LHCb: Heavy ion physics results and prospects

Roman Litvinov
on behalf of the LHCb collaboration.

OUTLINE

The LHCb detector at CERN

Available samples in Run2

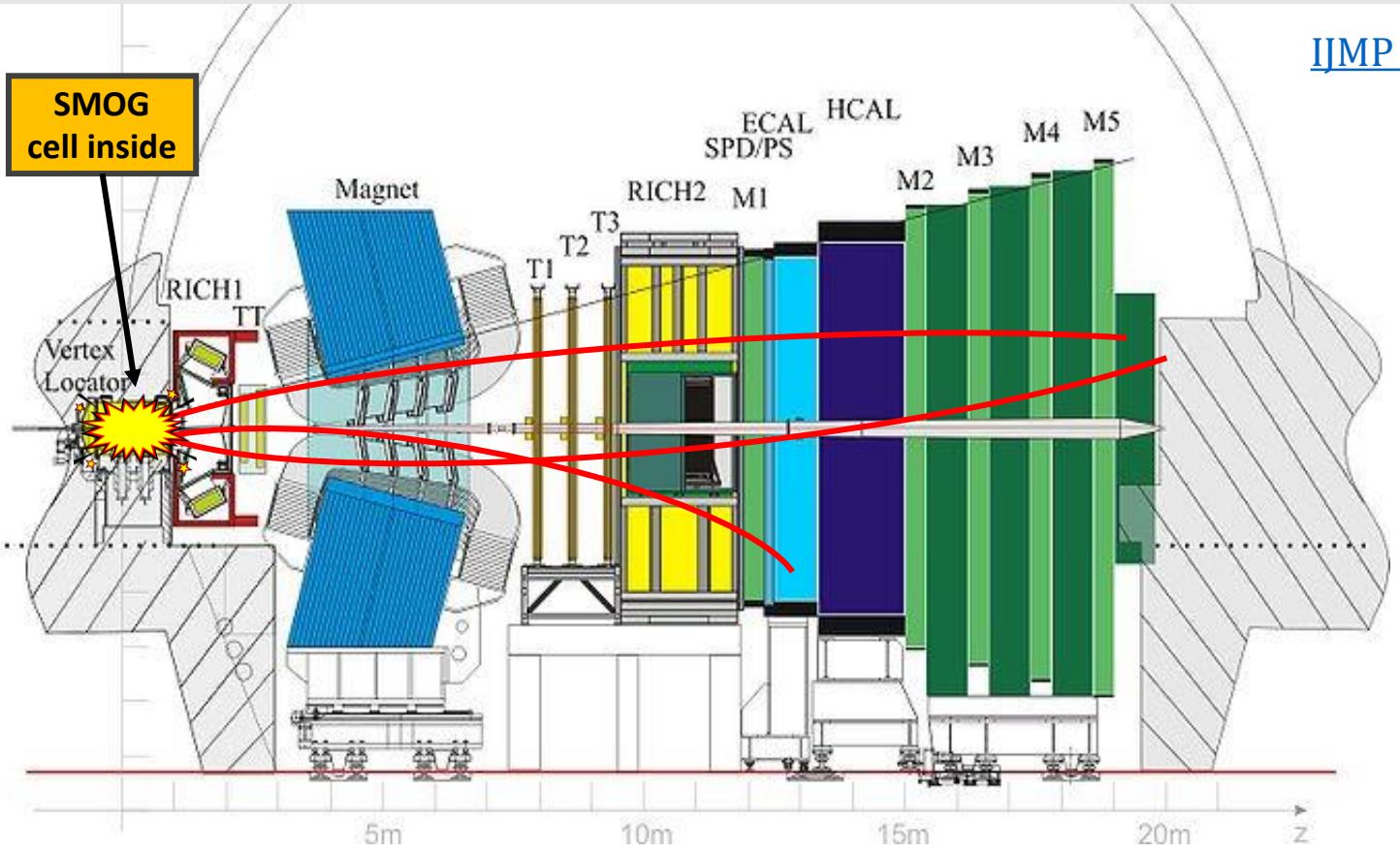
Results and ongoing analyses:

- Υ production in pPb
- X(3872)production in high multiplicity in pp
- Double Charm Production in pPb

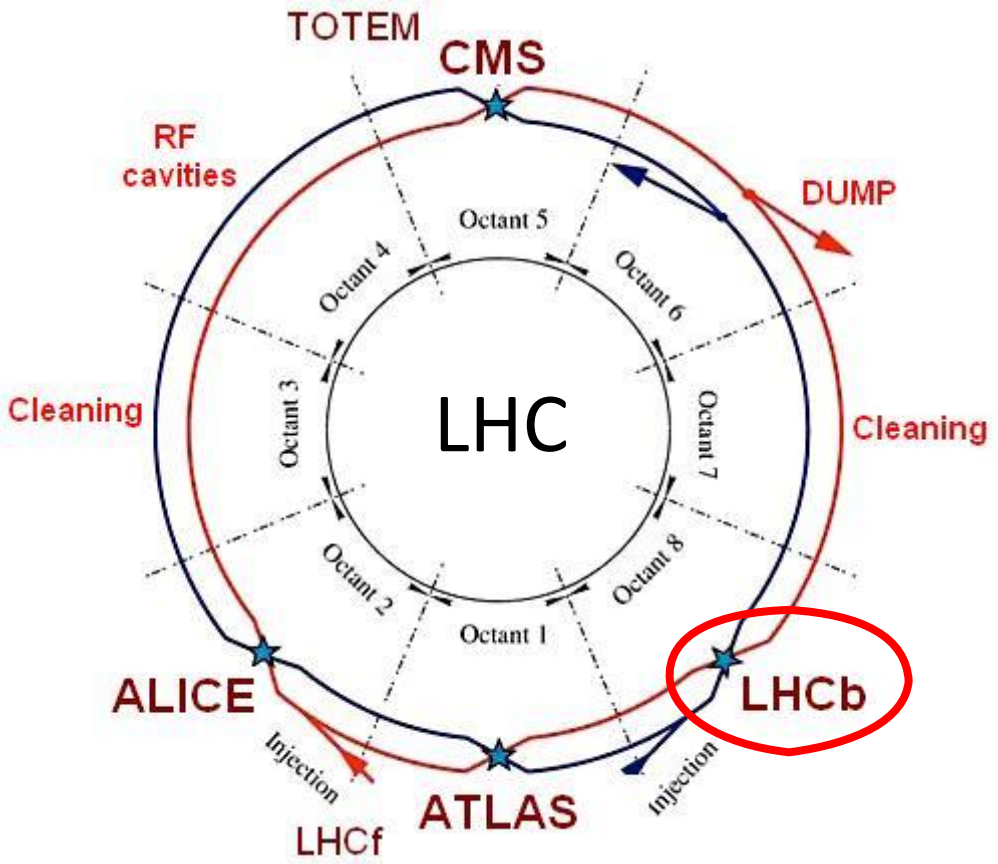
Prospects:

- LHCb upgrade Run3
- Fixed Target: SMOG2

The LHCb detector at CERN

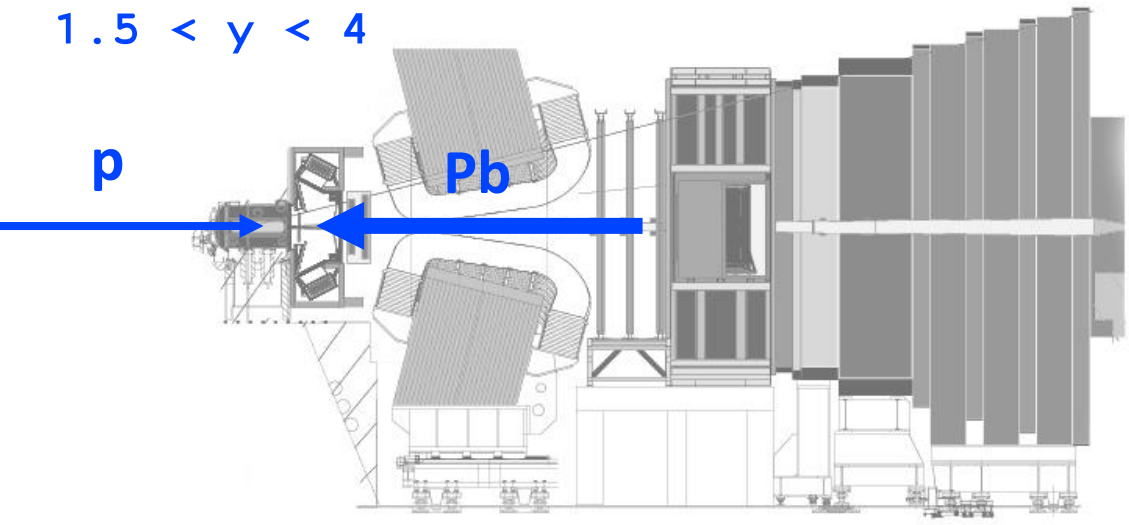


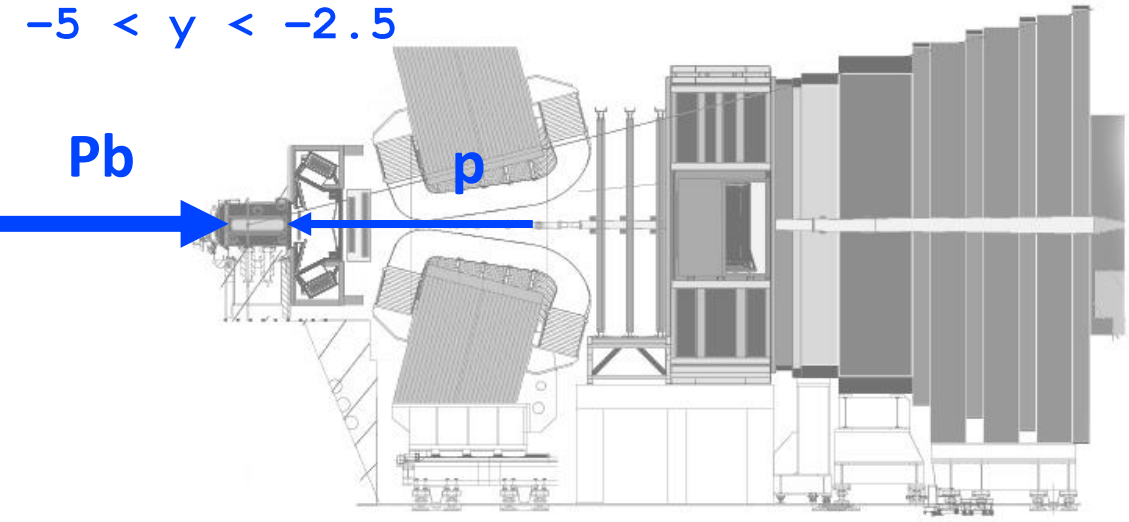
IJMP A, Vol. 30, No. 07, 1530022 (2015)



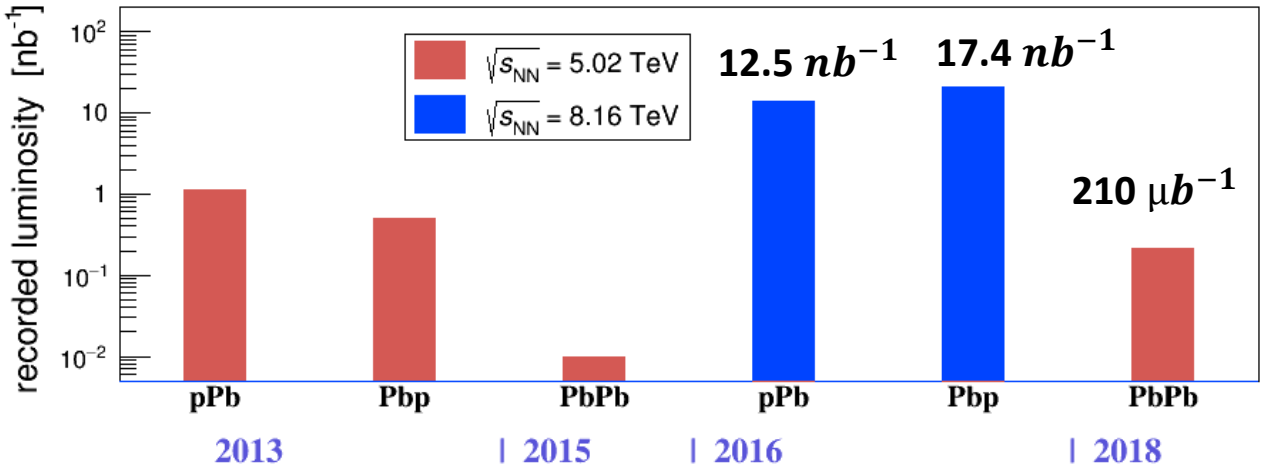
- 2 < y < 5 pseudo-rapidity range;
- pp/Pbp/PbPb and fixed target mode;
- Interaction point resolution < 10 μm;
- Momentum resolution 0.5-1.0% (5-200 GeV/c);
- Excellent **e, μ, π, K, p, γ** identification ;

Available samples in Run2

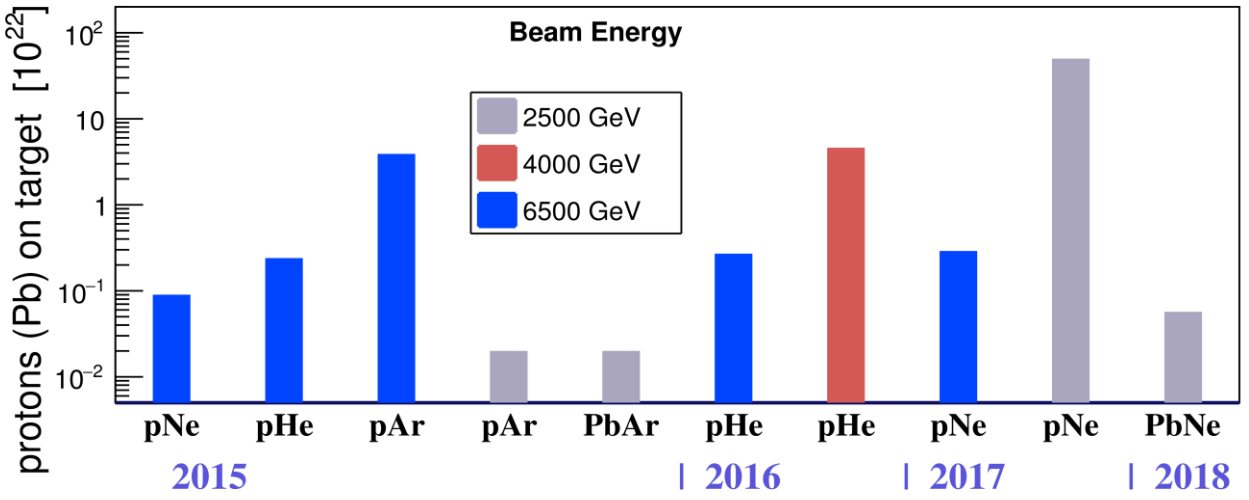




Collider mode samples:



Fixed target mode samples:



Results and ongoing analyses

Published Results

A summary in the WG data base:

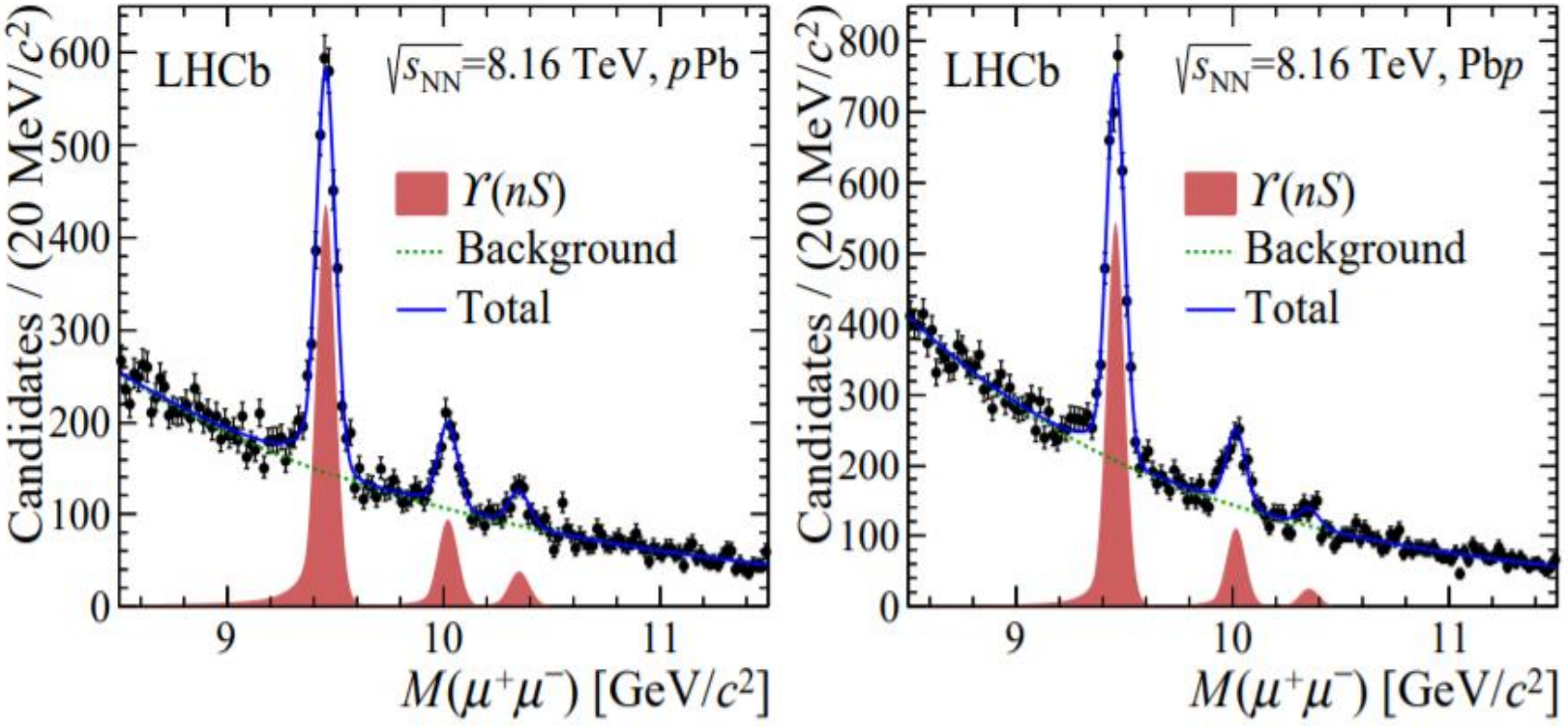
Title	Details	Reference
open beauty in p-Pb 8 TeV	PAPER-2018-048	Phys. Rev. D 99, 052011
Status and Prospects for Fixed Target Physics (PBC)	LHCB-PUB-2018-015	
SMOG2 Technical Design Report	LHCB-TDR-020	
Projections for pPb analyses in Run 3 and Run 4	LHCB-CONF-2018-005	
First measurements of charm production fixed-target configuration at the LHC	PAPER-2018-023	PRL 122 (2019) 132002
Study of Upsilon production in pPb collisions at √sNN=8 TeV	PAPER-2018-035	JHEP11(2018)194
Prompt Lc production in pPb collisions at √sNN=5.02 TeV	PAPER-2018-021	JHEP 02 (2019) 102
Measurement of antiproton production in pHe collisions at √sNN=110 GeV	PAPER-2018-031	PRL 121 (2018) 222001
Study of prompt D0 meson production in pPb collisions at √sNN=5 TeV	PAPER-2017-015	JHEP 10 (2017) 090
Prompt and nonprompt J/ψ production and nuclear modification in pPb collisions at √sNN=8.16 TeV	PAPER-2017-014	PLB 774 (2017) 159
Study of ψ(2S) production and cold nuclear matter effects in pPb collisions at 5 TeV	PAPER-2015-058	JHEP 03 (2016) 133
Measurements of long-range near-side angular correlations in sNN=5 TeV proton-lead collisions in the forward region	PAPER-2015-040	PLB 762 (2016) 473
Observation of Z production in proton-lead collisions at LHCb	PAPER-2014-022	JHEP 09 (2014) 030
Study of Y production and cold nuclear matter effects in pPb collisions at 5 TeV	PAPER-2014-015	JHEP 07 (2014) 094
Study of J/ψ production and cold nuclear matter effects in pPb collisions at 5 TeV	PAPER-2013-052	JHEP 02 (2014) 72

and many more to come…

Υ production in pPb

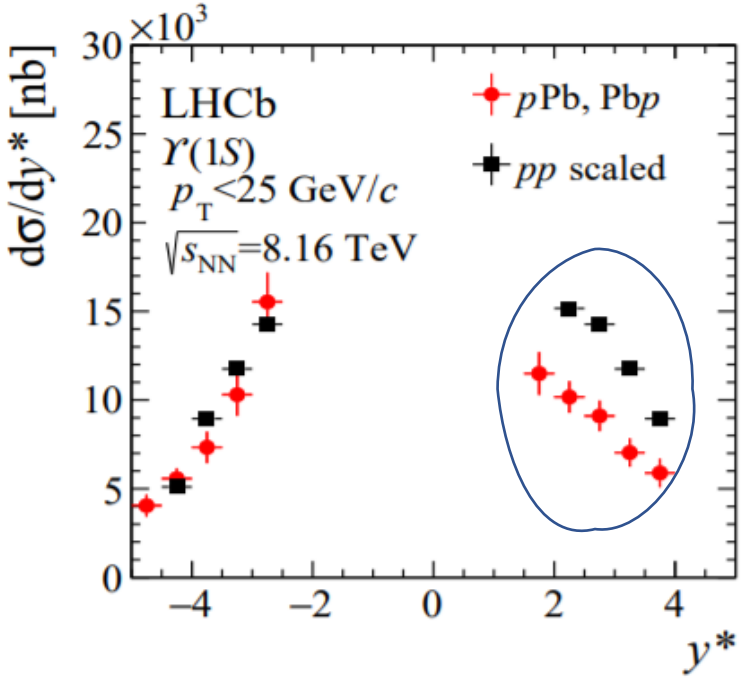
Signal yields

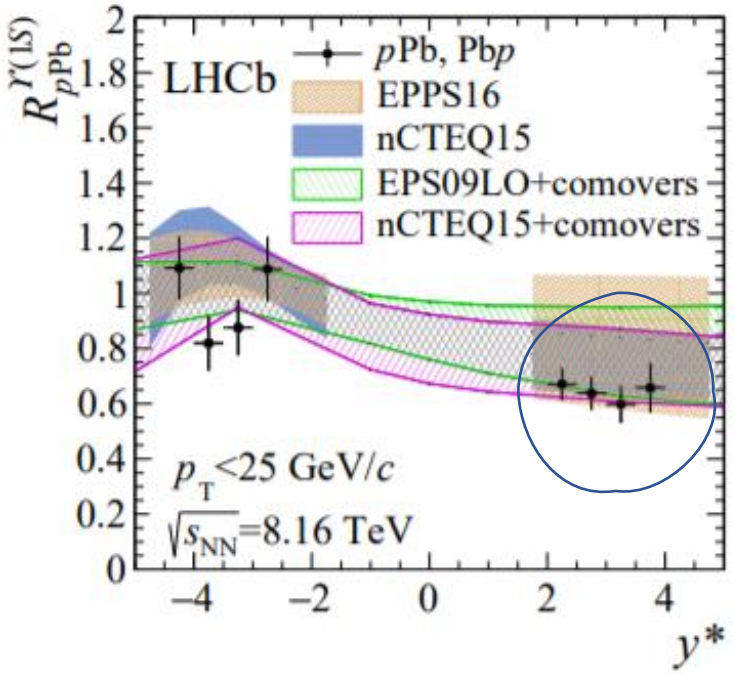
Samples	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$	$\mathcal{L}$
pPb	2705 ± 87	584 ± 49	262 ± 44	12.5 nb^{-1}
Pbp	3072 ± 82	679 ± 54	159 ± 39	19.3 nb^{-1}

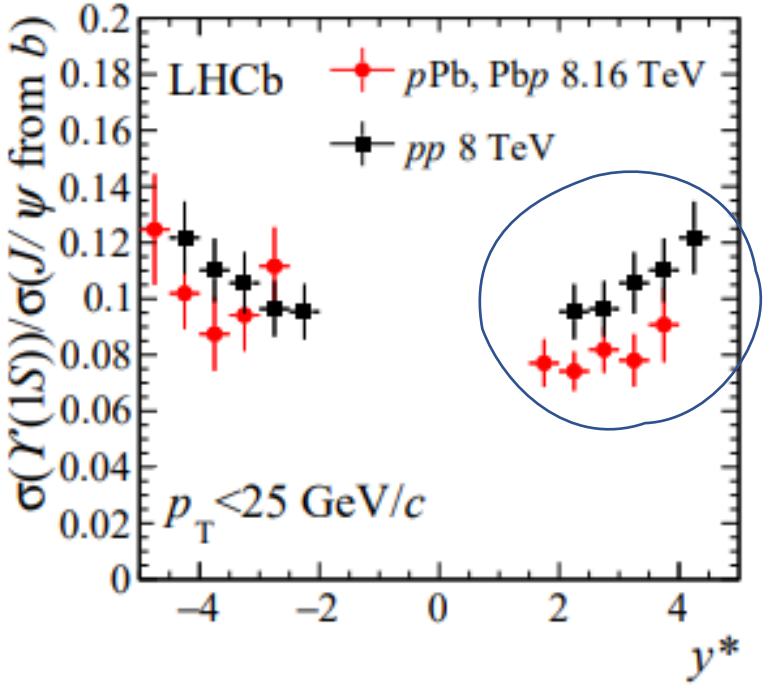


JHEP11(2018)194

Υ production in pPb







The production of Υ(1S) is suppressed in the forward region.

R_{pPb} – nuclear modification factor, suppressed in pPb collisions up to about 40%, consistent with model calculations.

A small suppression is visible, which could be attributed to final-state CNM effects.

[JHEP11(2018)194]

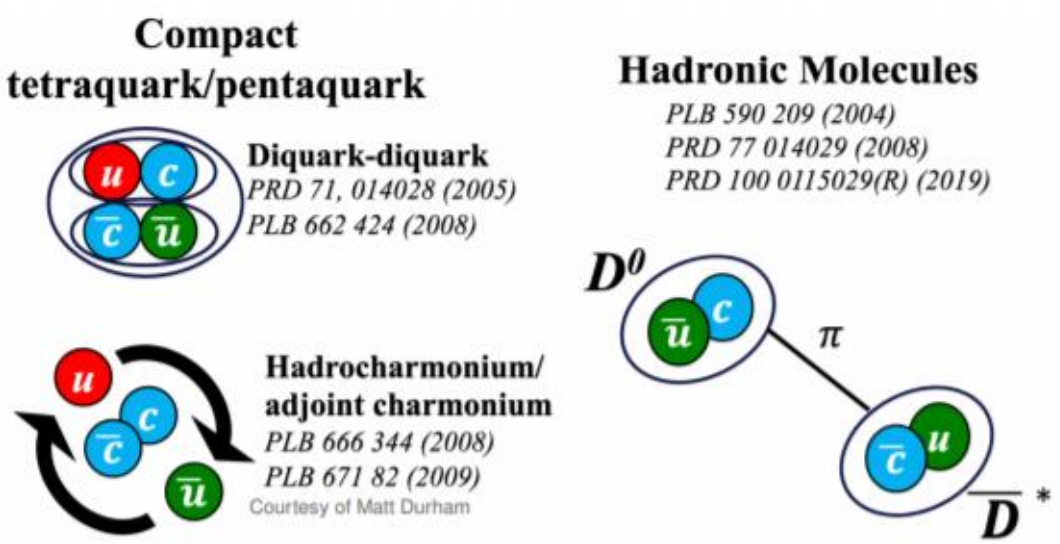
MODELS:
EPPS16: Eur. Phys. J. C (2017) 77: 163
EPS09: JHEP 04 (2009) 065, arXiv:0902.4154
nCTEQ15: Phys. Rev. D93 (2016) 085037
Comovers: arXiv:1804.04474; Phys. Lett. B749 (2015) 98, arXiv:1411.0549

$$R_{pPb}(p_T) = \frac{\text{Yield}_{pPb}(p_T)}{\langle N_{bin}\rangle_{pPb} \times \text{Yield}_{pp}(p_T)}$$

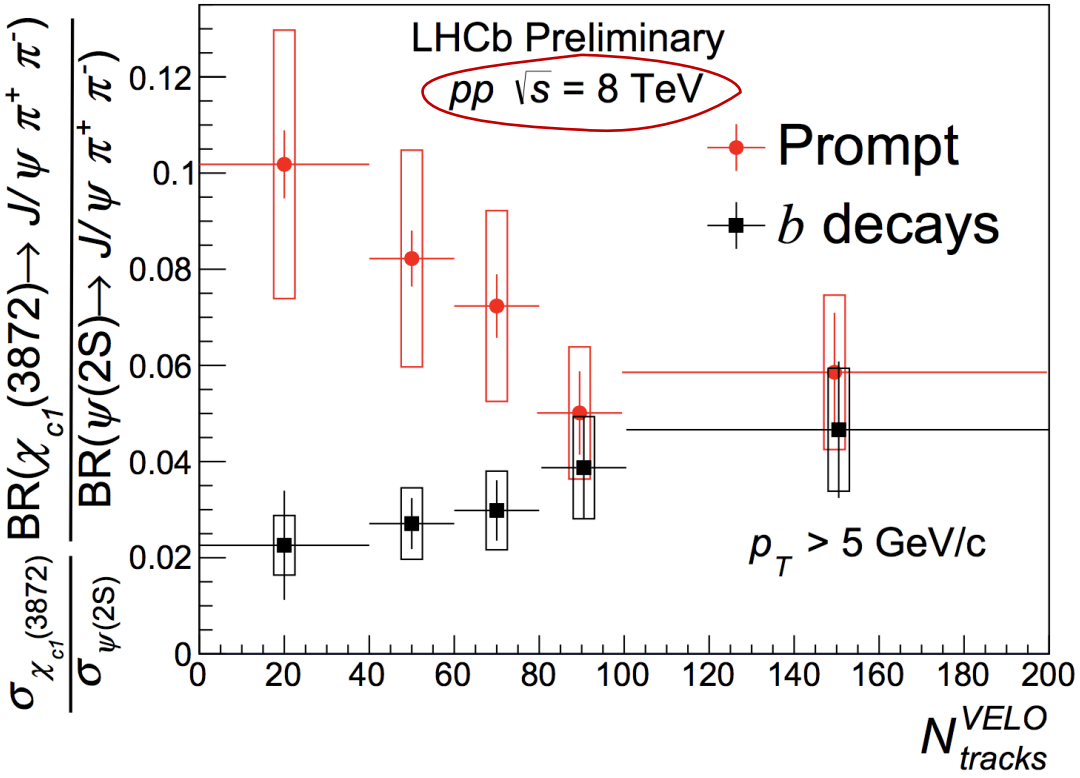
X(3872) production in high multiplicity in pp

First observed by Belle in $B^+ \to J/\psi\ \pi^+\ \pi^-\ K^+$ [PRL 91, 262001]

LHCb measurement of quantum numbers $J^{PC} = 1^{++}$ [PRL 110, 222001]

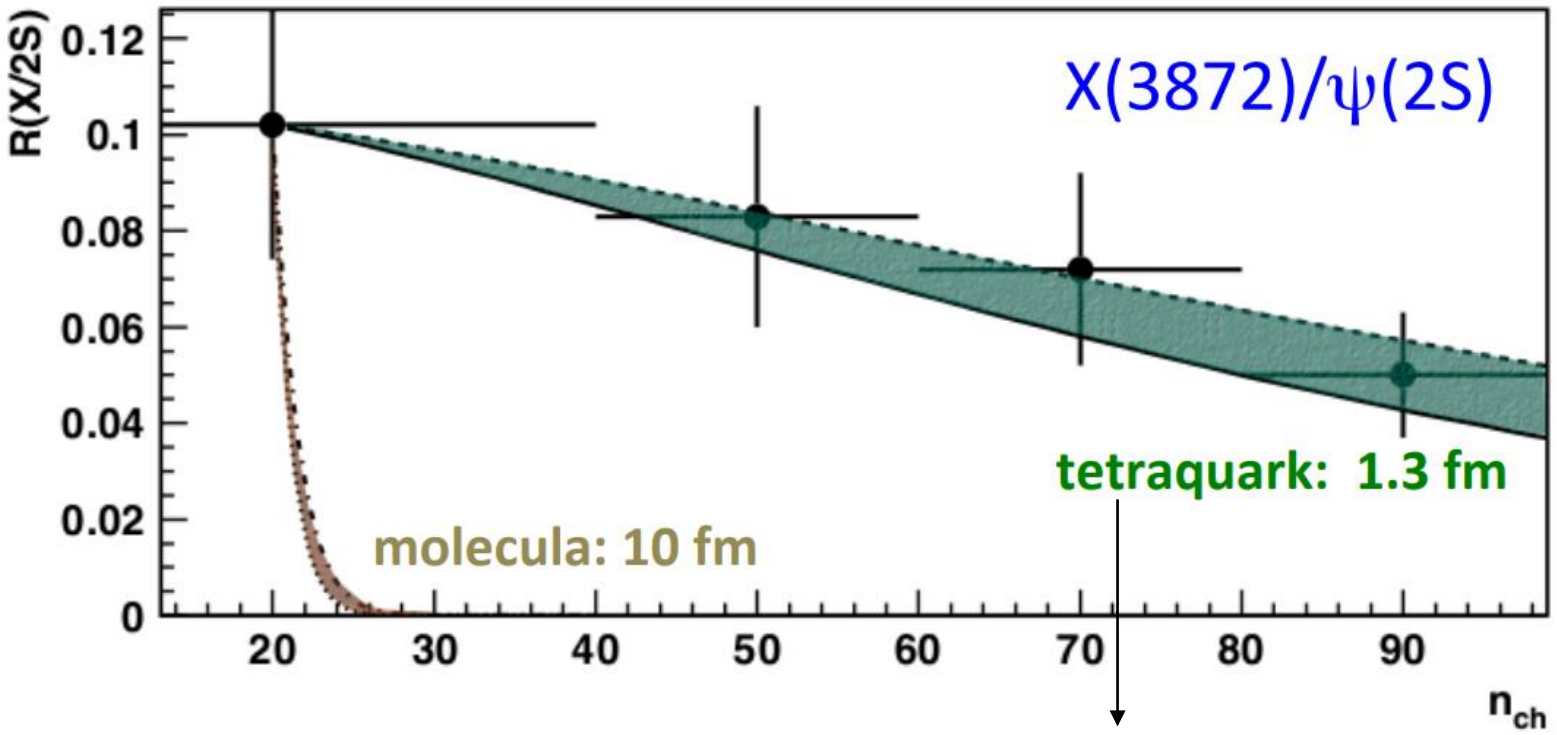


$L = 2\ fb^{-1}$ LHCb-CONF-2019-005



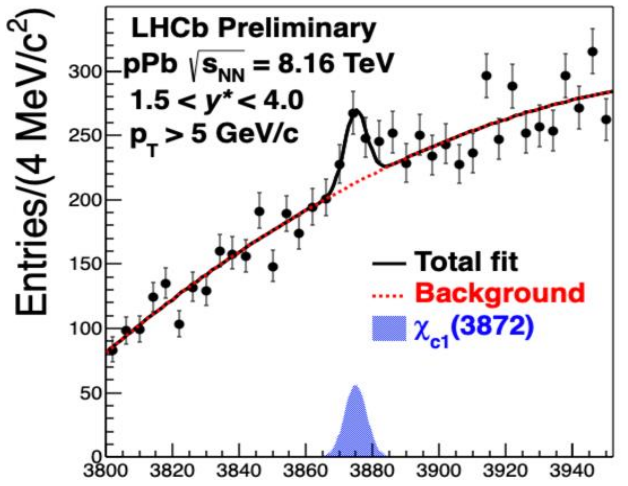
- We can probe the structure through multiplicity dependent measurements.

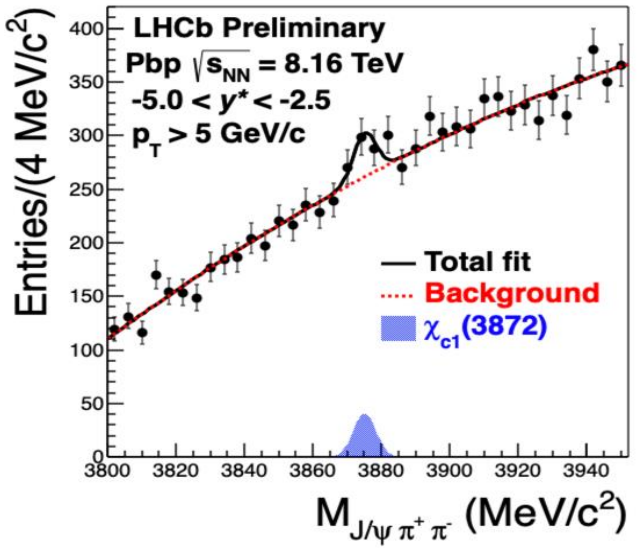
X(3872)production in high multiplicity in pp



LHCb-CONF-2019-005

Comovers model:
arXiv:2006.15044

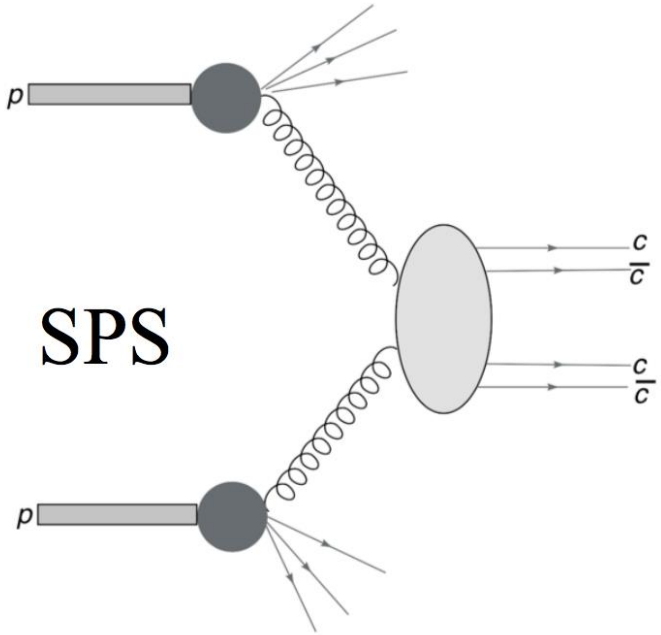




- Molecular particle would disappear with modest multiplicity;
- Tendency that X(3872) is a compact tetraquark of 1.3 fm;
- Coming soon in **pPb**…

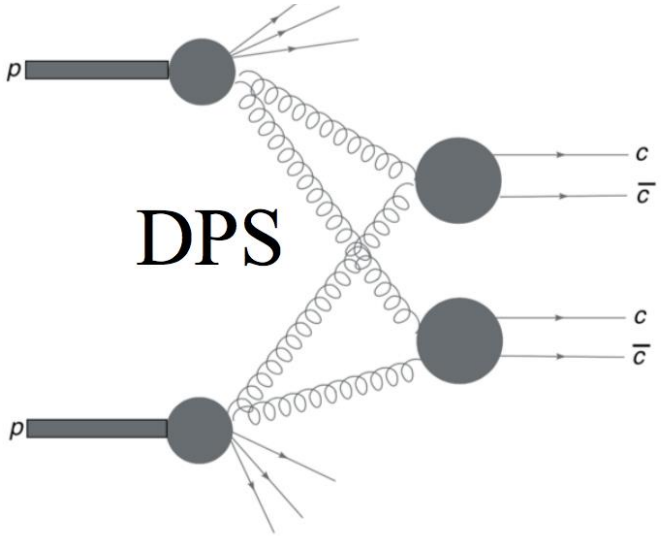
Double Charm Production

Single Parton Scattering



Double Parton Scattering

Phys. Rev. D **96**, 074013



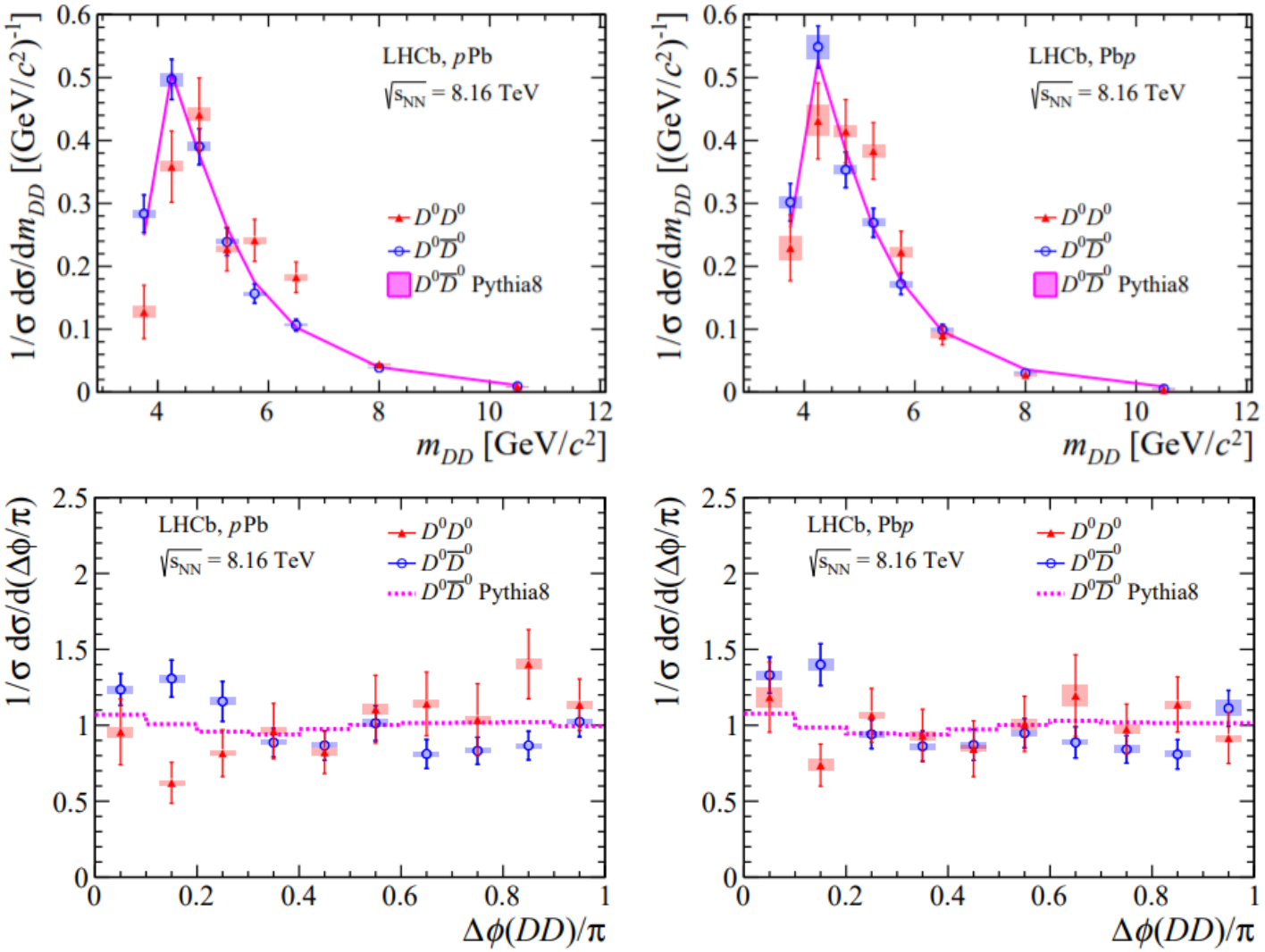
$$\sigma_{DPS}^{AB} = \frac{\sigma^A \sigma^B}{\sigma_{eff}}$$

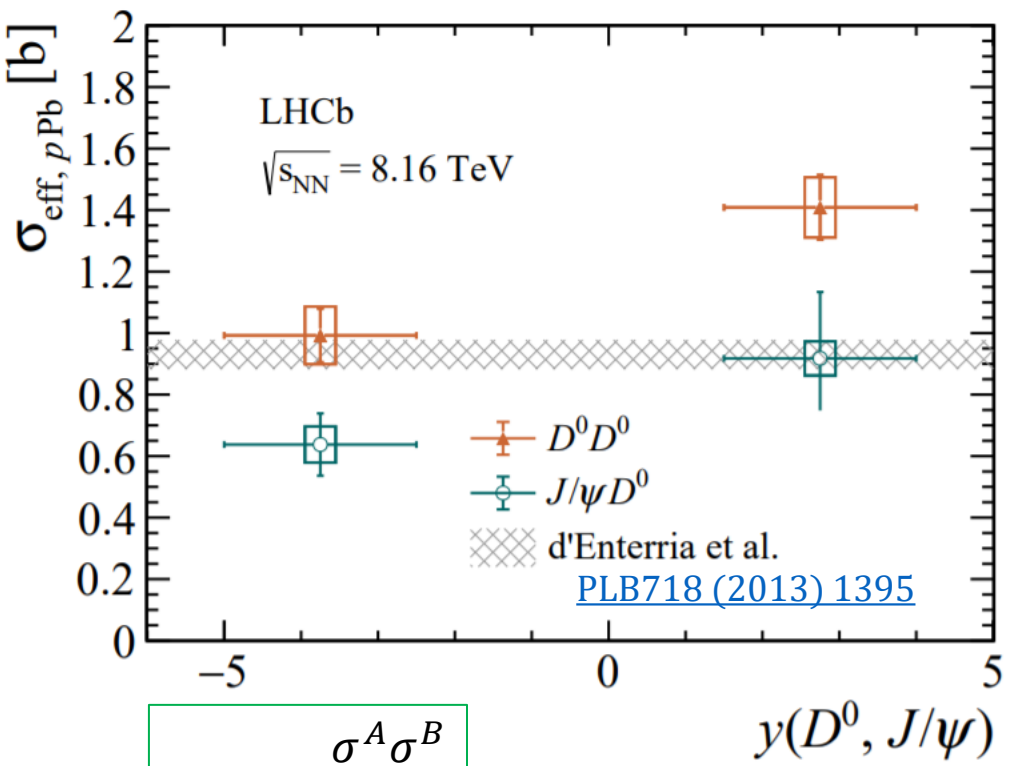
Opposite-sign (OS): mesons are formed in SPS;

Like-sign (LS): mesons are produced in DPS. Should be uncorrelated if there is no parton correlation.

- The first measurement of charm pair production in pPb (Pbp) with 12.2 (18.6 nb^{-1}) at 8.16 TeV;
- Studies of LS pair production and correlations in different environments help to test the universality of the parameter σ_{eff} and thus of the underlying parton correlations.

Double Charm Production





$$\sigma_{eff} = \frac{\sigma^A \sigma^B}{\sigma^{AB}_{DPS}}$$

- σ_{eff} using J/ψ-D_0 smaller than D_0–D_0 (due to SPS contamination or DPS enhancement in J/ψ-D_0 production);
- σ_{eff} for pPb data higher than Pbp data, suggesting a suppression of DPS signal in pPb data.

arXiv:2007.06945v1

Prospects

LHCb upgrade Run3

New tracking system:
- Silicon upstream detector (UT)
- Scintillating tracking fiber (SciFi)

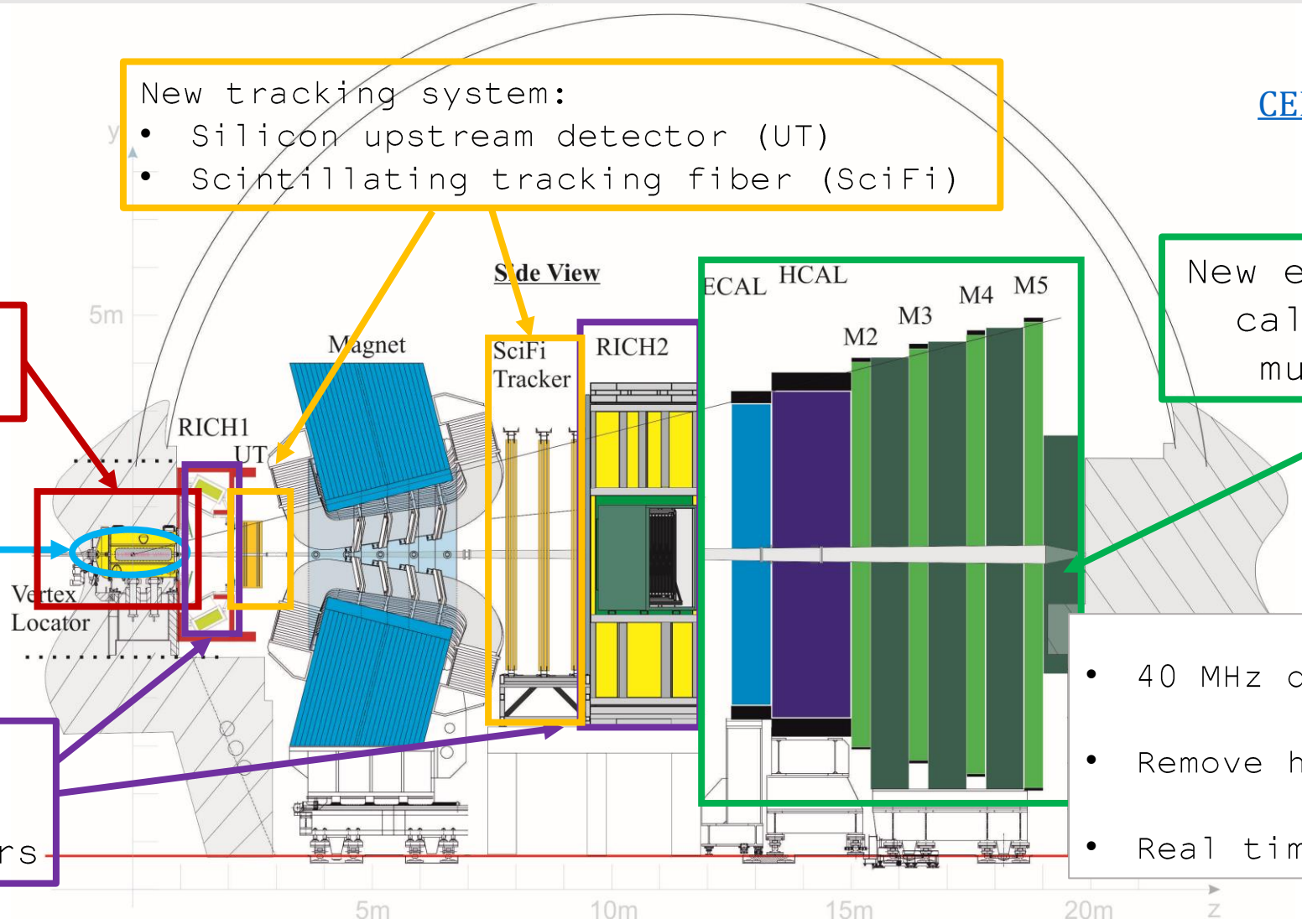
CERN-LHCC-2012-007

New Pixel VELO

New SMOG2 cell

New RICH optics and photodetectors

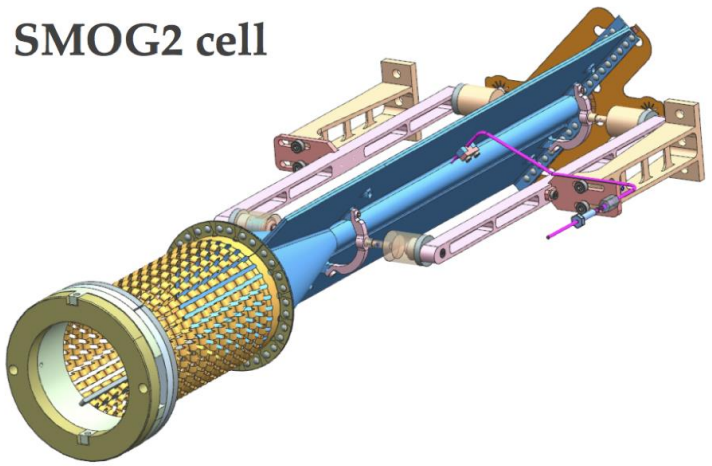
New electronics for calorimeter and muon chambers



- 40 MHz data acquisition
- Remove hardware trigger
- Real time data reconstruction

Heavy ion program will profit from this upgrade!

Fixed Target: SMOG2

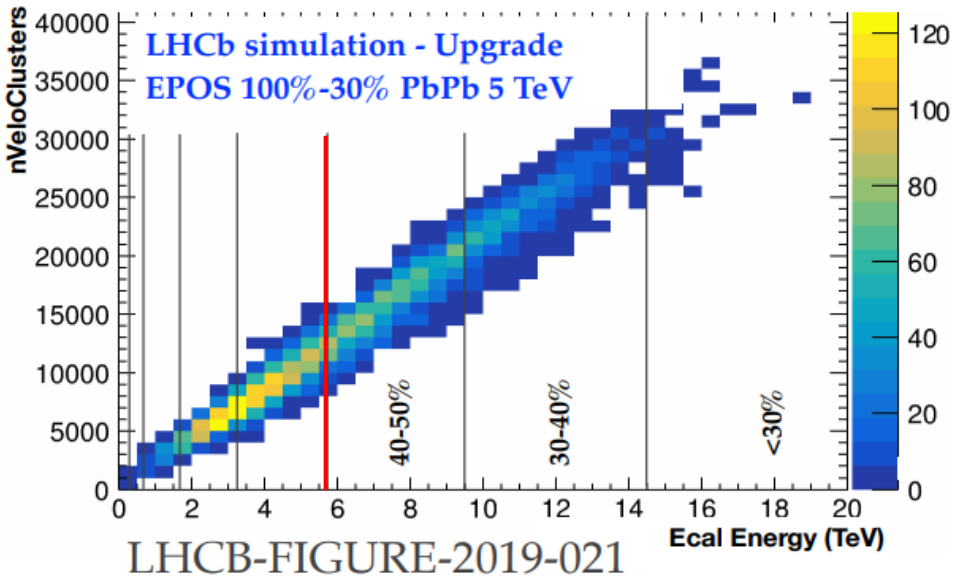


- SMOG2 will replace SMOG
- Higher density of the gas (up to 100x higher luminosity);
- First preliminary studies show minimal disturbance to the pp -> run in parallel;
- New gas H_2, D_2, O_2 in addition to all noble gases;

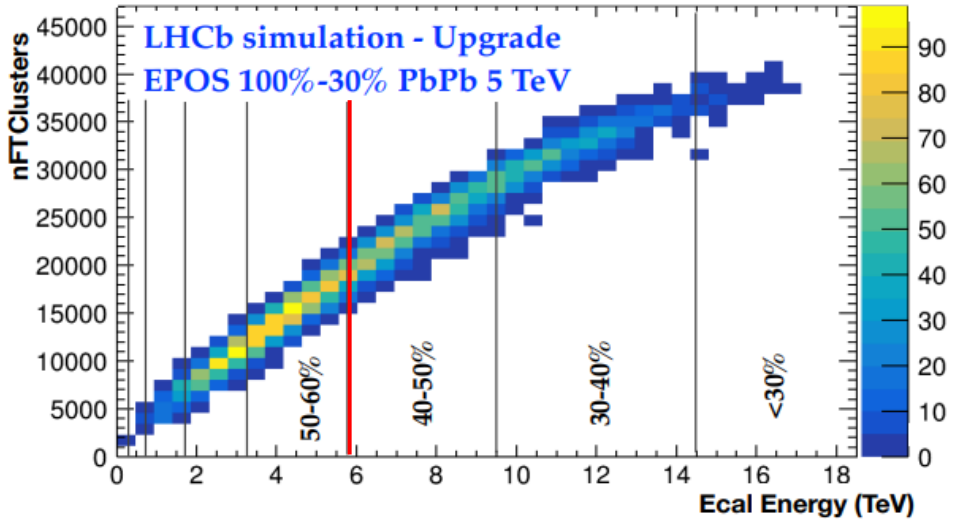
LHCb-PUB-2018-015	SMOG published result pHe@87 GeV	SMOG largest sample pNe@69 GeV	SMOG2 example pAr@115 GeV
Integrated luminosity	7.6 nb^{-1}	$\sim$ 100 nb^{-1}	$\sim$ 45 pb^{-1}
syst. error on J/ψ x-sec.	7%	6 - 7%	2 - 3 %
J/ψ yield	400	15k	15M
D^0 yield	2000	100k	150M
Λ_c^+ yield	20	1k	1.5M
$\psi(2S)$ yield	negl.	150	150k
$\Upsilon(1S)$ yield	negl.	4	7k
Low-mass Drell-Yan yield	negl.	5	9k

LHCb upgrade Run3

- Run3 → Feb 2022 start
- 2 runs of PbPb
- 1 run of pPb+Pbp
- other species
- several fix target samples



LHCB-FIGURE-2019-021



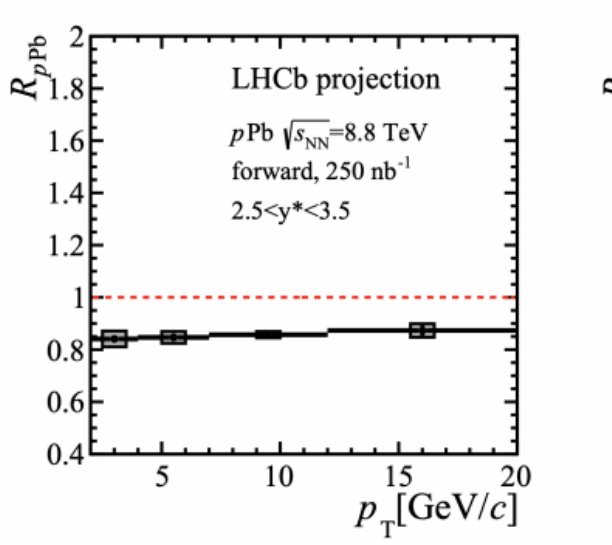
- No significant saturation for 70% most peripheral collisions (simulation for higher centralities are being produced);
- Semi-central PbPb collisions soon available : QGP studies for LHCb in Run3!
- Expect almost no saturation for Run4 (90% most peripheral) and no saturation for Run5.

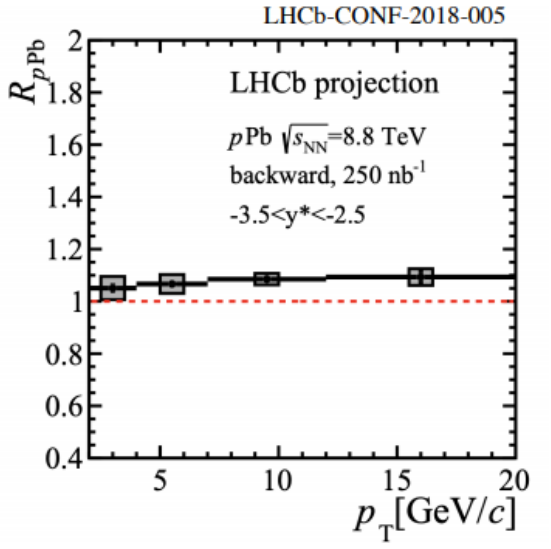
Conclusions

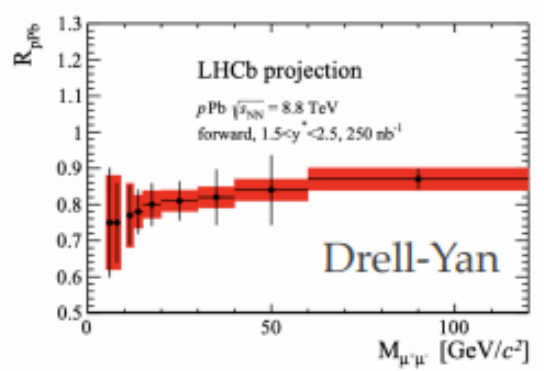
- LHCb data is already providing essential information for the understanding of hard probes in Heavy Ion collisions;
- New results on double charm production provide rich material for the study of parton correlations;
- LHCb has a solid and complete Heavy Ion physics program, with unique capabilities;
- The LHCb detector will soon be able to perform Quark Gluon Plasma studies with the improvements of the detector in high occupancy.

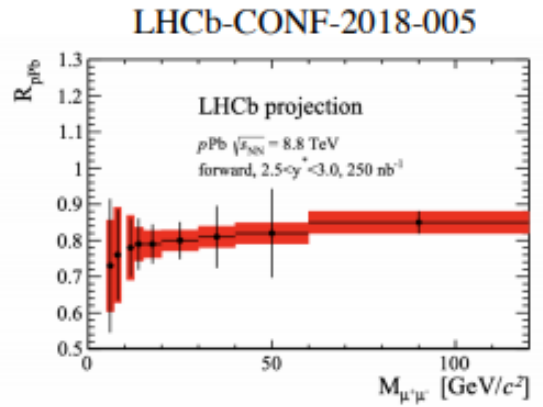
backup

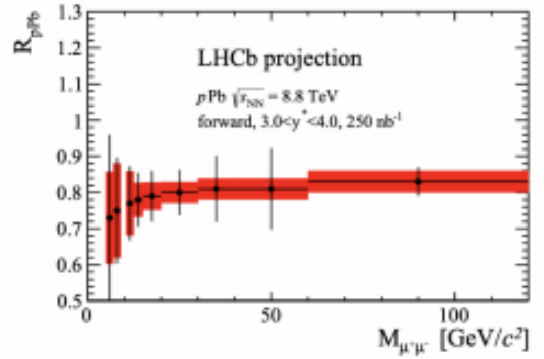
LHCb upgrade Run3

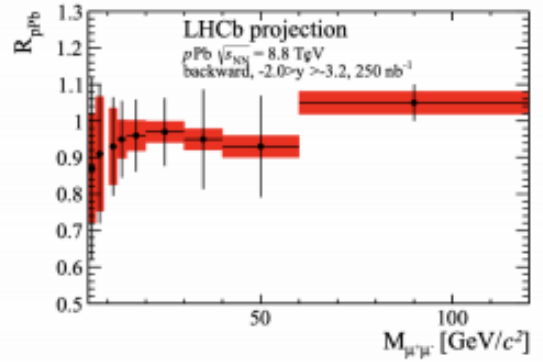


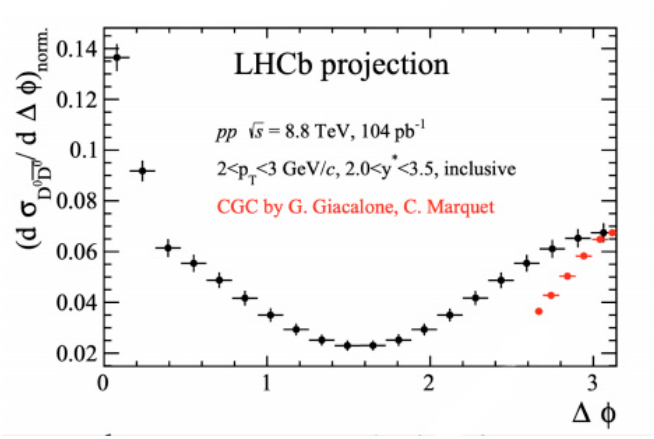


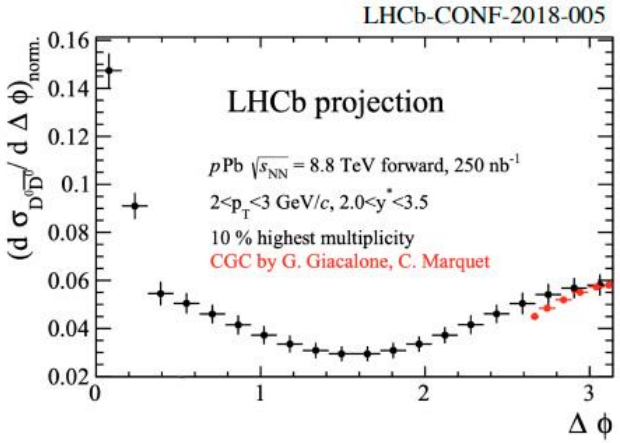










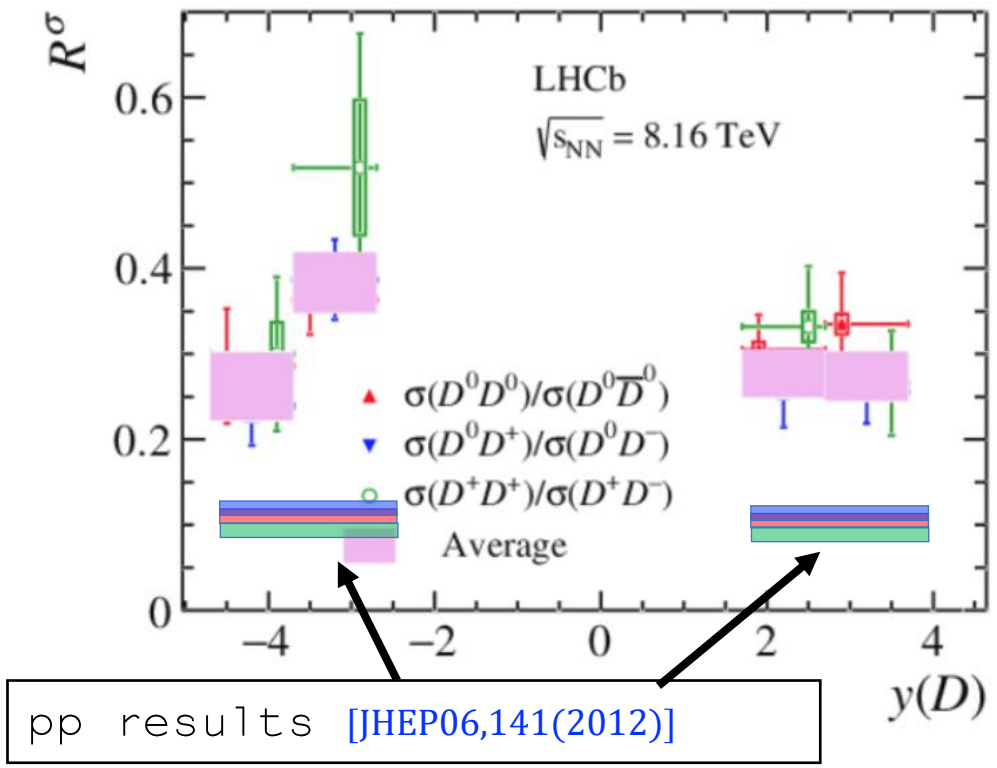


and many more…

Double Charm Production

$$\sqrt{s_{NN}} = 8.16TeV$$

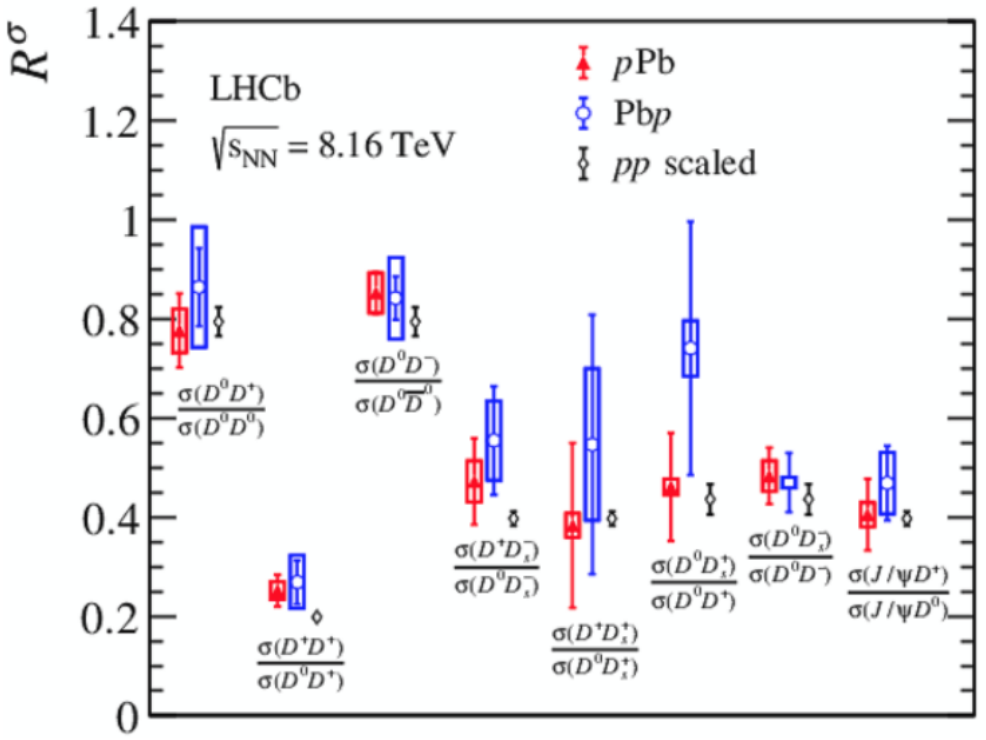
arXiv:2007.06945v1



pp results [JHEP06,141(2012)]

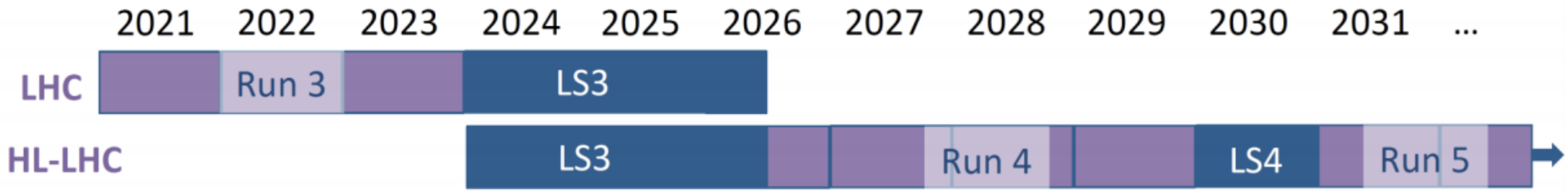
Like-sign production enhanced by a factor ~3 in pPb and even more in Pbp

pPb Pbp



No significant modification of charm hadronization in pPb and Pbp collisions compared to pp collisions.

Future samples (possible schedule)



LS2 – LHCb upgrade 1a →

LS3 – LHCb upgrade 1b →

LS4 – LHCb upgrade 2 →

Year	Systems, $\sqrt{s_{NN}}$	Time	L_{int}
2021	Pb–Pb 5.5 TeV	3 weeks	2.3 nb^{-1}
	pp 5.5 TeV	1 week	3 pb^{-1} (ALICE), 300 pb^{-1} (ATLAS, CMS), 25 pb^{-1} (LHCb)
2022	Pb–Pb 5.5 TeV	5 weeks	3.9 nb^{-1}
	O–O, p–O	1 week	500 μb^{-1} and 200 μb^{-1}
2023	p–Pb 8.8 TeV	3 weeks	0.6 pb^{-1} (ATLAS, CMS), 0.3 pb^{-1} (ALICE, LHCb)
	pp 8.8 TeV	few days	1.5 pb^{-1} (ALICE), 100 pb^{-1} (ATLAS, CMS, LHCb)
2027	Pb–Pb 5.5 TeV	5 weeks	3.8 nb^{-1}
	pp 5.5 TeV	1 week	3 pb^{-1} (ALICE), 300 pb^{-1} (ATLAS, CMS), 25 pb^{-1} (LHCb)
2028	p–Pb 8.8 TeV	3 weeks	0.6 pb^{-1} (ATLAS, CMS), 0.3 pb^{-1} (ALICE, LHCb)
	pp 8.8 TeV	few days	1.5 pb^{-1} (ALICE), 100 pb^{-1} (ATLAS, CMS, LHCb)
2029	Pb–Pb 5.5 TeV	4 weeks	3 nb^{-1}
Run-5	Intermediate AA	11 weeks	e.g. Ar–Ar 3–9 pb^{-1} (optimal species to be defined)
	pp reference	1 week	

arXiv:1812.06772 - CERN-LPCC-2018-07