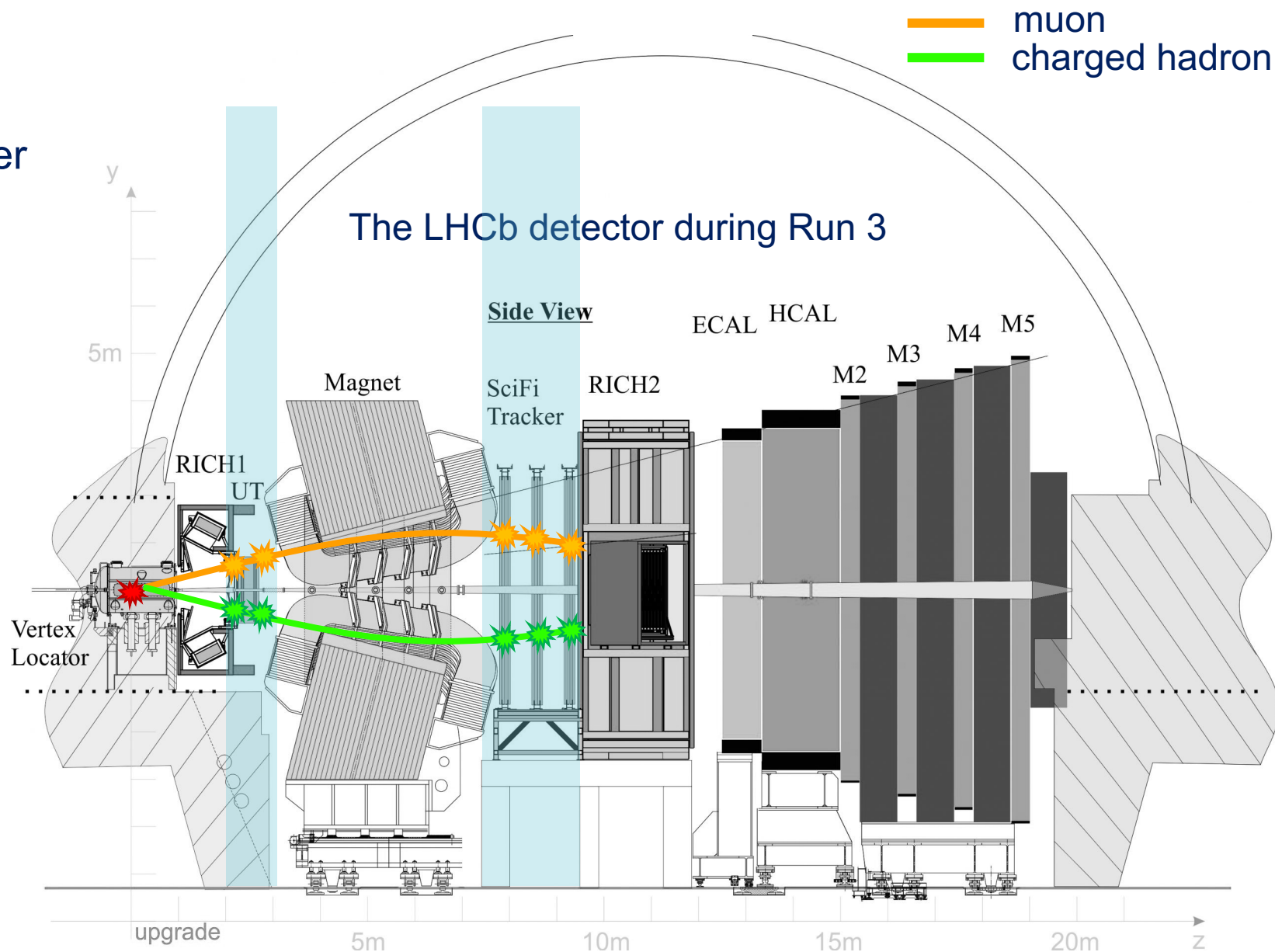
Single-arm **forward** spectrometer

$$2 < \eta < 5$$

Tracking system

Excellent down to low p_T

Resolution $\frac{\Delta p}{p} = 0.45\% - 1.1\%$
for $p \in [2, 200] \text{ GeV}/c$



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The LHCb detector

Single-arm **forward** spectrometer

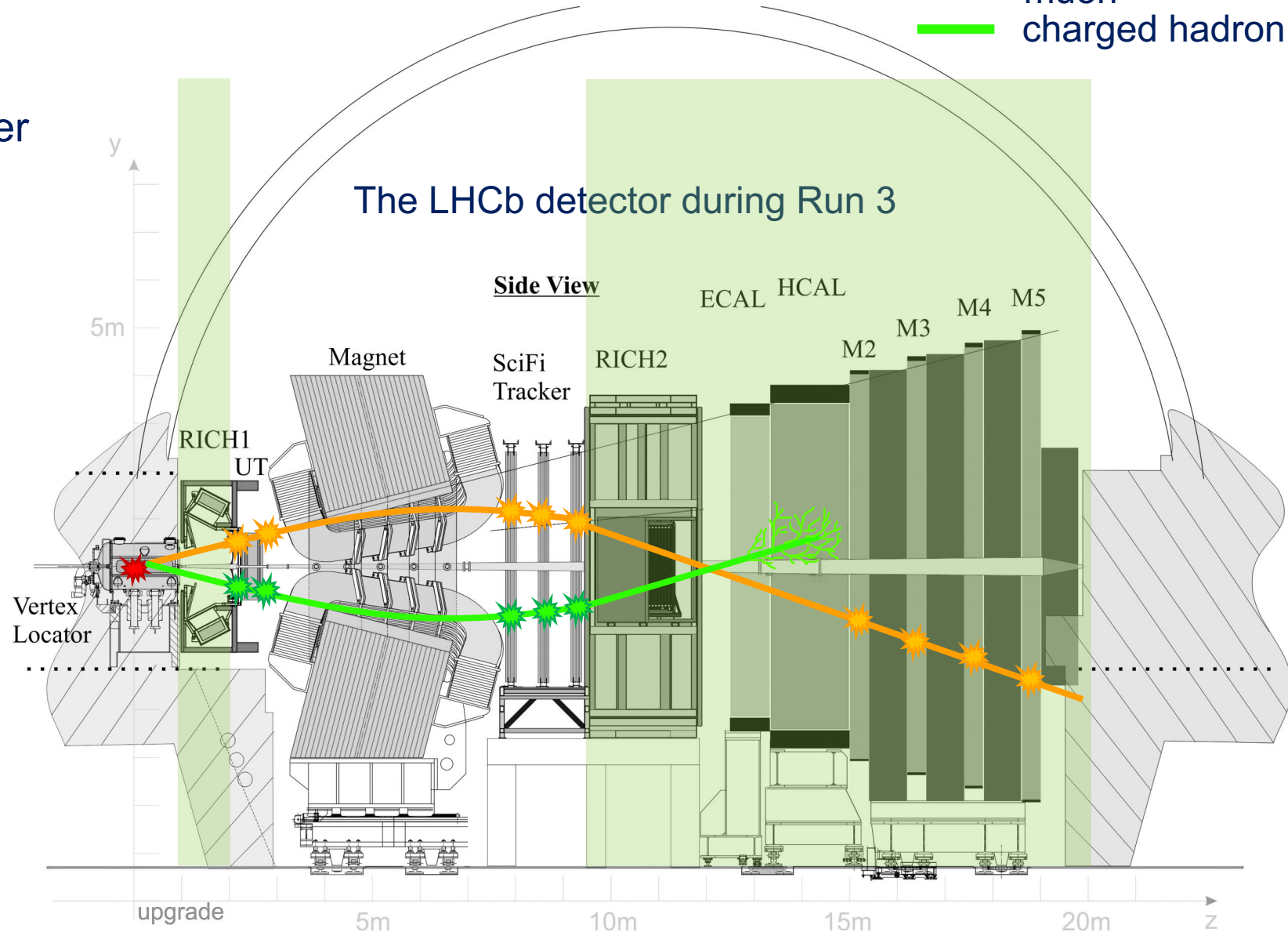
$$2 < \eta < 5$$

Particle identification

2 RICH detectors + ECAL +
HCAL + 4 muon stations

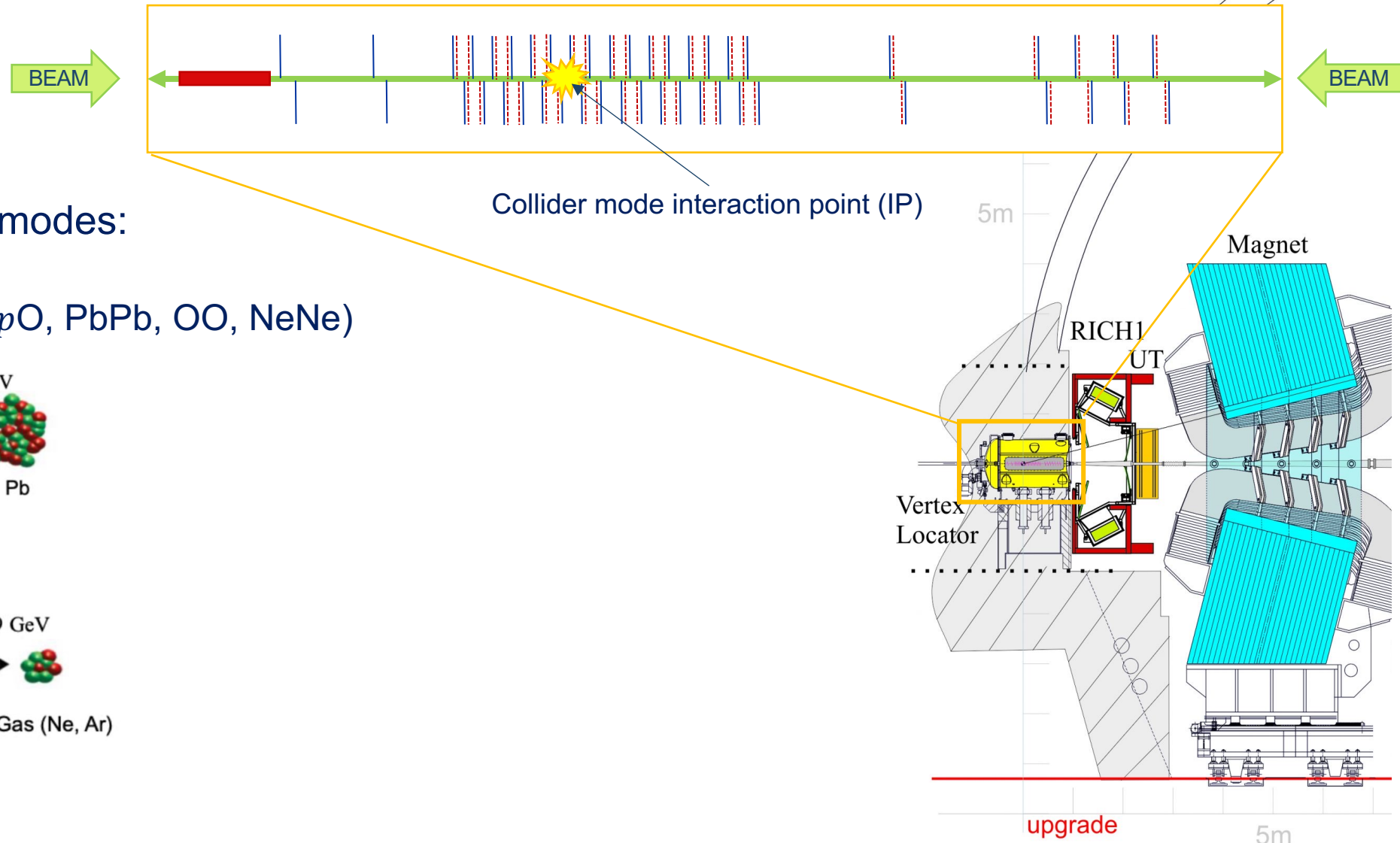
p, K, π separation
for $p \in [10, 100] \text{ GeV}/c$

— muon
— charged hadron



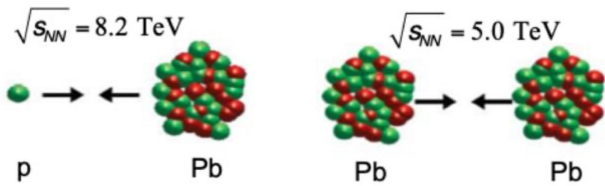
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The LHCb fixed-target programme

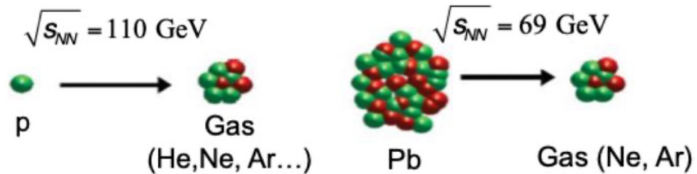


LHCb has two operation modes:

1. Collider (pp , $p\text{Pb}/\text{Pbp}$, $p\text{O}$, PbPb , OO , NeNe)

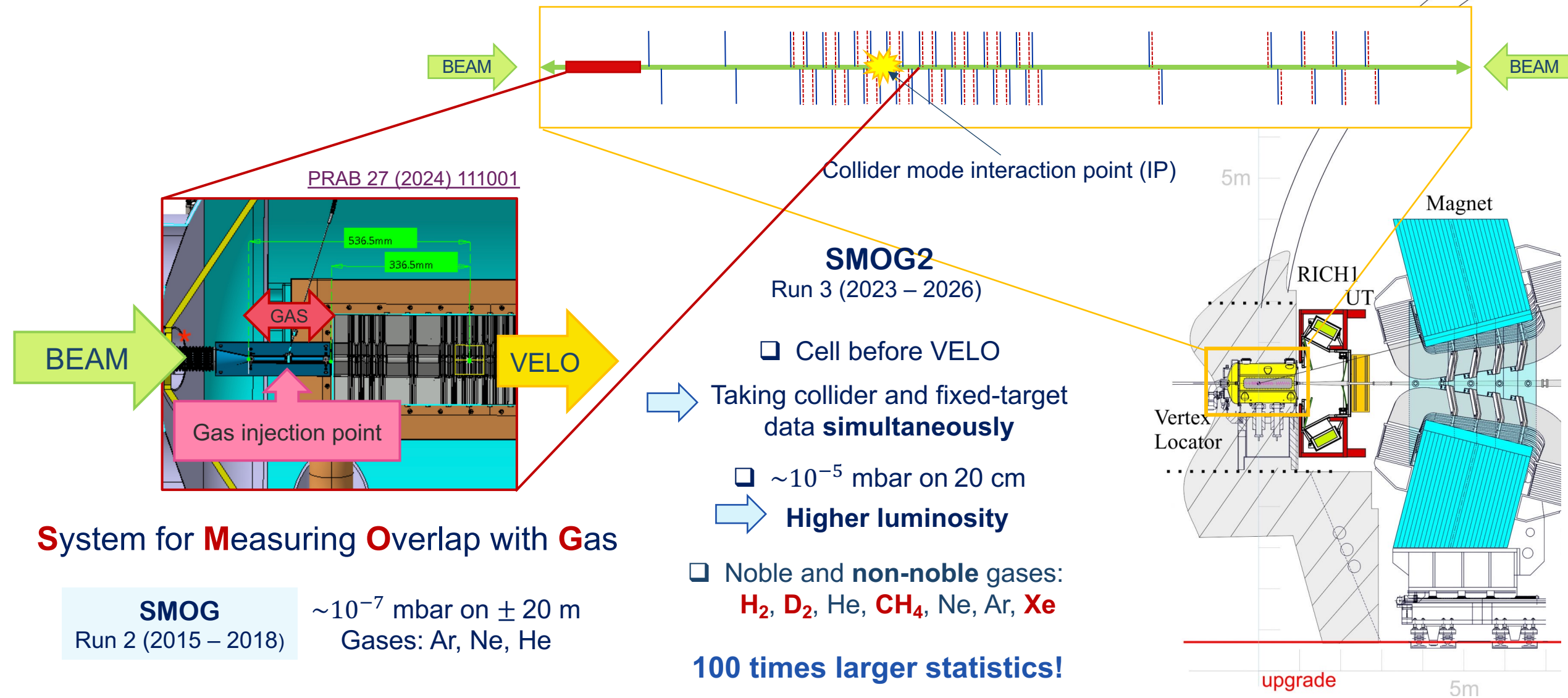


2. Fixed-target ($p\text{A}$, PbA)

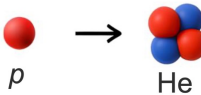
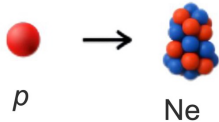
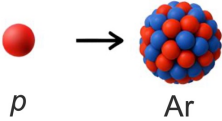
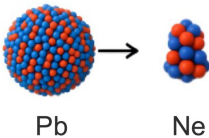
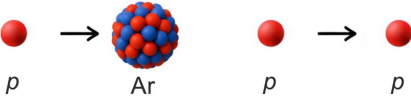


$$-2.29 < y^* \lesssim 0$$

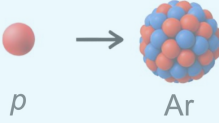
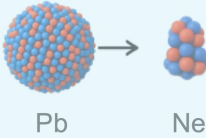
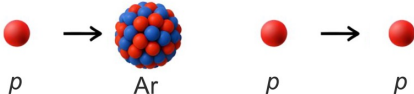
The LHCb fixed-target programme



Summary of LHCb fixed-target charmonia results

System	$\sqrt{s_{NN}}$ [GeV]	Measurement
	86.6	J/ψ and D^0 total and differential cross-sections in y^* and p_T PRL 122 (2019) 132002
	68.5	J/ψ total and differential cross-sections in y^* and p_T , $\psi(2S)$ -to- J/ψ and J/ψ -to- D^0 production ratio EPJC 83 (2023) 625
	110.4	J/ψ and D^0 total and differential cross-sections in y^* and p_T PRL 122 (2019) 132002
	68.5	J/ψ -to- D^0 production ratio EPJC 83 (2023) 658
	113	$\psi(2S)$ -to- J/ψ production and double ratio in pp and $p\text{Ar}$, total and differential in y^* and p_T LHCb-PAPER-2026-026

Summary of LHCb fixed-target charmonia results

	System	$\sqrt{s_{NN}}$ [GeV]	Measurement
RUN 2		86.6	J/ψ and D^0 total and differential cross-sections in y^* and p_T PRL 122 (2019) 132002
		68.5	J/ψ total and differential cross-sections in y^* and p_T , $\psi(2S)$ -to- J/ψ and J/ψ -to- D^0 production ratio EPJC 83 (2023) 625
		110.4	J/ψ and D^0 total and differential cross-sections in y^* and p_T PRL 122 (2019) 132002
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		113 Today	$\psi(2S)$ -to- J/ψ production and double ratio in pp and $p\text{Ar}$, total and differential in y^* and p_T LHCb-PAPER-2026-026

First Run 3 fixed-target result!

J/ψ and $\psi(2S)$ production in $p\text{Ar}$ and pp collisions at $\sqrt{s_{NN}} = 113 \text{ GeV}$

☐ Inclusive charmonium

☐ Reconstructed through dimuon decay channels

$$J/\psi \rightarrow \mu^+ \mu^-$$

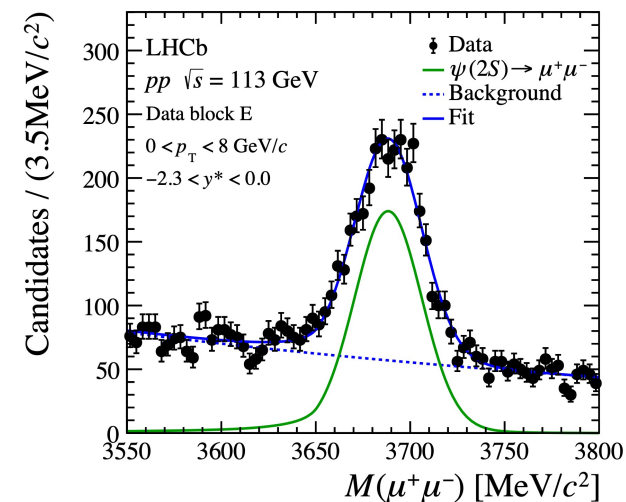
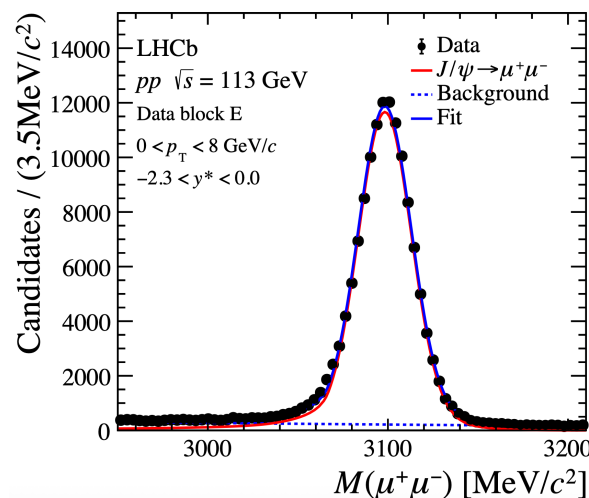
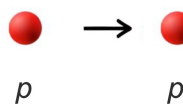
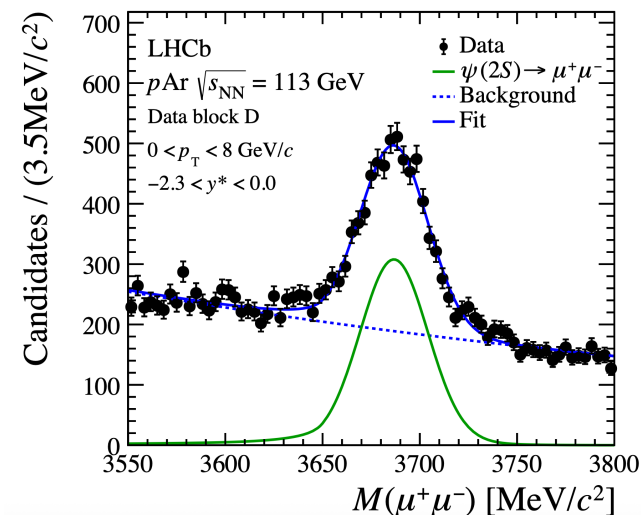
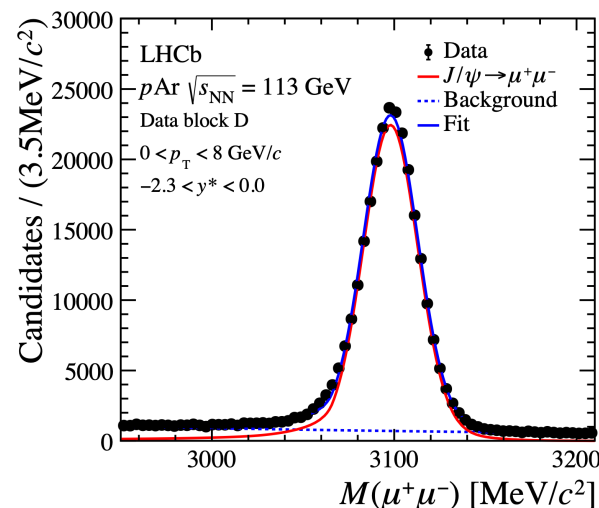
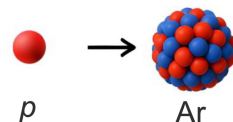
$$\psi(2S) \rightarrow \mu^+ \mu^-$$

☐ Kinematic range

$$0 < p_T < 8 \text{ GeV}/c$$

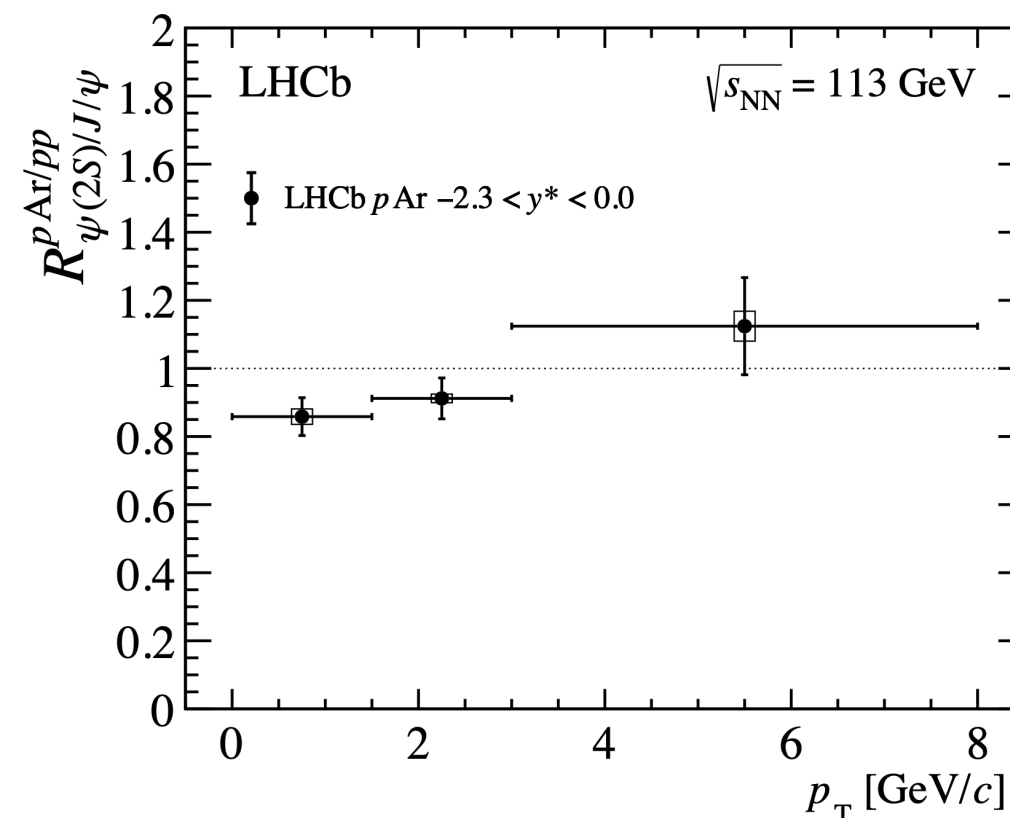
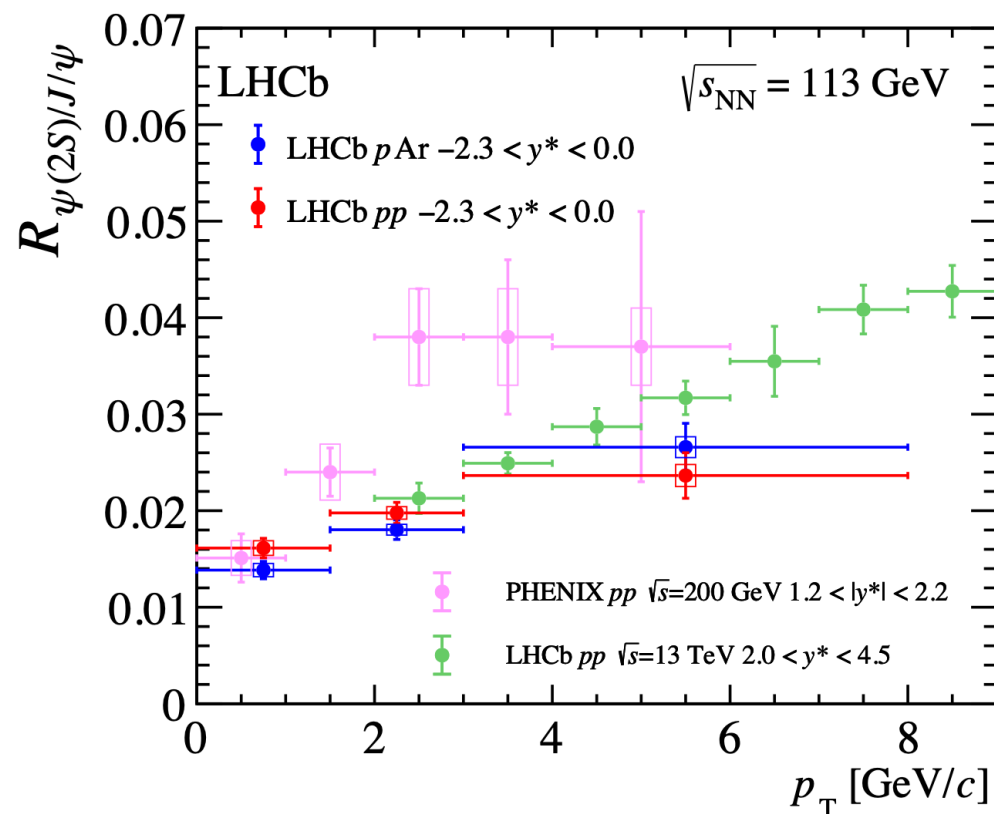
$$-2.3 < y^* < 0$$

☐ Two orders of magnitude larger signal yield compared to Run 2 $p\text{Ne}$!



LHCb-PAPER-2026-026

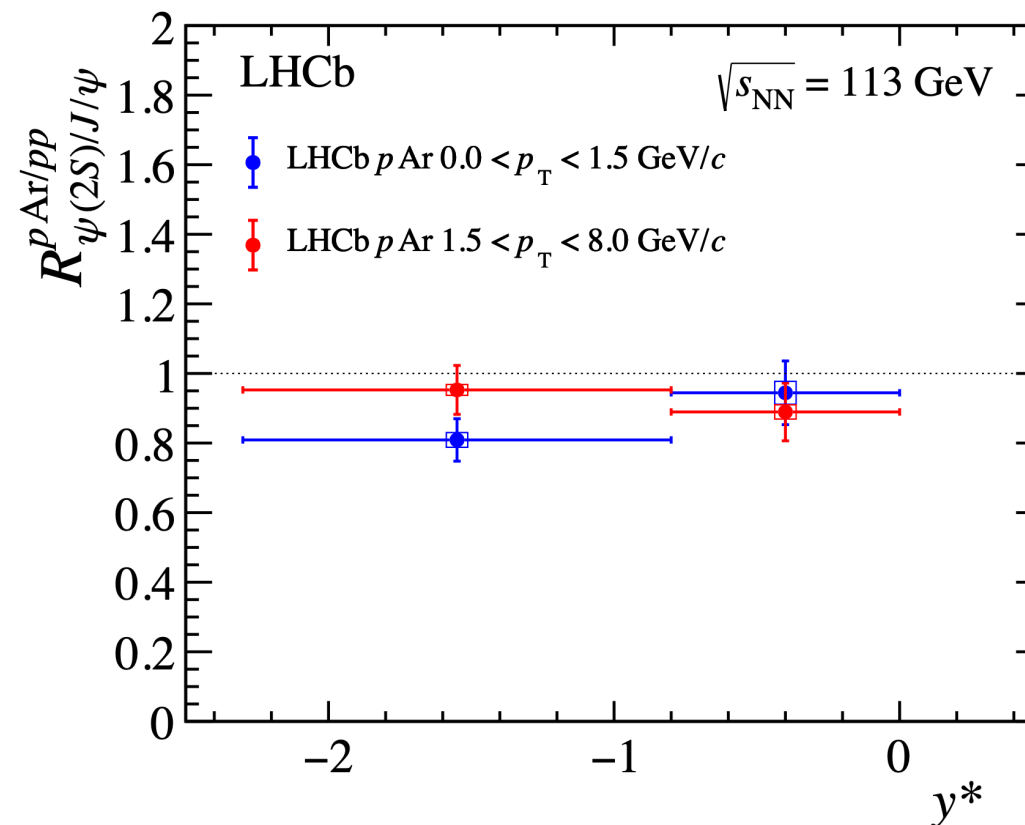
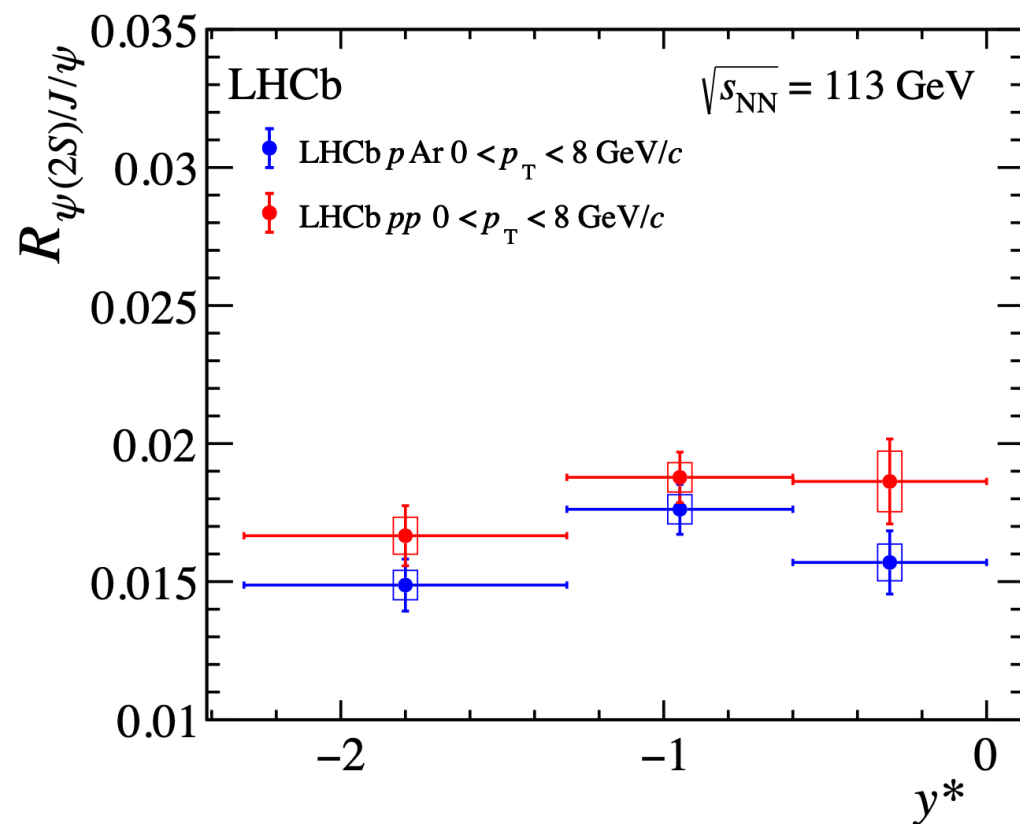
$\psi(2S)$ -to- J/ψ production ratio as a function of p_T



$R_{\psi(2S)/J/\psi}$ increases with p_T , trend agreeing with PHENIX and LHCb pp collider data

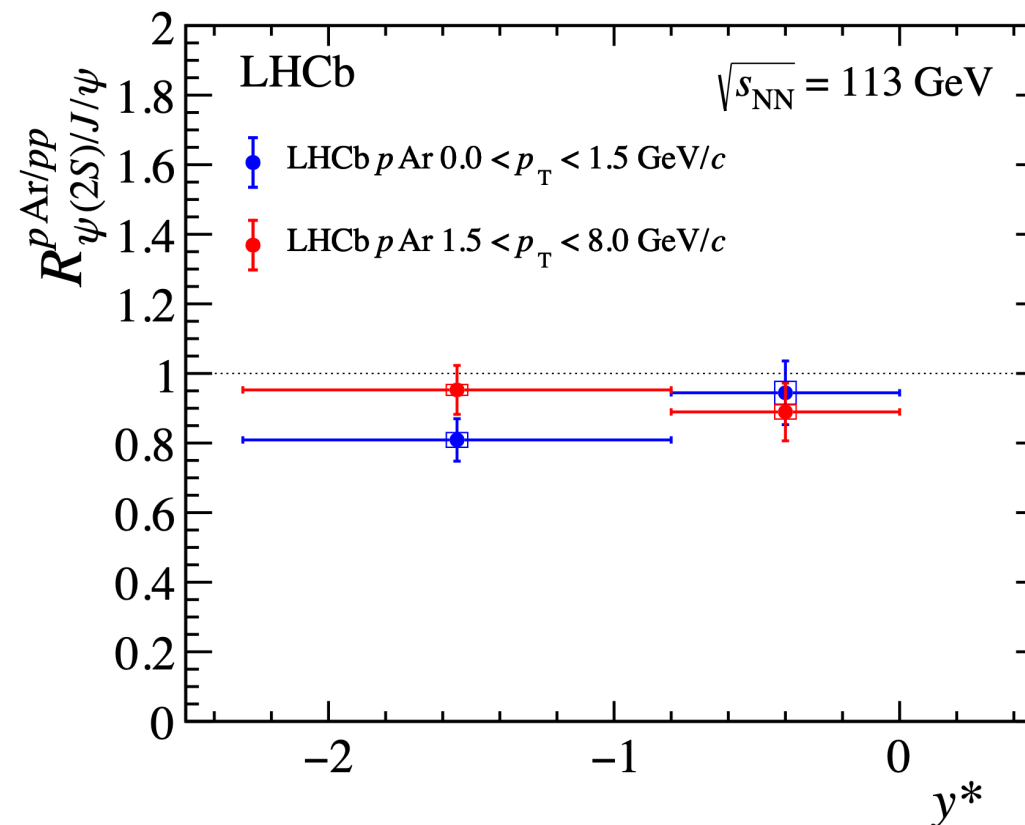
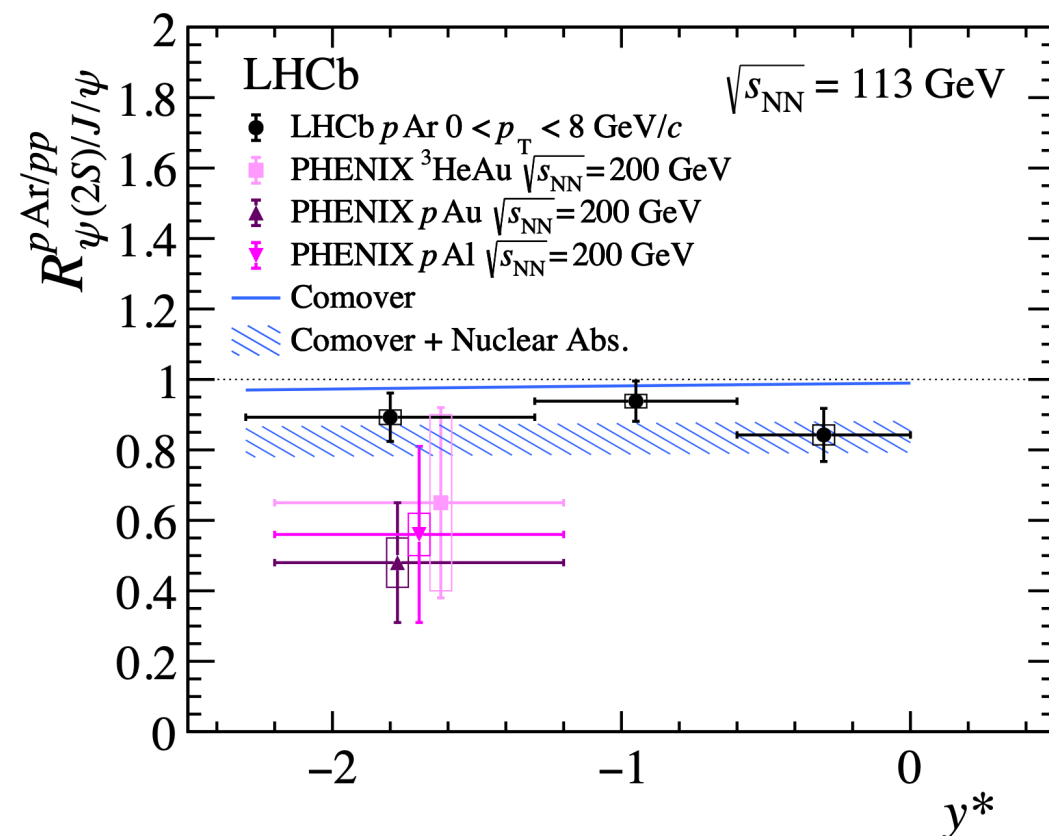
$\psi(2S)$ additionally suppressed with respect to J/ψ in $p\text{Ar}$ collisions in lower p_T region

$\psi(2S)$ -to- J/ψ production ratio as a function of y^*



Indication of $\psi(2S)$ production **suppression in low- y^* low- p_T region**, especially relevant for nucleon absorption

$\psi(2S)$ -to- J/ψ production ratio as a function of y^*



Indication of $\psi(2S)$ production **suppression in low- y^* low- p_T region**, especially relevant for nucleon absorption

Integrated in p_T , double-ratio **compatible with comover + nuclear absorption model prediction**

Ratios integrated in y^* and p_T

$\psi(2S)$ -to- J/ψ ratio

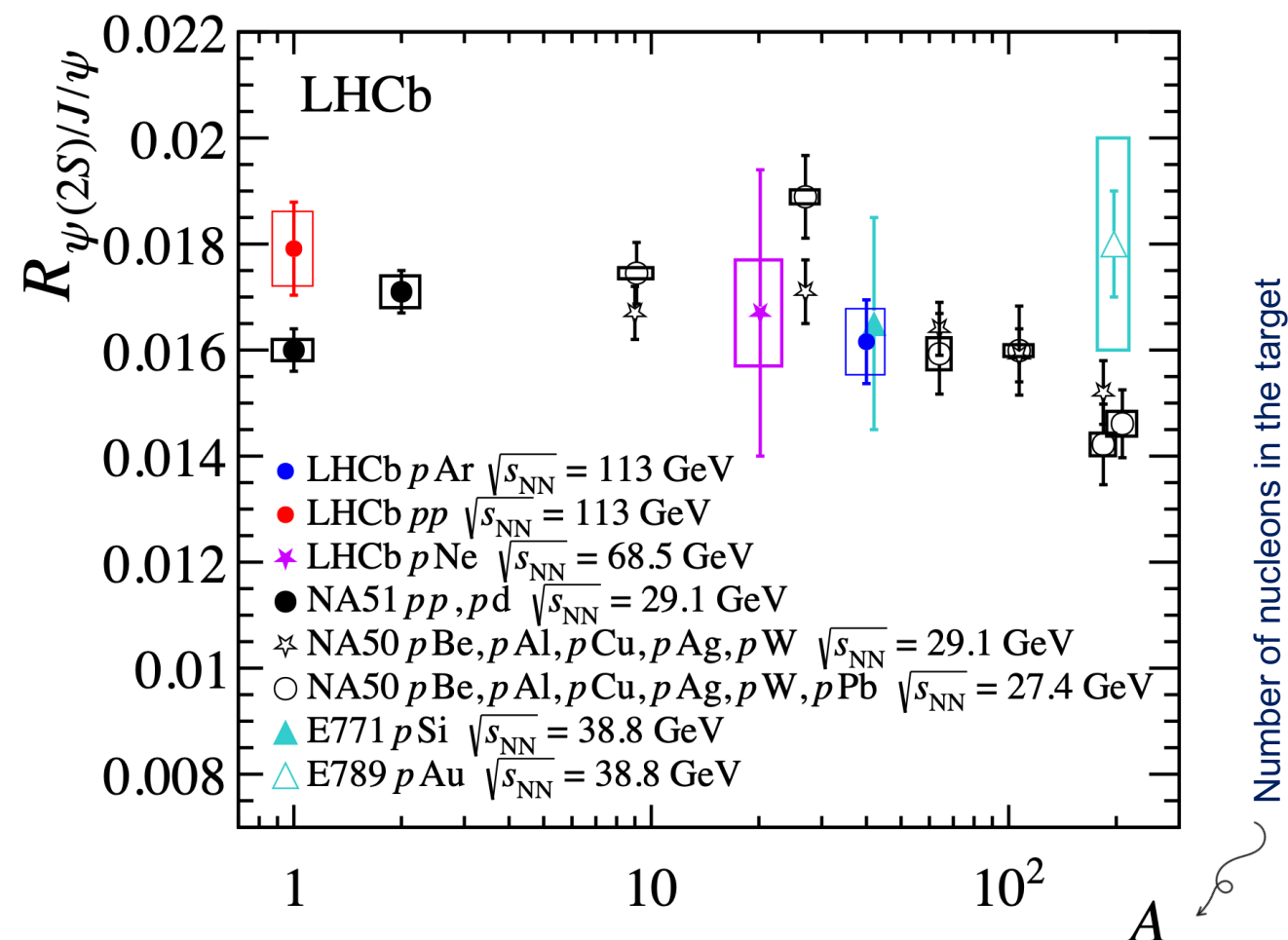
$$R_{\psi(2S)/J/\psi} \Big|_{pAr} = (1.62 \pm \overset{\text{stat.}}{0.05} \pm \overset{\text{syst.}}{0.06}) \times 10^{-2}$$

$$R_{\psi(2S)/J/\psi} \Big|_{pp} = (1.79 \pm \overset{\text{stat.}}{0.05} \pm \overset{\text{syst.}}{0.07}) \times 10^{-2}$$

Double-ratio

$$R_{\psi(2S)/J/\psi} = 0.90 \pm 0.04 \pm 0.02$$

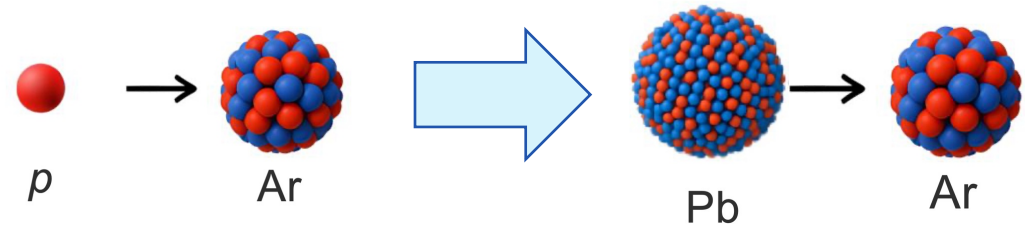
The **most precise** measurements of the suppression effect at energies $\sqrt{s_{NN}} \sim 100$ GeV!



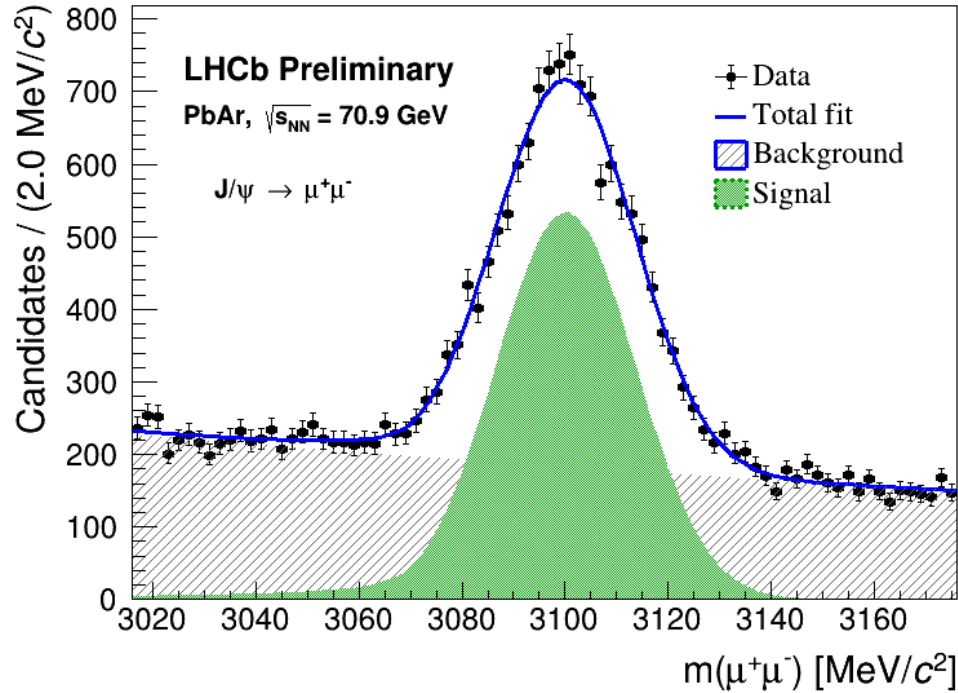
Production ratios **consistent** with measurements from other experiments, much **more precise** than Run 2 result

Double-ratio hints at **suppression of $\psi(2S)$ with respect to J/ψ in a nuclear environment**

From p Ar to PbAr collisions



LHCb-FIGURE-2025-014



- ✓ J/ψ and $\psi(2S)$ production measured in p Ar and pp collisions at $\sqrt{s_{NN}} = 113$ GeV
- Soon: same measurement at $\sqrt{s_{NN}} = 70.9$ GeV
- LHCb can now continue probing **hot nuclear matter effects** in PbAr collisions at $\sqrt{s_{NN}} = 70.9$ GeV, as a function of **collision centrality**

Reminder: $\mathcal{O}(1)$ $c\bar{c}$ pairs on average expected at this energy

Unique opportunity to **disentangle cold nuclear matter effects with those of a hot medium...**

...and look for new **evidence of J/ψ sequential suppression** in a fixed-target experiment!

Conclusions

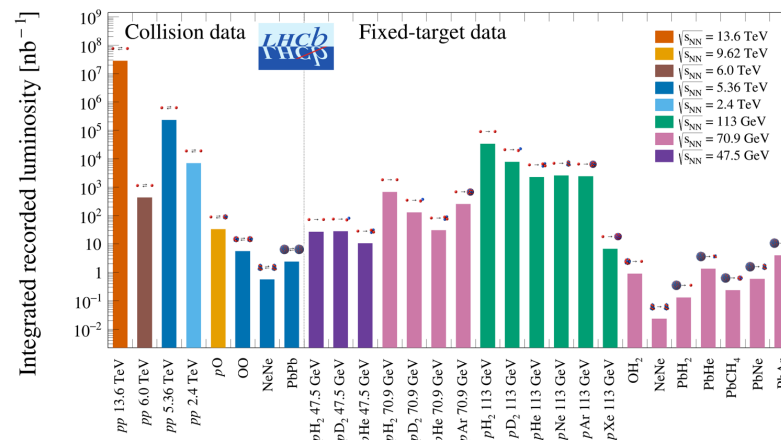
LHCb Run 3 fixed-target data offer exciting prospects for charmonium physics!

Today

- ❑ **First SMOG2 result:** First measurement of the ratio of $\psi(2S)$ -to- J/ψ inclusive production in $p\text{Ar}$ and pp collisions at $\sqrt{s_{NN}} = 113 \text{ GeV}$

Soon

- ❑ Other heavy-flavour studies: open charm and polarisation measurements, centrality-dependent studies...



Run 3 Collision system

https://lbggroups.cern.ch/online/operations_plots/

New results are on the horizon! 😊

Thank you!

Backup slides

Systematic uncertainties

Uncertainty	Block D, $p\text{Ar}$ [%]	Block D, pp [%]	Block E, pp [%]
Statistical	3.0 – 8.4	5.6 – 17.3	3.2 – 10.0
Uncorrelated Systematic uncertainties			
Tracking	0.6 – 2.1	0.6 – 2.1	0.4 – 1.7
Trigger	0.3 – 1.2	0.7 – 2.8	0.4 – 1.2
Muon identification	0.6 – 2.8	1.4 – 3.7	0.8 – 2.6
Simulation sample size	0.1 – 0.4	0.2 – 0.4	0.1 – 0.4
Total uncorrelated	1.0 – 2.9	2.1 – 4.2	1.0 – 2.8
Correlated Systematic uncertainties			
Signal extraction	1.3 – 2.9	0.7 – 3.7	0.8 – 4.1
Acceptance	0.2 – 3.3	0.2 – 3.3	0.2 – 3.3
Primary vertex	1.0	1.0	1.0
Tracking	0.3 – 1.2	0.4 – 1.2	0.1 – 2.1
Trigger	0.1 – 2.6	1.0 – 4.6	0.8 – 1.6
Muon identification	0.0 – 1.3	0.0 – 1.3	0.0 – 3.0
Total correlated	2.1 – 4.8	2.7 – 6.6	2.4 – 5.2
Total systematic uncertainty	2.6 – 5.5	3.6 – 7.8	2.7 – 5.6
Total	4.9 – 9.3	7.0 – 18.2	5.2 – 11.3

[LHCb-PAPER-2026-026](#)