AFTER@LHC: A fixed-target programme at the LHC for heavy-ion, hadron, spin and astroparticle physics

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WHAT IS AFTER@LHC AND WHAT FOR?

AFTER@LHC is a proposal for a multi-purpose fixed target experiment using the multi-TeV proton or heavy ion beams of the LHC

- **Advance our understanding of the large-x gluon, antiquark and heavy-quark content in the nucleon and nucleus**
  - Very large PDF uncertainties for x $\gtrsim$ 0.5
  - Proton charm content important to high-energy neutrino and cosmic-ray physics
  - EMC effect is an open problem; studying a possible gluon EMC effect is essential
  - Relevance of nuclear PDF to understand initial state of heavy-ion collisions
  - Search and study of rare proton fluctuations, where one gluons carries most of the proton momentum
- **Dynamics and spin of gluons inside (un)polarised nucleons**
  - Possible missing contribution to the proton spin: orbital angular momentum
  - Test of the QCD factorisation framework
  - Determination of linearly polarised gluons in unpolarised protons
- **Heavy-ion collisions from mid- to large rapidities**
  - Explore the longitudinal expansion of QGP formation with hard probes
  - Test the factorisation of cold nuclear effect from p+A to A+B collisions
  - Test azimuthal asymmetries: hydro vs. initial-state radiation

Advantages of a fixed target experiment at LHC

✓ **Advantages of a fixed-target experiment:**

- **access to large Feynman $|x_F|$**
- **target versatility**
- **possibility to polarize target**
  - **spin physics program**
- **high luminosities with either dense targets or high intensity beams**

→ With LHC beams:

7 TeV proton beam on a fixed target

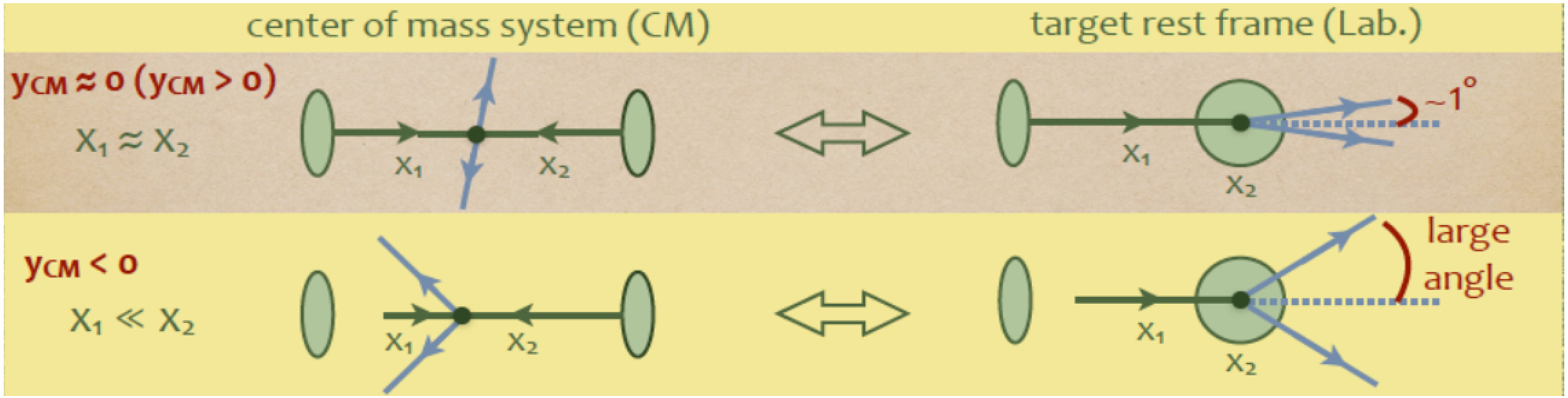
CMS energy:	$\sqrt{s} = \sqrt{2m_N E_p} \approx 115$ GeV	**Rapidity shift:** $y_{CM} = 0 \rightarrow y_{lab} = 4.8$
Boost:	$\gamma = \sqrt{s}/(2m_p) \approx 60$	

2.76 TeV Pb beam on a fixed target

CMS energy:	$\sqrt{s_{NN}} = \sqrt{2m_N E_{\rm Pb}} \approx 72$ GeV	**Rapidity shift:** $y_{CM} = 0 \rightarrow y_{lab} = 4.3$
Boost:	$\gamma \approx 40$	

Advantages of a fixed target experiment at LHC

✓ Testing QCD at large $x = (0.3,1)$



✓ Entire forward hemisphere – $y_{CM} > 0$ – within: $0° < \theta_{lab} < O(1°)$ - large occupancy – more challenging

✓ Backward region - $y_{CM} < 0$ – at large angles in the lab frame – low occupancy, no constrain from a beam pipe

- Backward physics fully accessible for the first time
- Access to partons with momentum fraction $x_2 \rightarrow 1$ in the target ($x_F \rightarrow -1$)

Possible fixed-target modes with LHC beams

- ✓ **Beam line extracted with a bent crystal**
- ✓ **Beam "split" with a bent crystal**
  - ✗ beam collimation at LHC using bent crystals is studied by the UA9 collaboration
  - ✗ UA9 test @SPS of the crystal with proton and ion beams
  - ✗ LUA9 (beam bending experiment at LHC using crystal)
    - 2 bent crystals installed in IR7 during LS1, 2015/2016 tests with beams
  - ✗ proton beam extraction: single or multi-pass extraction efficiency, 50%
  - ✗ expected extracted p beam: 5×10^8 p/s (LHC beam loss: $\sim 10^9$ p/s)
  - ✗ expected extracted Pb beam: 2×10^5 Pb/s

Dense targets

- ✓ **Internal gas target similar to SMOG at LHCb / inspired by HERMES at HERA**
  - ✗ can be installed in one of the existing LHC cavens or in a new one
  - ✗ currently tested by the LHCb collaboration via a luminosity monitor (SMOG)
    - proton flux: 3.4×10^{18} p/s
    - Pb flux: 3.6×10^{14} Pb/s

High Intensity beams

- ✓ **Internal wire target**

Advances in High Energy Physics,
Volume 2015 (2015), Article ID 760840

Luminosities in pH and pA at 115 GeV

Instantaneous luminosity:

$$\mathcal{L} = \Phi_{beam} \times N_{target} = N_{beam} \times (\rho \times \ell \times \mathcal{N}_A)/A$$

l is a target thickness

Extracted beam

Target	ρ (g.cm^{-3})	A	L (μb^{-1}.s^{-1})	$\int$L (pb^{-1}.yr^{-1})
Liq H_2 (1m)	0.07	1	2000	20000
Liq D_2 (1m)	0.16	2	2400	24000
Be (1cm)	1.85	9	62	620
Cu (1cm)	8.96	64	42	420
W (1cm)	19.1	185	31	310
Pb (1cm)	11.35	207	16	160

Internal gas target

Beam	Target	Usable gas zone (cm)	Pressure (Bar)	L (μb^{-1}.s^{-1})	$\int$L (pb^{-1}.yr^{-1})
p	Perfect gas	100	10^{-9}	10	100

With pressure of 10^{-6} mbar - 3 times SMOG – one gets 100 pb^{-1} yr^{-1}

→ target storage cell that can be **polarised**

P = 10^{-4} mbar

Advances in High Energy Physics, Volume 2015 (2015), Article ID 463141

Luminosities in pH and pA at 115 GeV

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Advances in High Energy Physics, Volume 2015 (2015), Article ID 463141

Integrated luminosities with 10^7 s (LHC year – 9 months of running)

For 1m long H_2 target

$\int \mathcal{L}$ **= 20 fb^{-1}yr^{-1}**

$\int \mathcal{L}$ **= 10 fb^{-1}yr^{-1}** for P = 10^{-4} mbar

Large luminosities comparable to LHC, 3 orders of magnitude larger that at RHIC

Similar integrated luminosities in **pA** in the target storage cell case as with the extracted beam option

Luminosities in PbH and PbA at 72 GeV

Instantaneous luminosity:

$$\mathcal{L} = \Phi_{beam} \times N_{target} = N_{beam} \times (\rho \times \ell \times \mathcal{N}_A)/A$$

l is a target thickness

Extracted beam

Target	ρ (g.cm^{-3})	A	L (μb^{-1}.s^{-1})	∫L (pb^{-1}.yr^{-1})
Liq H_2 (1m)	0.07	1	0.8	0.8
Liq D_2 (1m)	0.16	2	1	1
Be (1cm)	1.85	9	0.025	0.025
Cu (1cm)	8.96	64	0.017	0.017
W (1cm)	19.1	185	0.013	0.013
Pb (1cm)	11.35	207	0.007	0.007

Internal gas target

Beam	Target	Usable gas zone (cm)	Pressure (Bar)	L (μb^{-1}.s^{-1})	∫L (pb^{-1}.yr^{-1})
Pb	Perfect gas	100	10^{-9}	0.001	0.001

$P = 10^{-6}$ *mbar*

→ target storage cell that can be **polarised**

Integrated luminosities with 10^6 s (Pb LHC year – 1 months of running)

For 1m long H_2 target

$\int\mathcal{L} = 0.8\ \mathrm{pb^{-1}yr^{-1}}$

For 1cm long Pb target

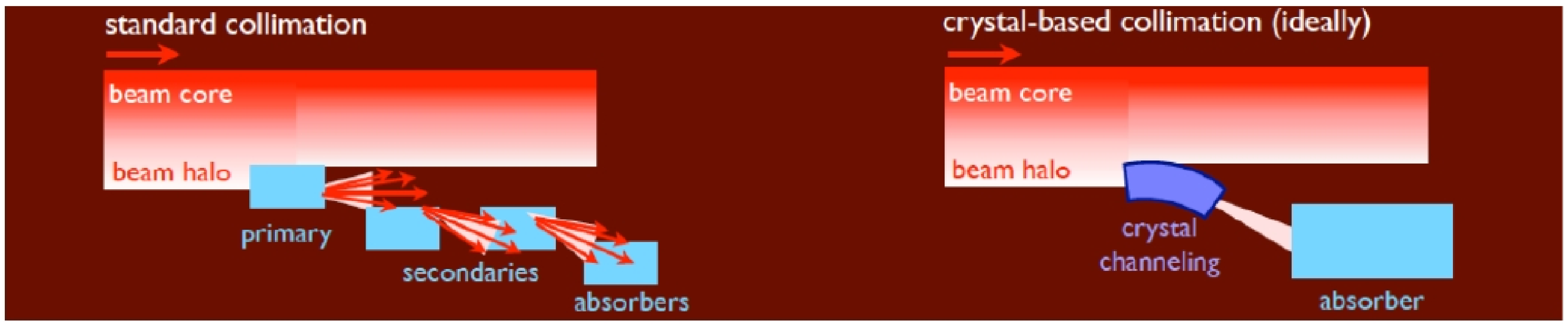
$\int\mathcal{L} = 7\ \mathrm{nb^{-1}yr^{-1}}$

$\int\mathcal{L} = 0.001\ \mathrm{pb^{-1}yr^{-1}}$ $P = 10^{-6}$ *mbar*

Nominal LHC collider luminosity for PbPb: 0.5 nb^{-1}

Beam extraction using bent crystal

✓ <u>Motivated for collimation purposes</u>



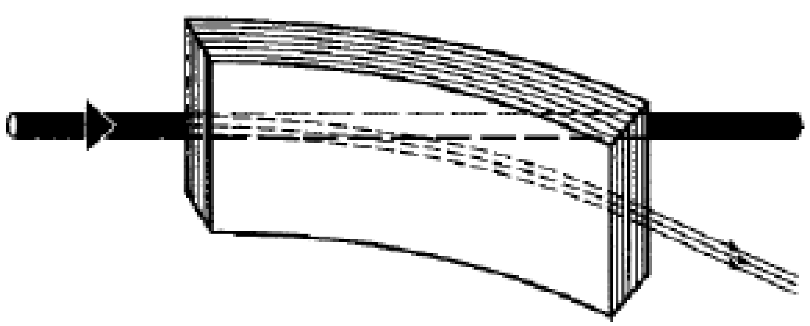
Standard collimation today → Crystal-based collimation
- UA9 (@SPS)
- LUA9 (@LHC)

→ To beam extraction
- CRYSBEAM (@SPS then LHC)
- AFTER@LHC

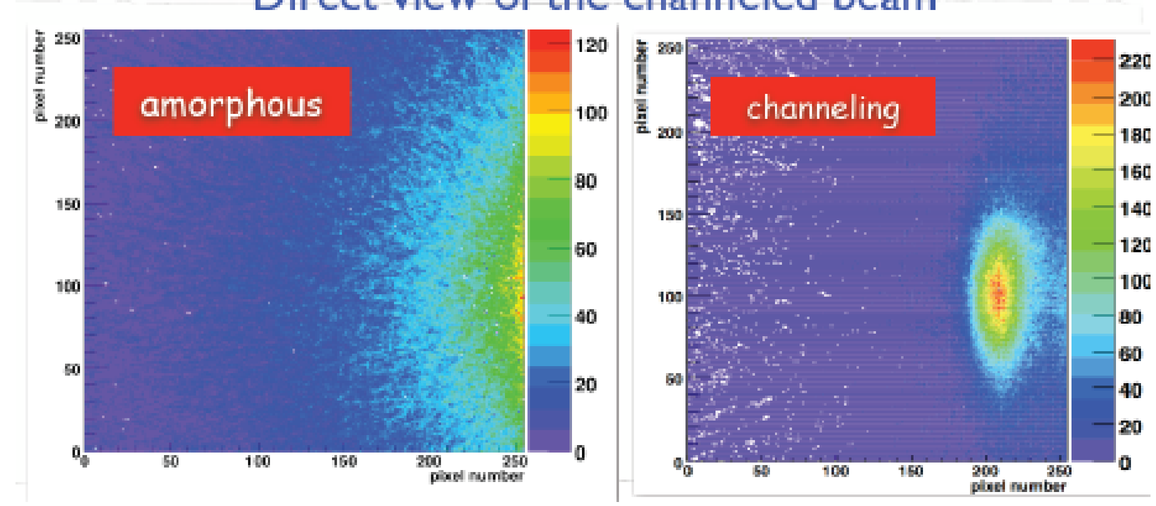
W. Scandale et al., JINST 6 T10002 (2011)

✓ The LHC beam extraction with "strong crystalline filed"

E. Uggerhøj, U.I Uggerhøj, NIM B 234 (2005) 31, Rev. Mod. Phys. 77 (2005) 1131



Direct view of the channeled beam



S. Montesano, W. Scandale, Joint LUA9-AFTER meeting, Nov. 2013

✓ <u>LUA9 test in the LHC complex</u>

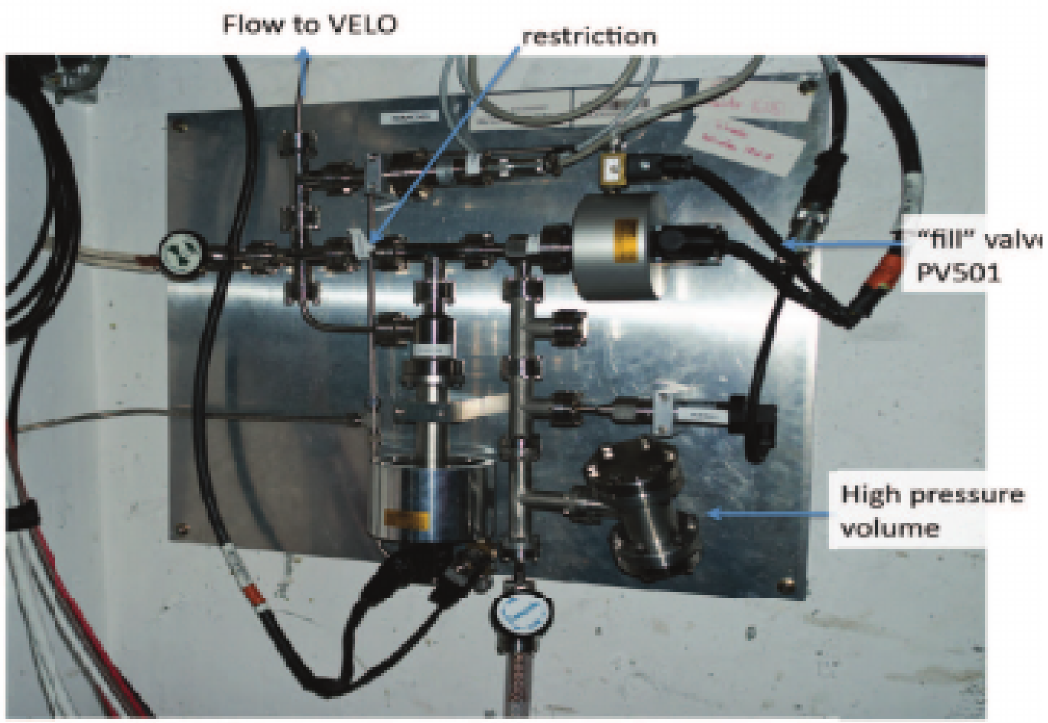
Deflecting the beam halo at 7σ distance to the beam

<u>Reduce the LHC beam loss</u>

Internal gas target, *SMOG@LHC*

✓ **Motivated for precise luminosity determination**

SMOG: System for Measuring Overlap with Gas



→ injection of Ne-gas into VELO

- ✓ Low density noble gas injected into VELO in LHCb
- ✓ Short pNe pilot run at $\sqrt{s_{NN}}$ = 87 GeV (2012)
- ✓ Short PbNe pilot run at $\sqrt{s_{NN}}$ = 54 GeV (2013) *LHCb-CONF-2012-034*
- ✓ He, Ne and Ar gas injected (2015)
- ✓ pNe, pAr run at $\sqrt{s_{NN}}$ = 110 GeV (end of August 2015)
- ✓ 1.5 week of PbAr at $\sqrt{s_{NN}}$ = 69 GeV (2015)

- ✗ So far only noble gases
- ✗ No decrease of LHC performances observed in test runs
- ✗ Target polarization is not possible with SMOG
- ✗ However internal gas target can be polarized, like HERMES target

Physics Highlights

Physics Highlights: AFTER@LHC

- ***Physics Reports 522 (2013) 239; Few Body Syst. 53 (2012) 11-25.***

Physics Reports 522 (2013) 239–255

Contents lists available at SciVerse ScienceDirect

Physics Reports

journal homepage: www.elsevier.com/locate/physrep

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Physics opportunities of a fixed-target experiment using LHC beams

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Contents

- ***Many more ideas for a fixed target experiment at LHC in a Special Issue in Advances in High Energy Physics***

Advances in High Energy Physics

Hindawi

Special Issue on
Physics at a Fixed-Target Experiment Using the LHC Beams

CALL FOR PAPERS

- ***Heavy-ion physics***
- ***Exclusive reactions***
- ***Spin physics studies***
- ***Hadron structure***
- ***Feasibility study and technical ideas***

http://after.in2p3.fr/after/index.php/Recent_published_ideas_in_favour_of_AFTER@LHC

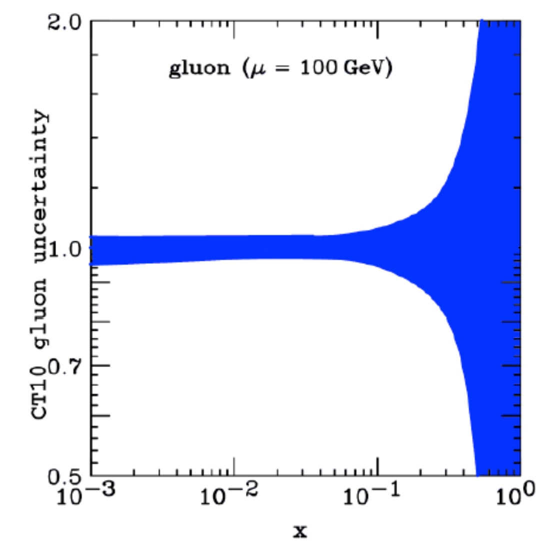
Expression of Interest in preparation

Physics Highlights: AFTER@LHC

pp and pA @ $\sqrt{s_{NN}}$ = 115 GeV

✓ **Nucleon partonic structure**

- Gluon pdf in the proton – large uncertainties at high x
  - → $g_p(x) = g_n(x)$?

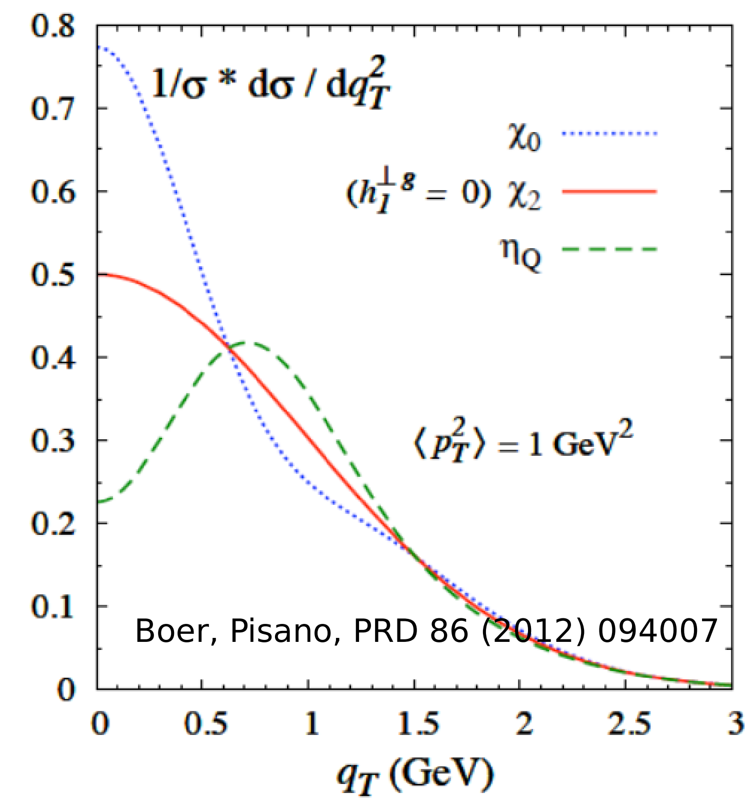


✓ **Heavy-quark distribution at large x in the proton**

✓ **Spin physics**

- Test of the QCD factorisation framework
- Linearly polarised gluons in unpolarised protons: $h_1^{\perp g}$, "Boers-Mulder" effect
- Sivers effect
- Single Spin Asymmetry in DY and HF studies

<u>See also</u>: arXiv:1502.04021; arXiv:1504.03791; arXiv:1504.04332, arXiv:1203.5579; arXiv:1208.364



With AFTER@LHC: boost – better access to the low-p_T C-even quarkonia

✓ **W and Z production near threshold ?**

Physics Highlights: AFTER@LHC

PbA @ $\sqrt{s_{NN}}$ = 72 GeV, pA @ $\sqrt{s_{NN}}$ = 115 GeV

- ✓ **Gluon distribution in nucleus at large x**
  - ➔ Complementary to EIC, LheC
  - ➔ Large uncertainty in nuclei at large x, unknown gluon EMC effect
  - ➔ Relevance of nuclear PDF to understand the initial state of heavy-ion collisions
  - ➔ Search and study rare proton fluctuations where one gluon carries most of the proton momentum
- ✓ **Heavy-Ion collisions from mid to large rapidities**
  - ➔ **Precise estimation of Cold Nuclear Matter effect from pA and AB – test of the factorization**
    - ➔ In PbA, different nuclei, A-dependent studies
  - ➔ **Quark-Gluon Plasma studies in heavy-ion collisions**
  - ➔ **Longitudinal expansion of QGP formation**
    - Quarkonia, HF jets quenching, low mass lepton pairs, direct photons
  - ➔ **Test the formation of azimuthal asymmetries: hydrodynamics vs initial-state radiation**
- ✓ **Ultra-peripheral collisions**

Phys.Rev. D91 (2015) 9, 094014
JHEP 1509 (2015) 087

Physics Highlights: AFTER@LHC

PbA @ $\sqrt{s_{NN}}$ = 72 GeV, pA @ $\sqrt{s_{NN}}$ = 115 GeV

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- ✓ **Heavy-Ion collisions from mid to large rapidities**
  - ➔ **Precise estimation of Cold Nuclear Matter effect from pA and AB – test of the factorization**
    - ➔ In PbA, different nuclei, A-dependent studies
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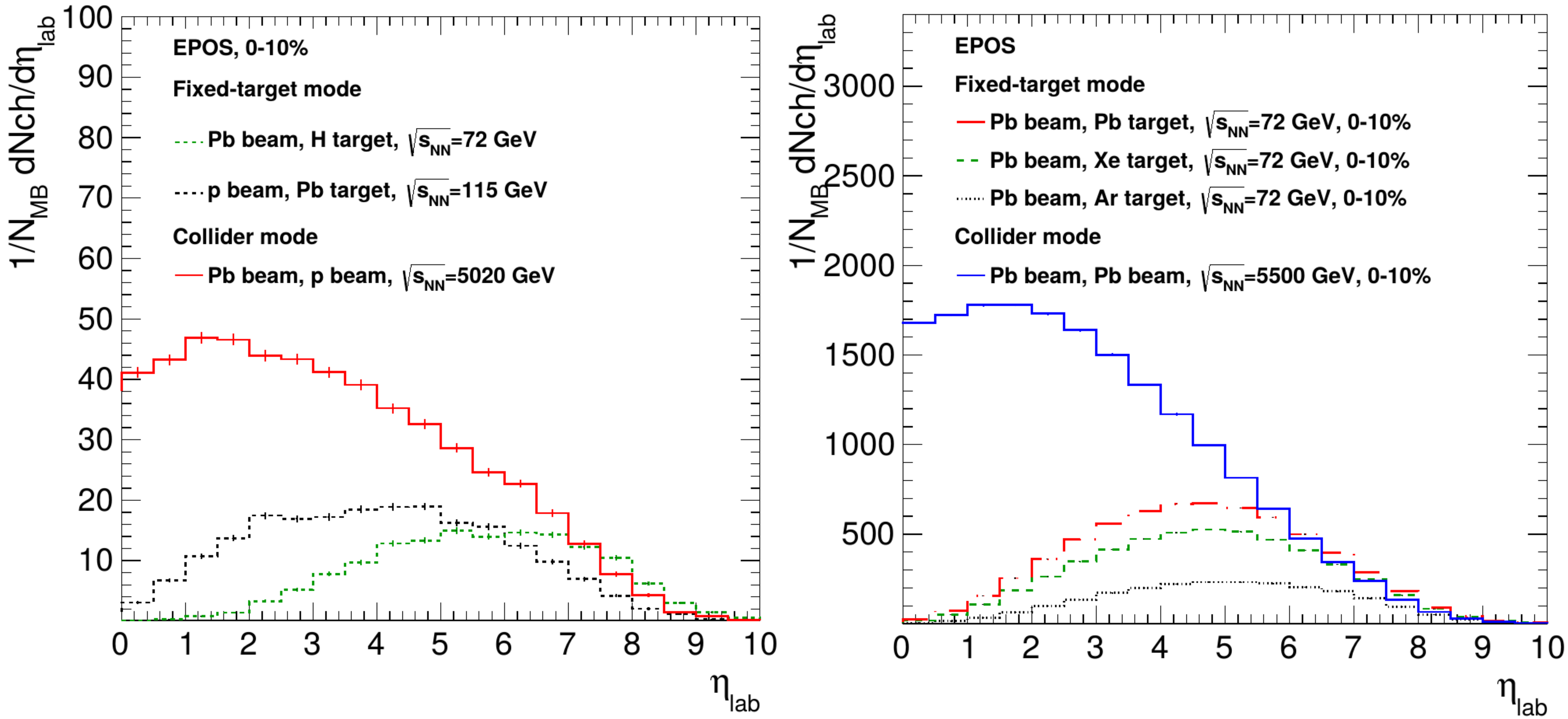
  - ➔ **Longitudinal expansion of QGP formation**
    - Quarkonia, HF jets quenching, low mass lepton pairs, direct photons
  - ➔ **Test the formation of azimuthal asymmetries: hydrodynamics vs initial-state radiation**
- ✗ With AFTER@LHC:
  - Access to target x_F = 0.3 - 1 (>1 Fermi motion in nucleus)
  - With different targets:
    - ➔ probing A dependence of shadowing and nuclear matter effects

Feasibility studies

Charge particle multiplicities in a fixed target mode

Advances in High Energy Physics, Volume 2015 (2015), Article ID 986348



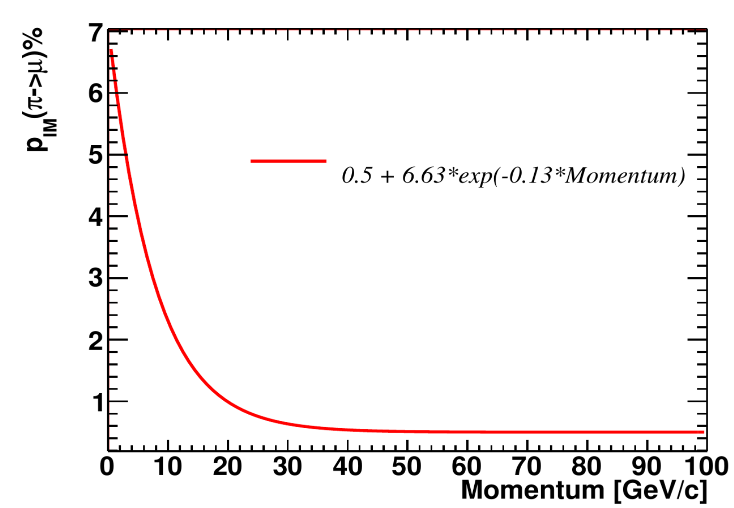
✓ Charge particle multiplicities, for all possible fixed target modes, p+Pb, Pb+H, Pb+Pb, are smaller than the ones reached in the collider modes. A detector with the LHCb capabilities is able to reconstruct all event centralities up to Pb-Ar.

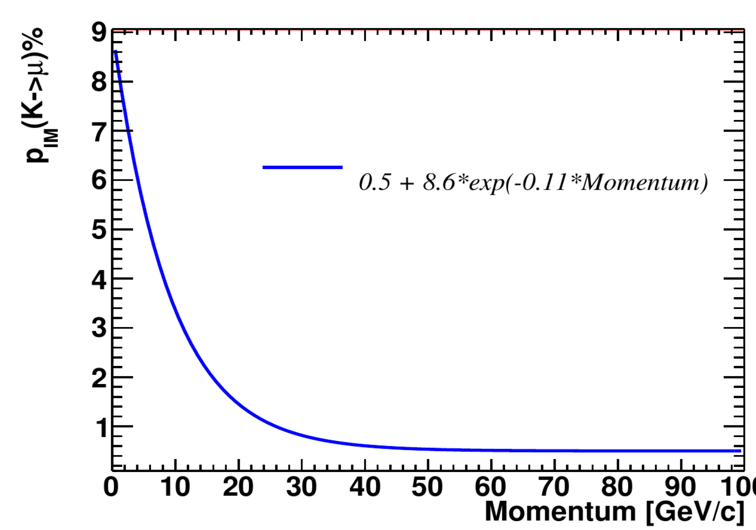
First simulations of quarkonia and Drell-Yan

Advances in High Energy Physics, Volume 2015 (2015), Article ID 986348

- ✓ *Input for quarkonium signals:* *HELAC-Onia*
- ✓ *Estimation of different dimuon background sources:*
  - ➔ Drell-Yan – HELAC-Onia
  - ➔ cc, bb – HELAC-Onia
  - ➔ Uncorrelated background – min bias PYTHIA 8
- ✓ Outputs from HELAC-Onia were processed with Pythia to perform the hadronization, initial/final radiations, and resonance decays
- ✗ Separate simulations to have under control p_T and y input distributions and normalization of different sources

- ✓ PYTHIA 8.185, fast simulations with LHCb-like reconstruction parameters
- ✗ <u>*Single μ cuts:*</u>
  - ➔ $2 < \eta_\mu < 5$
  - ➔ Minimum $p_T^\mu > 0.7$ GeV/c
- ✗ <u>*Requirements:*</u>
  - ➔ momentum resolution: $\Delta p/p = 0.5\%$
  - ➔ μ identification efficiency: 98%
  - ➔ <u>*μ misidentification (with π or K) for the uncorrelated background*</u>



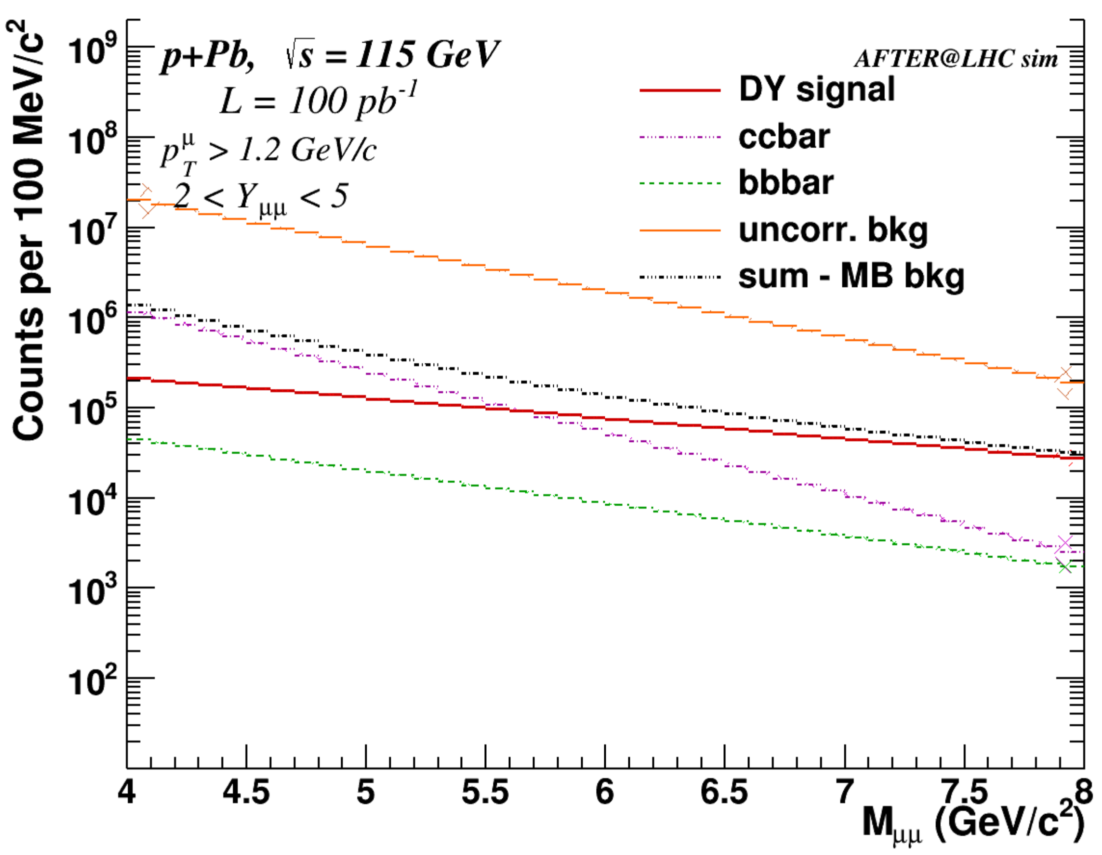


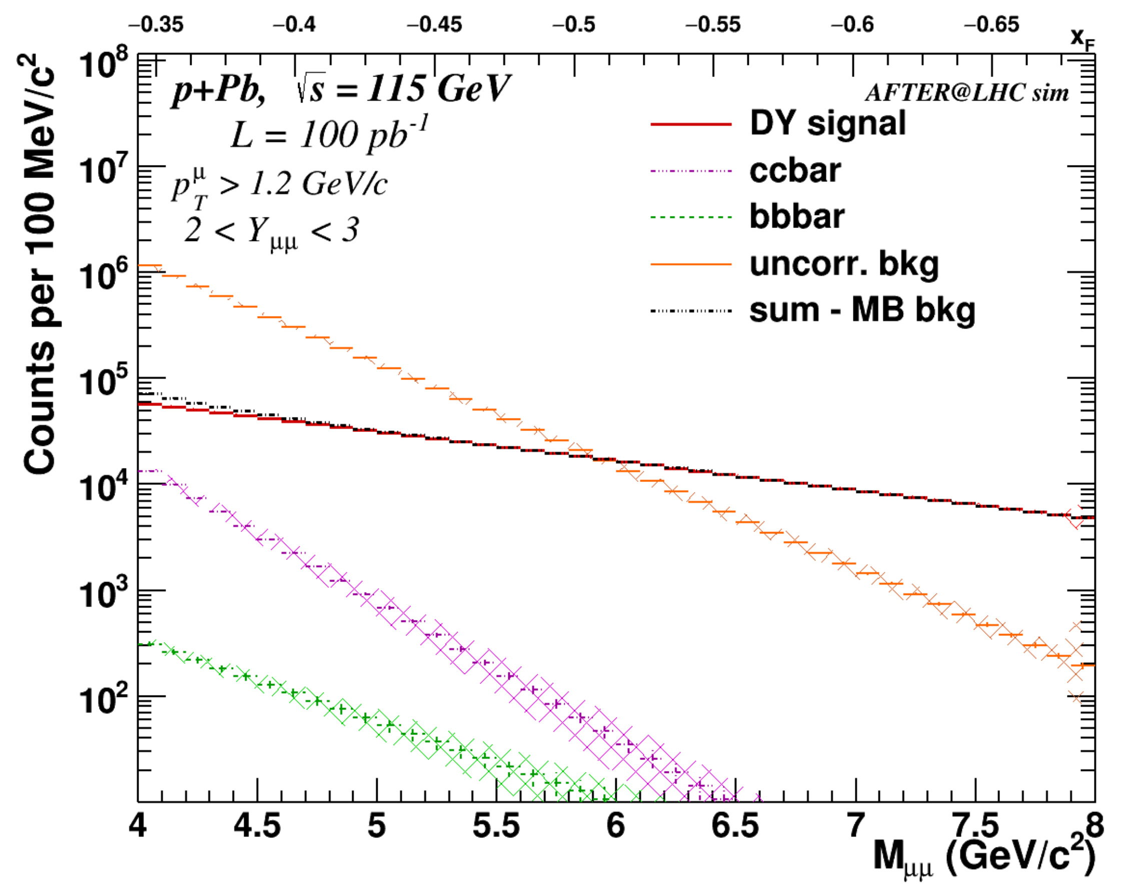
F. Achilli et al, JINST 8 (2013) P10020
arXiv:1306.0249

Drell-Yan simulations with full background

p+Pb 115 GeV

∫L = 100 pb^{-1}, **with 1cm Pb target**



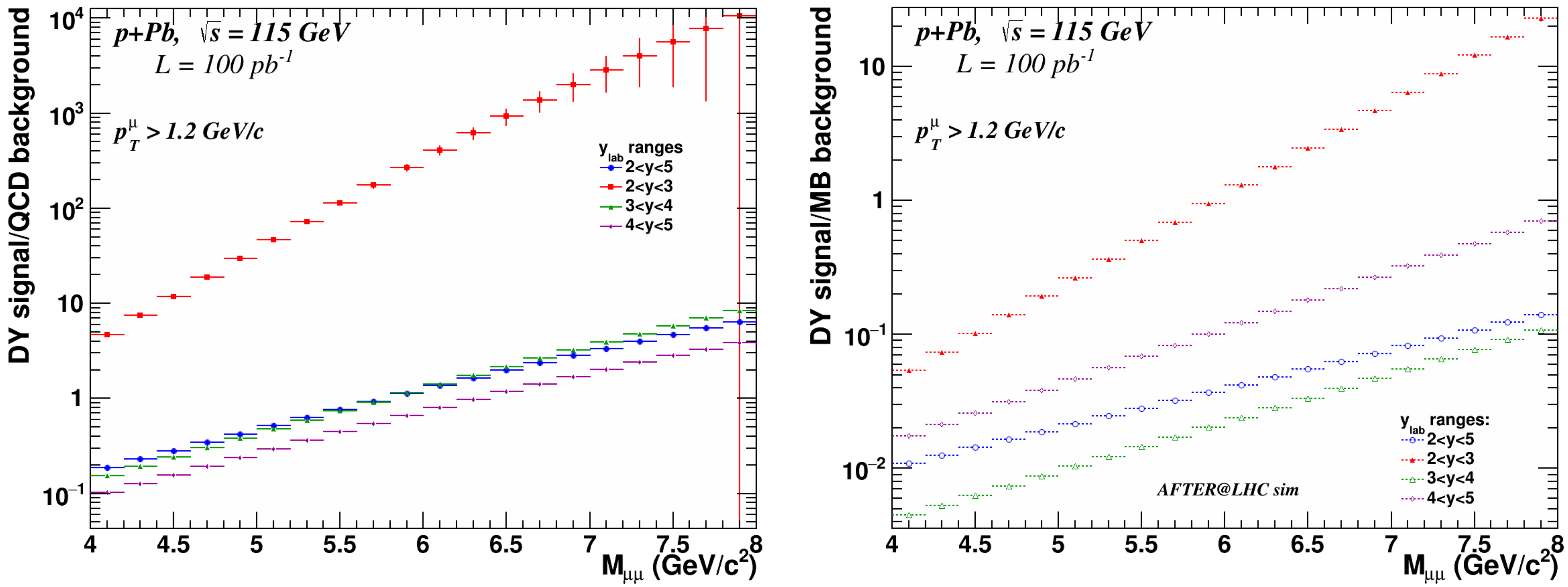


- No nuclear effects assumed
- At backward rapidities quark-induced processes are favoured → background gets smaller
- Charm and beauty background can be reduced (secondary vertex cut) – interesting by its own
- High Drell-Yan yields for both pp and pPb – combinatorial background can be subtracted using the event-mixing technique
- Precise measurements of A_N^{DY} at high x

Drell-Yan simulations with full background - signal / background

p+Pb 115 GeV

- Different rapidity ranges, single μ $p_T > 1.2$ GeV/c
  - QCD background: ccbar + bbbar background
  - MB background: uncorrelated background

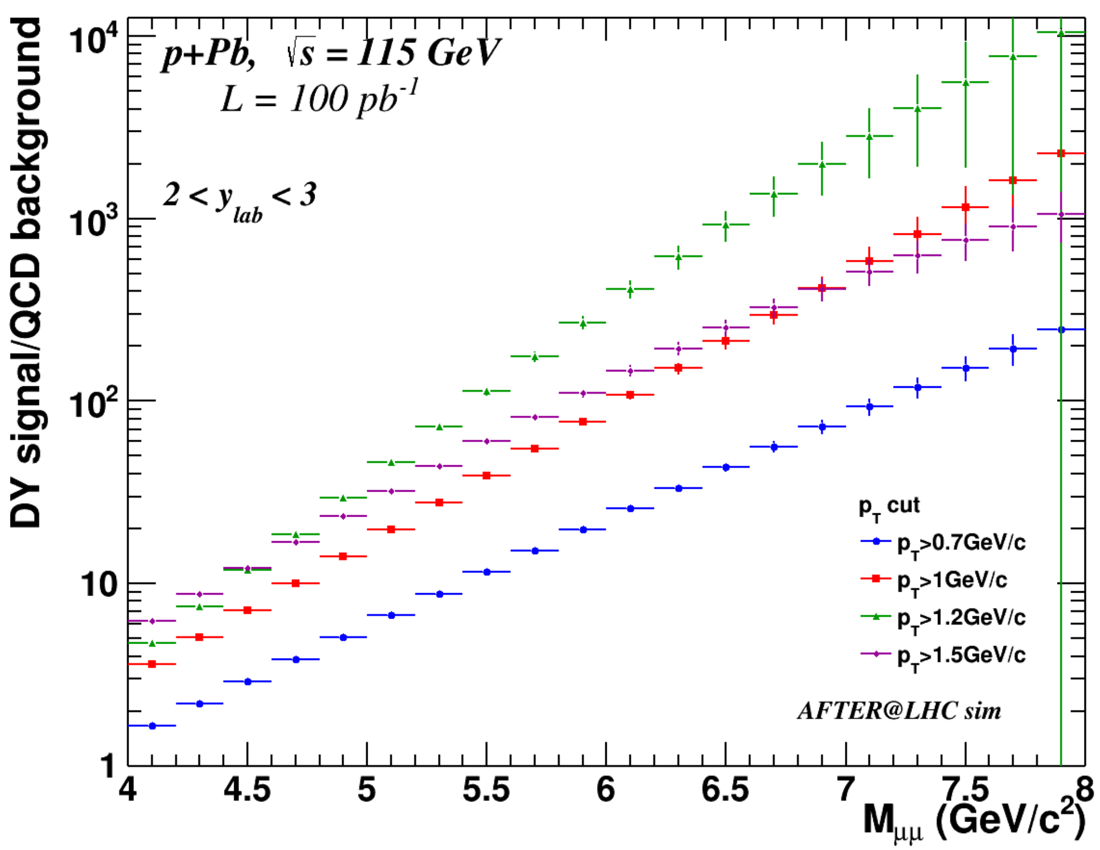


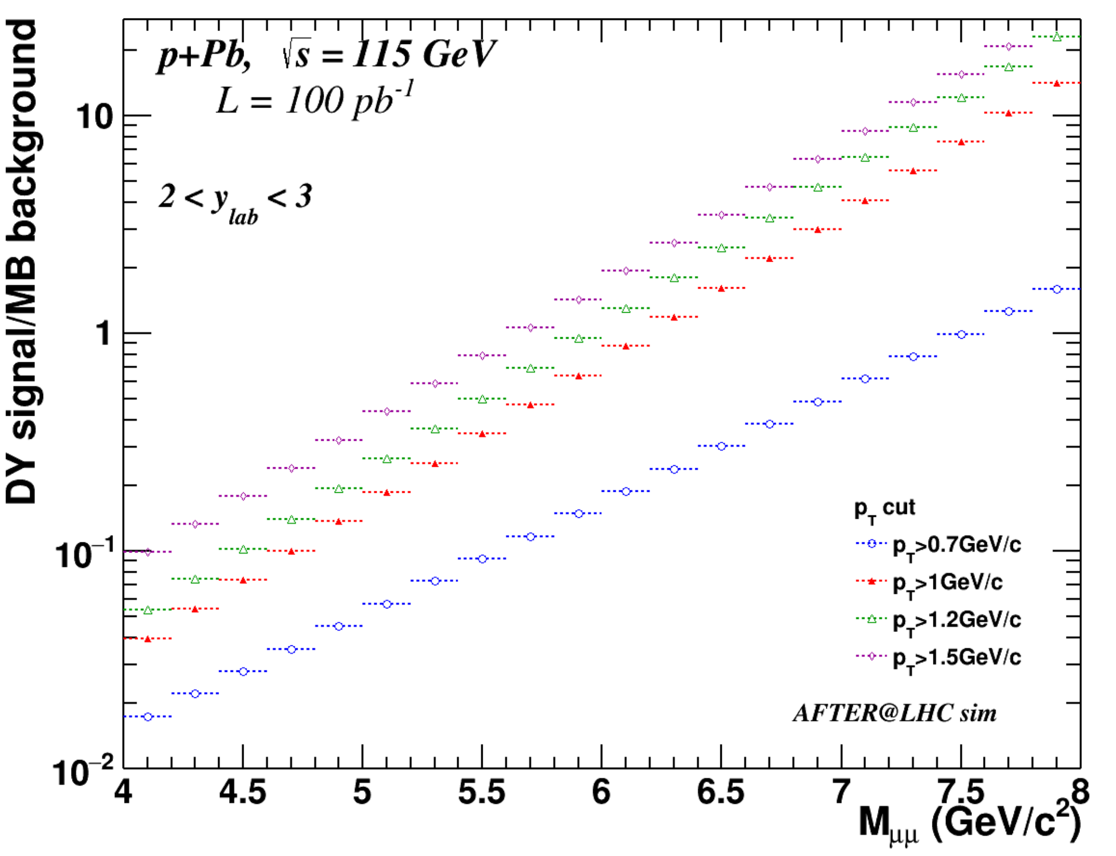
- At backward rapidities quark-induced processes are favoured → background gets smaller

Drell-Yan simulations with full background - signal / background

p+Pb 115 GeV

- Backward rapidity: 2 < y < 3
- Different single μ p_T cuts
  - QCD background: ccbar + bbbar background
  - MB background: uncorrelated background





- Raising single μ p_T cut from default 0.7 GeV/c improves signal / background

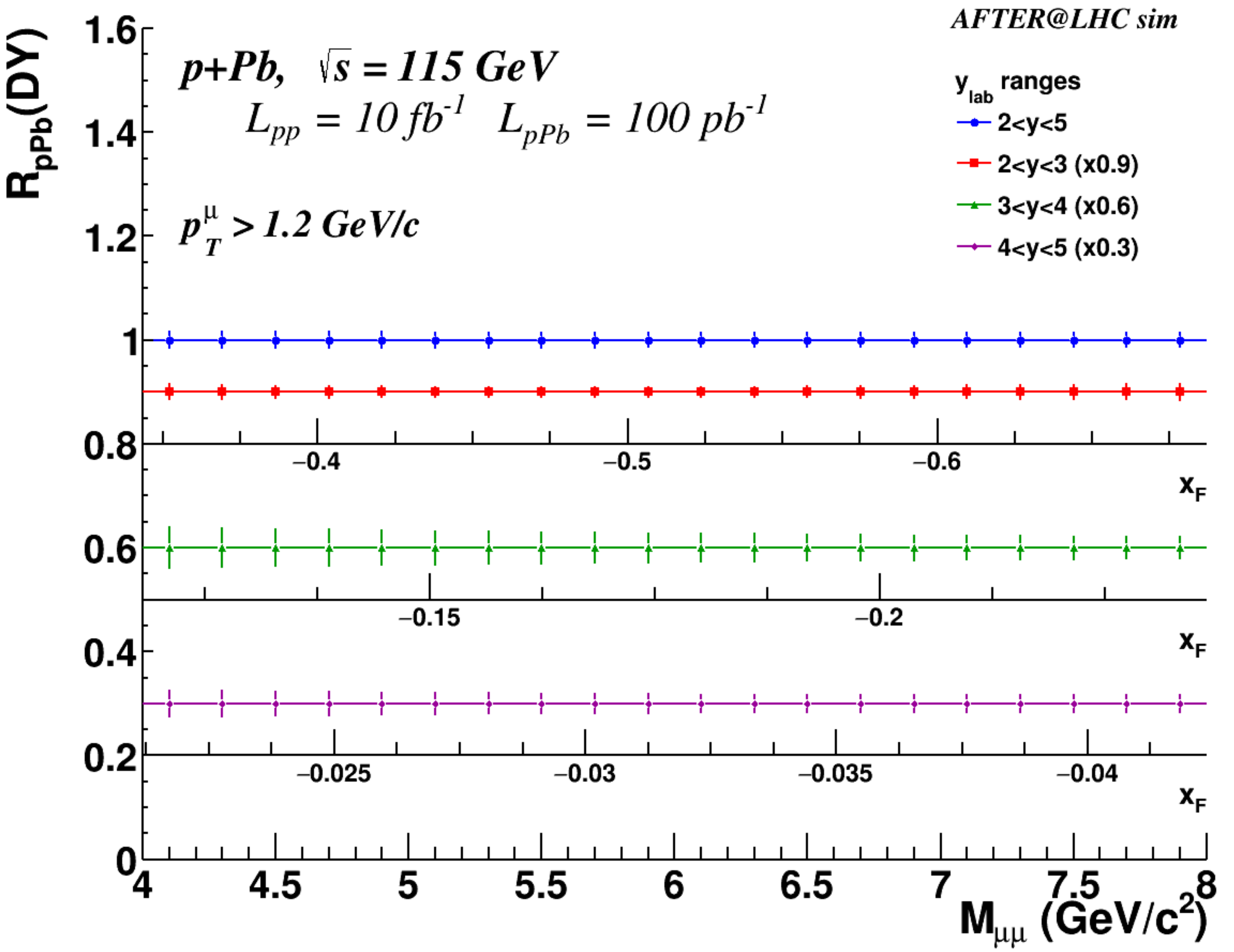
Drell-Yan simulations with full background - R_{pPb}

p+Pb 115 GeV

- Statistical precision on R_{pPb} vs di-μ invariant mass – x_F in different rapidity ranges
- Combinatorial background uncertainties taken into account assuming like-sign background subtraction
- No nuclear effects assumed

$\int L_{pp} = 10\ fb^{-1}$

$\int L_{pPb} = 100\ pb^{-1}$



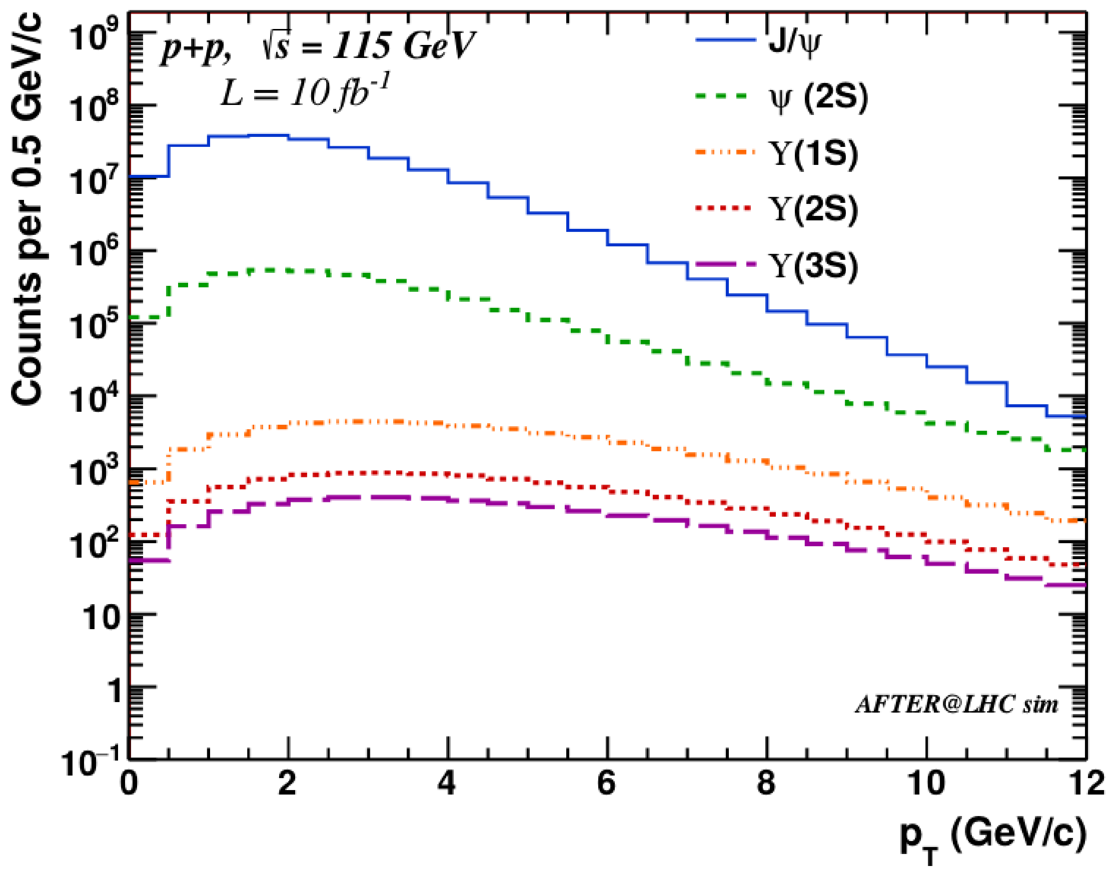
- Precise measurements of R_{pPb}^{DY} up to high x_F - nPDF constraints

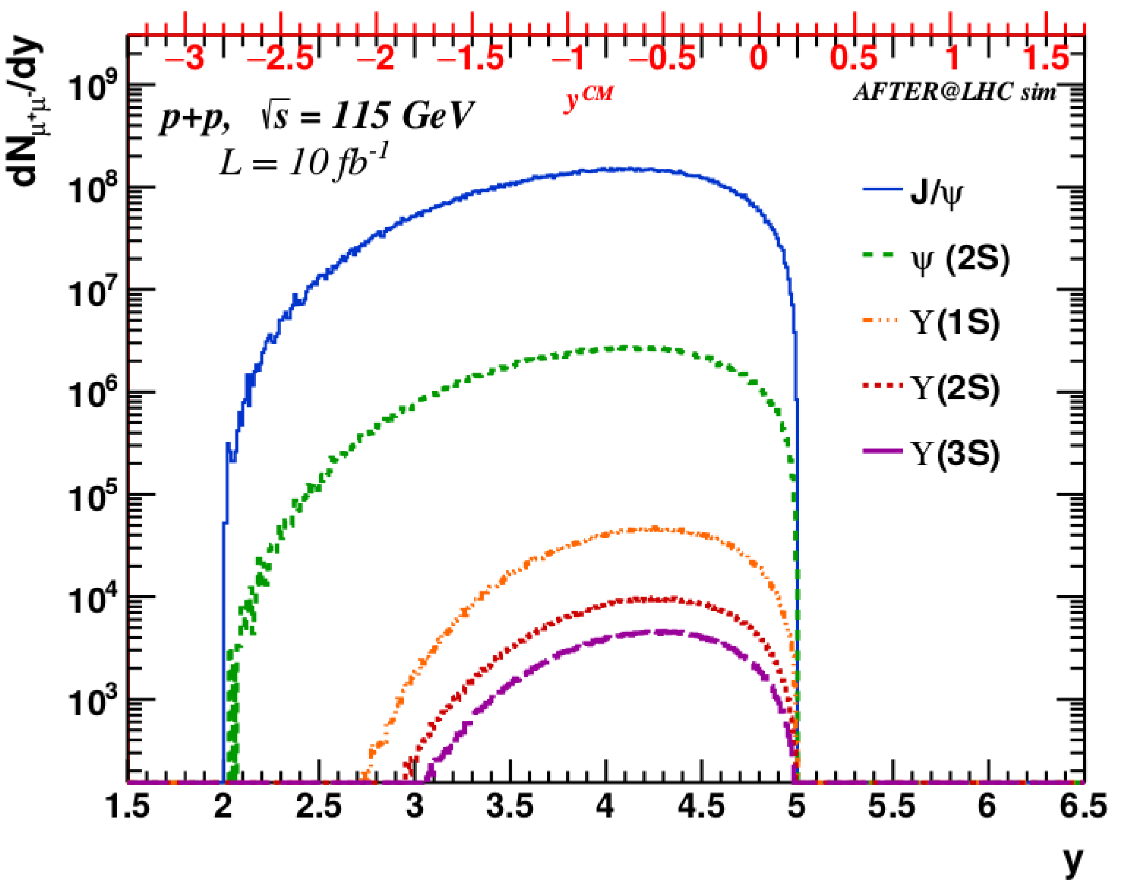
Quarkonium acceptance and p_T reach

p+p 115 GeV

$\int L$ = 10 fb^{-1}, **0.5 year of data taking with 1m H_2 target** (in the crystal case)

- single μ p_T cut > 0.7 GeV/c





- J/ψ and ψ(2S) signals can be studies up to ~ 15 GeV/c, ϒ(nS) up to ~ 10 GeV/c
- All quarkonium states can be measured down to 0 GeV/c
- Similar p_T reach expected for pA

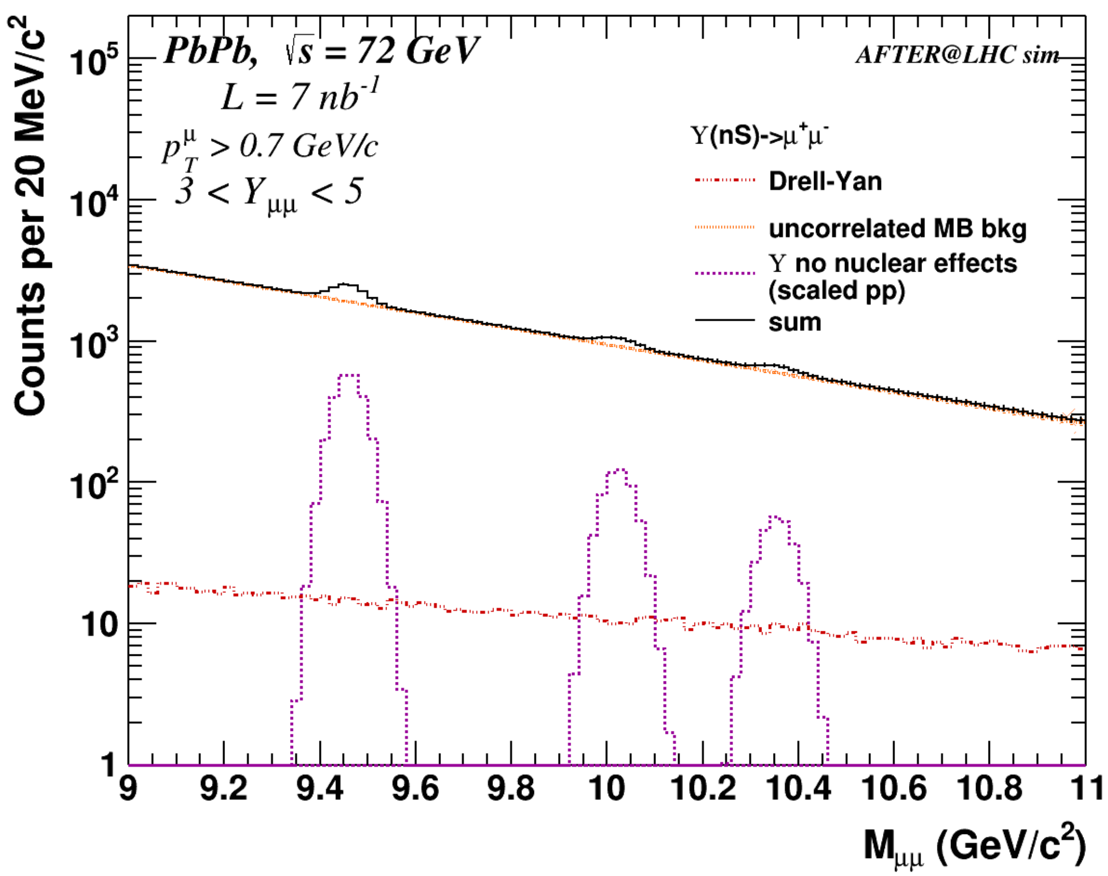
- Study is limited to the rapidity range of 2 < y < 5 (2 < η_μ < 5)
- J/ψ and ψ(2S) signals can be studies in the whole range, lowest y for ϒ(nS) is ~ 2.5-3

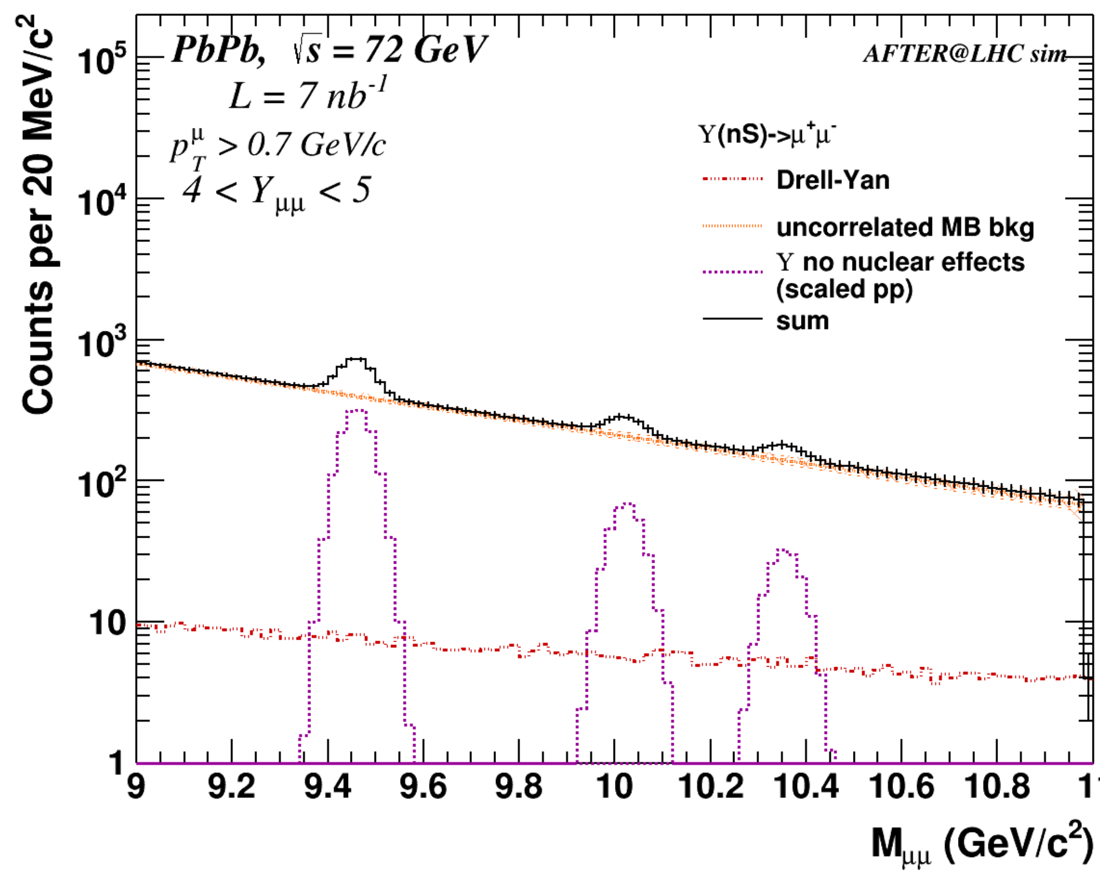
Upsilon simulations with full background

$\int L_{PbPb} = 7\ nb^{-1}$

Pb+Pb 72 GeV

- Rapidity reach: $3 < y < 5$
- Combinatorial background uncertainties assuming like-sign background reconstruction
- No nuclear effects assumed





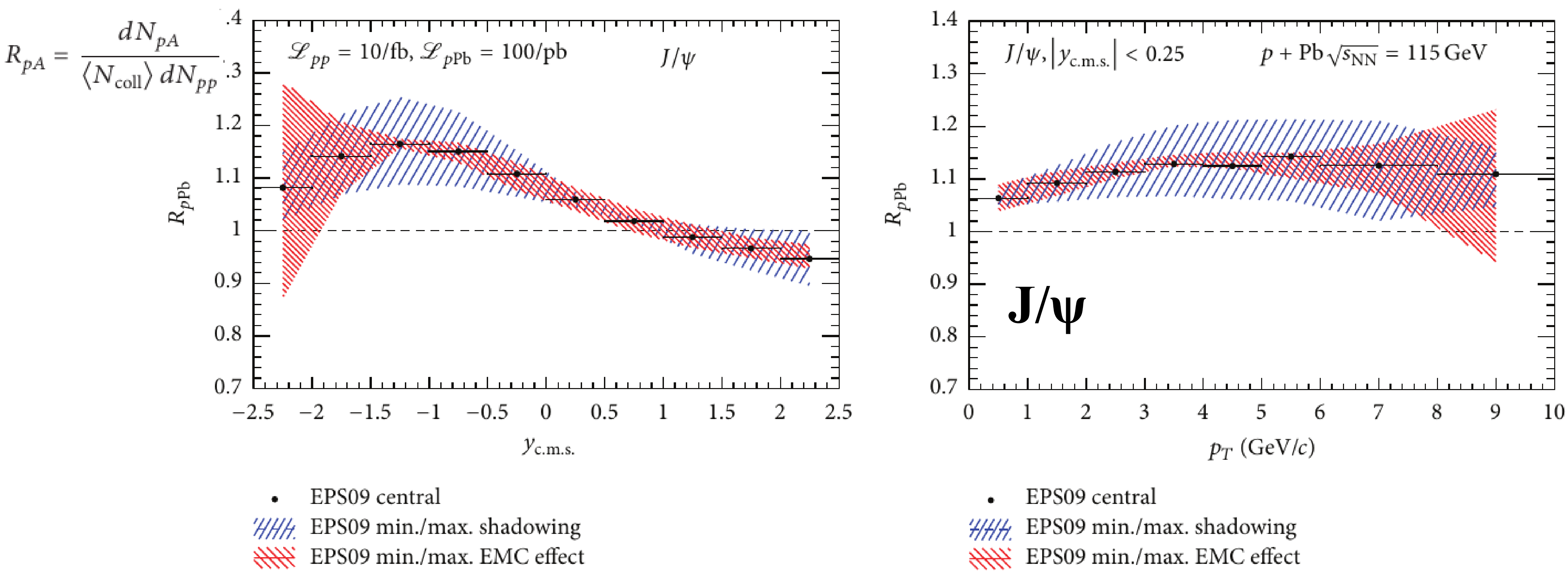
- Good separation of different Upsilon states
- Better signal/background for more forward rapidities ($y_{cms} \sim 0$)

Impact of nPDF effects on quarkonium R_{pPb}

p+Pb 115 GeV

Simulations done using JIN with EPS09

- Combination of measurements of $\Upsilon(nS)$, J/ψ and $\psi(2S)$ for $-3 < y_{CMS} < 0$ will allow to pin down the existence of a possible gluon EMC and antishadowing effect



CHARM

- Statistical uncertainties from the signal yield only

pp: ∫L = 10 fb^{-1}, pPb: ∫L = 100 pb^{-1}

Very good statistical precision !

Advances in High Energy Physics, Volume 2015 (2015), Article ID 986348

<u>See also</u>: Advances in High Energy Physics, Article ID 492302 and 783134
arXiv:1507.05413; arXiv:1504.07428

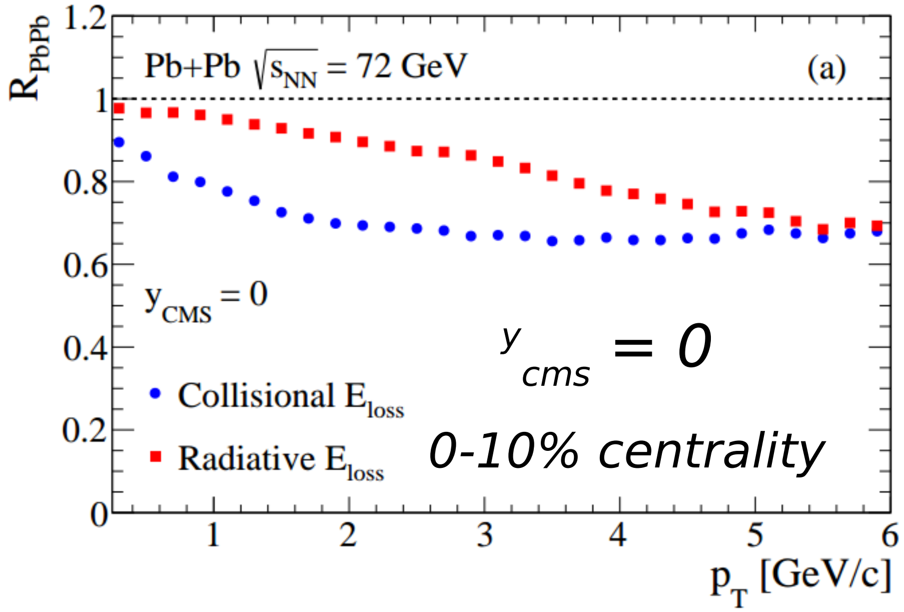
Open Heavy Flavour in Heavy Ion collisions

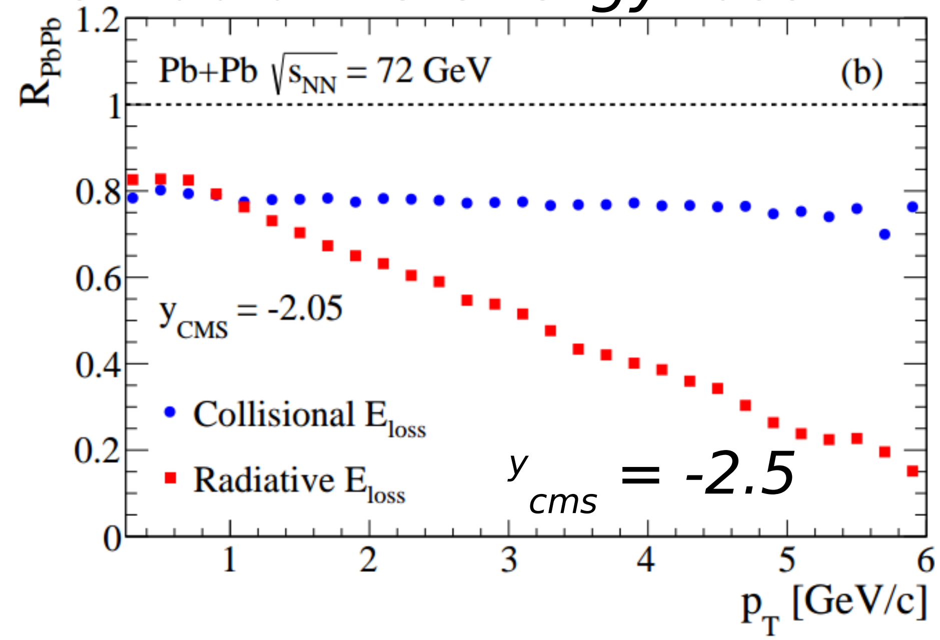
Pb+Pb 72 GeV

What is the source of the energy loss of heavy quarks?

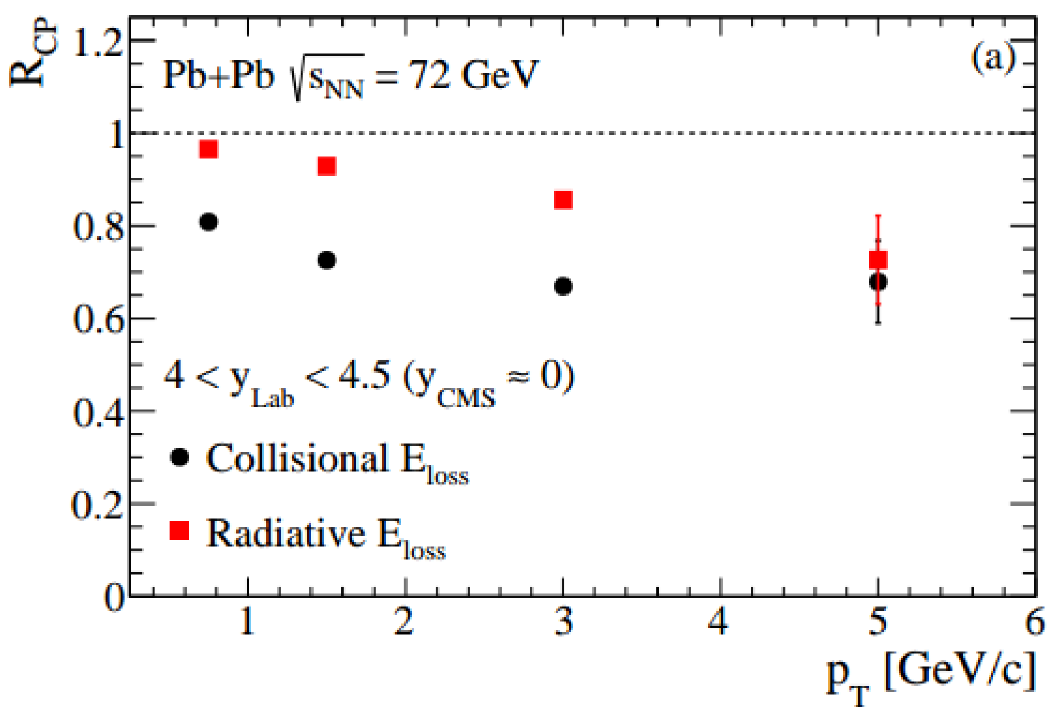
Collisional vs. radiative energy loss

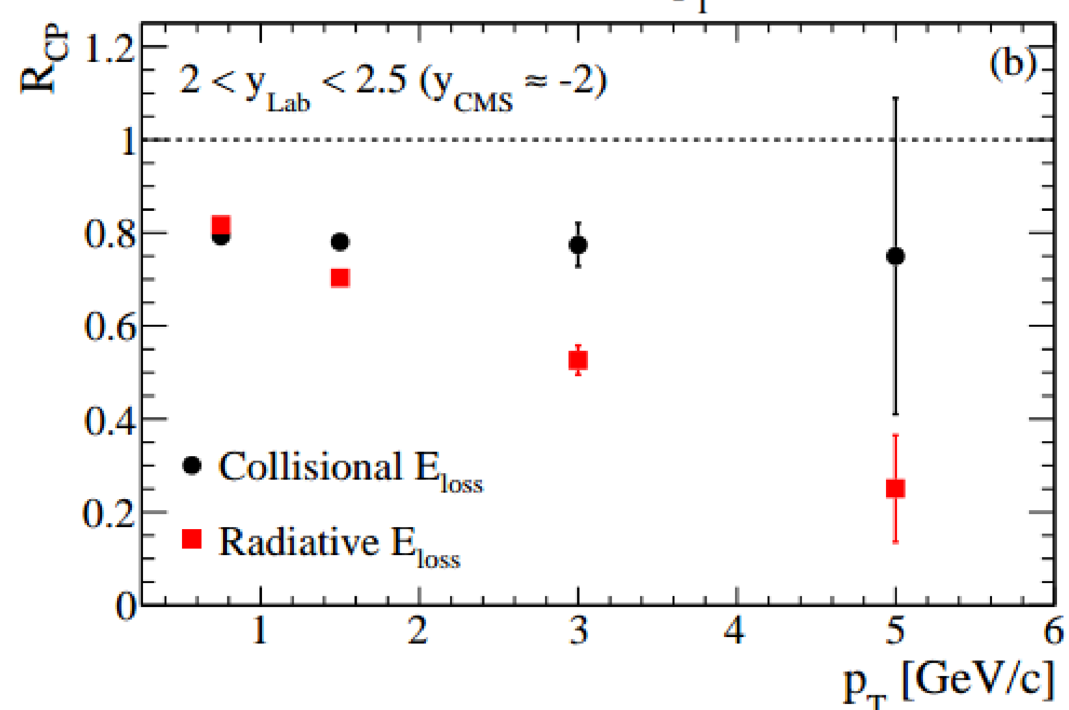
$D^0 \to K^- \pi^-$





Energy loss based on:
J. Aichelin, P. B. Gossiaux, and T. Gousse Journal of Physics:
Conference Series, vol. 455, no. 1, Article ID 012046, 2013.





R_{AA} vs y and p_T → insight into charm E_{loss}

- Statistical uncertainties from the signal yield only

Advances in High Energy Physics, Volume 2015 (2015), Article ID 783134

Summary

- Many physics opportunities with a fixed target experiment using LHC p and Pb beams
- Novel testing ground for QCD in the high-x frontier with AFTER@LHC
- Extensive heavy-ion program
- With either dense targets or high intensity beams, very high luminosities can be achieved
- Target versatility: hydrogen, deuteron, nucleus – nuclear effects and QGP
- First fast simulations performed
- Many ideas in favour of AFTER@LHC published
- Expression of Interest in preparation

Summary

- Many physics opportunities with a fixed target experiment using LHC p and Pb beams
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after.in2p3.fr

Thank you !

BACKUP

Ideas in favour of AFTER@LHC

Future Reading

Heavy-Ion Physics

- *Gluon shadowing effects on J/ψ and Υ production in p+Pb collisions at $\sqrt{s_{NN}}$ = 115 GeV and Pb+p collisions at $\sqrt{s_{NN}}$ = 72 GeV at AFTER@LHC* by R. Vogt. Adv.Hi.En.Phys. (2015) ID:492302.
- *Prospects for open heavy flavor measurements in heavy-ion and p+A collisions in a fixed-target experiment at the LHC* by D. Kikola. Adv.Hi.En.Phys. (2015) ID:783134
- *Quarkonium suppression from coherent energy loss in fixed-target experiments using LHC beams* by F. Arleo, S.Peigné. [arXiv:1504.07428 [hep-ph]]. Adv.Hi.En.Phys. (2015) ID:961951
- *Anti-shadowing Effect on Charmonium Production at a Fixed-target Experiment Using LHC Beams* by K. Zhou, Z. Chen, P. Zhuang. arXiv:1507.05413 [nucl-th].
- *Lepton-pair production in ultraperipheral collisions at AFTER@LHC*
  By J.P. Lansberg, L. Szymanowski, J. Wagner. arXiv:1504.02733 [hep-ph]. To appear in JHEP
- *Quarkonium Physics at a Fixed-Target Experiment using the LHC Beams.* By J.P. Lansberg, S.J. Brodsky, F. Fleuret, C. Hadjidakis. [arXiv:1204.5793 [hep-ph]]. Few Body Syst. 53 (2012) 11.

Future Reading

Spin physics

- *Transverse single-spin asymmetries in proton-proton collisions at the AFTER@LHC experiment* by K. Kanazawa, Y. Koike, A. Metz, and D. Pitonyak. [arXiv:1502.04021 [hep-ph]. Adv.Hi.En.Phys. (2015) ID:257934.
- *Transverse single-spin asymmetries in proton-proton collisions at the AFTER@LHC experiment in a TMD factorisation scheme* by M. Anselmino, U. D'Alesio, and S. Melis. [arXiv:1504.03791 [hep-ph]]. Adv.Hi.En.Phys. (2015) ID:475040.
- *The gluon Sivers distribution: status and future prospects* by D. Boer, C. Lorcé, C. Pisano, and J. Zhou. [arXiv:1504.04332 [hep-ph]]. Adv.Hi.En.Phys. (2015) ID:371396
- *Azimuthal asymmetries in lepton-pair production at a fixed-target experiment using the LHC beams (AFTER)* By T. Liu, B.Q. Ma. [arXiv:1203.5579 [hep-ph]]. Eur.Phys.J. C72 (2012) 2037.
- *Polarized gluon studies with charmonium and bottomonium at LHCb and AFTER* By D. Boer, C. Pisano. [arXiv:1208.3642 [hep-ph]]. Phys.Rev. D86 (2012) 094007.

Future Reading

Hadron structure

- *Double-quarkonium production at a fixed-target experiment at the LHC (AFTER@LHC).*
  by J.P. Lansberg, H.S. Shao. [arXiv:1504.06531 [hep-ph]]. To appear in Nucl. Phys. B
- *Next-To-Leading Order Differential Cross-Sections for Jpsi, psi(2S) and Upsilon Production in Proton-Proton Collisions at a Fixed-Target Experiment using the LHC Beams (AFTER@LHC)*
  by Y. Feng, and J.X. Wang. Adv.Hi.En.Phys. (2015) ID:726393, in press.
- *η_c production in photon-induced interactions at a fixed target experiment at LHC as a probe of the odderon*
  By V.P. Goncalves, W.K. Sauter. arXiv:1503.05112 [hep-ph].Phys.Rev. D91 (2015) 9, 094014.
- *A review of the intrinsic heavy quark content of the nucleon*
  by S. J. Brodsky, A. Kusina, F. Lyonnet, I. Schienbein, H. Spiesberger, and R. Vogt. Adv.Hi.En.Phys. (2015) ID:231547, in press.
- *Hadronic production of Ξ_{cc} at a fixed-target experiment at the LHC*
  By G. Chen *et al.*. [arXiv:1401.6269 [hep-ph]]. Phys.Rev. D89 (2014) 074020.

Future Reading

Feasibility study and technical ideas

- *Feasibility studies for quarkonium production at a fixed-target experiment using the LHC proton and lead beams (AFTER@LHC)* by L. Massacrier, B. Trzeciak, F. Fleuret, C. Hadjidakis, D. Kikola, J.P.Lansberg, and H.S. Shao arXiv:1504.05145 [hep-ex]. Adv.Hi.En.Phys. (2015) ID:986348
- *A Gas Target Internal to the LHC for the Study of pp Single-Spin Asymmetries and Heavy Ion Collisions* by C. Barschel, P. Lenisa, A. Nass, and E. Steffens. Adv.Hi.En.Phys. (2015) ID:463141
- *Quarkonium production and proposal of the new experiments on fixed target at LHC* by N.S. Topilskaya, and A.B. Kurepin. Adv.Hi.En.Phys. (2015) ID:760840

Generalities

- *Physics Opportunities of a Fixed-Target Experiment using the LHC Beams*
  By S.J. Brodsky, F. Fleuret, C. Hadjidakis, J.P. Lansberg. [arXiv:1202.6585 [hep-ph]]. Phys.Rept. 522 (2013) 239.

http://www.hindawi.com/journals/ahep/si/354953/

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Physics at a Fixed-Target Experiment Using the LHC Beams

Guest Editors: Jean-Philippe Lansberg, Gianluca Cavoto, Cynthia Hadjidakis, Jibo He, Cédric Lorcé, and Barbara Trzeciak

Nominal luminosities in pH

Instantaneous luminosity:

$$\mathcal{L} = \Phi_{beam} \times N_{target} = N_{beam} \times (\rho \times \ell \times \mathcal{N}_A)/A$$

l is a target thickness

Extracted beam $l = 100$ cm **Internal gas target**

$\Phi_p = 5 \times 10^8$ p$^+$ s^{-1} (1)

$\rho = 0.7$ g cm^{-3} (Liq H_2)

$\mathcal{L} = 2000\ \mu b^{-1} s^{-1}$

$\Phi_p = 3.5 \times 10^{18}$ p$^+$ s^{-1} (2)

$\rho = A \times P/(2.24 \times 10^6)$ mbar^{-1} g cm^{-3} (3)

for $P = 10^{-4}$ mbar (4)

$\mathcal{L} = 1000\ \mu b^{-1} s^{-1}$ $\quad \mathcal{L} = \Phi_{beam} \times (\frac{\mathcal{N}_A}{22400} \times P \times \ell)$

→ target storage cell that can be **polarised**

For 1m long H_2 target

Advances in High Energy Physics, Volume 2015 (2015), Article ID 463141

Integrated luminosities with 10^7 s (LHC year – 9 months of running)

$\int \mathcal{L} = 20$ fb^{-1}yr^{-1} $\qquad \int \mathcal{L} = 10$ fb^{-1}yr^{-1}

With pressure of 10^{-6} mbar – 3 times SMOG – one gets 100 pb^{-1} yr^{-1}

(1) ½ of the beam loss
(2) 3.2×10^{14} p$^+$ s^{-1} × 11kHz
(3)1 mole of a perfect gas occupies 22 400 cm at 273 K and 1 bar
(4)Barschel et.al; Advances in High Energy Physics, Volume 2015 (2015), Article ID 463141

Nominal luminosities in PbH

Instantaneous luminosity:

$$\mathcal{L} = \Phi_{beam} \times N_{target} = N_{beam} \times (\rho \times \ell \times \mathcal{N}_A)/A$$ *l* is a target thickness

Extracted beam $l = 100$ cm **Internal gas target**

$\Phi_p = 5 \times 10^8\ p^+\ s^{-1}$ (1)

$\rho = 0.7$ g cm^{-3} (Liq H_2)

$\mathcal{L} = 0.8\ \mu b^{-1} s^{-1}$

$\Phi_p = 4.6 \times 10^{14}$ Pb s^{-1} (2)

$\rho = A \times P/(2.24 \times 10^6)$ mbar^{-1} g cm^{-3} (3)

for $P = 10^{-6}$ mbar (4)

$\mathcal{L} = 10^{-3}\ \mu b^{-1} s^{-1}$ $\mathcal{L} = \Phi_{beam} \times (\frac{\mathcal{N}_A}{22400} \times P \times \ell)$

→ target storage cell that can be **polarised**

For 1m long H_2 target

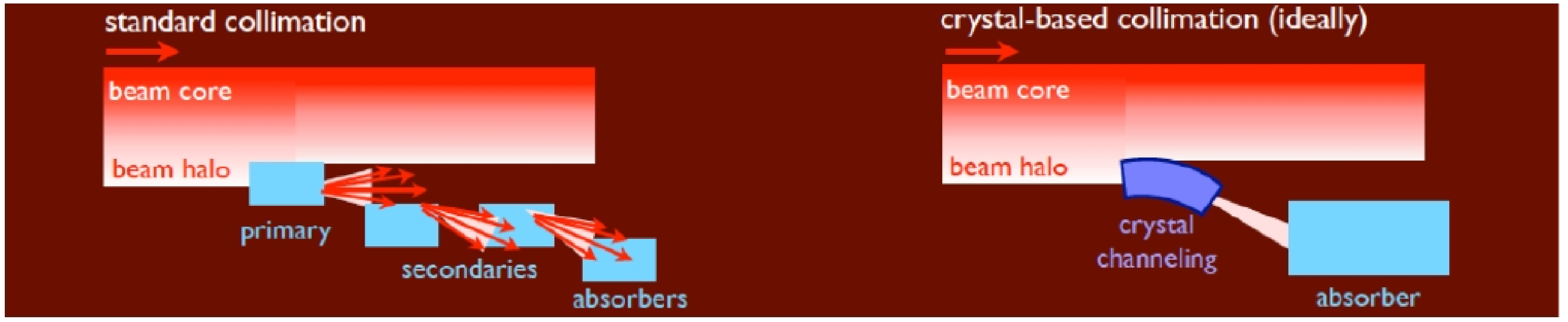
Integrated luminosities with 10^6 s (Pb LHC year – 1 months of running)

$\int \mathcal{L} = 0.8\ pb^{-1} yr^{-1}$ $\int \mathcal{L} = 0.001\ pb^{-1} yr^{-1}$

(1) ½ of the beam loss
(2) 4.2×10^{10} Pb s^{-1} × 11kHz
(3) 1 mole of a perfect gas occupies 22 400 cm at 273 K and 1 bar
(4) 3 times SMOG luminosity

Beam extraction using bent crystal

✓ **Motivated for collimation purposes**



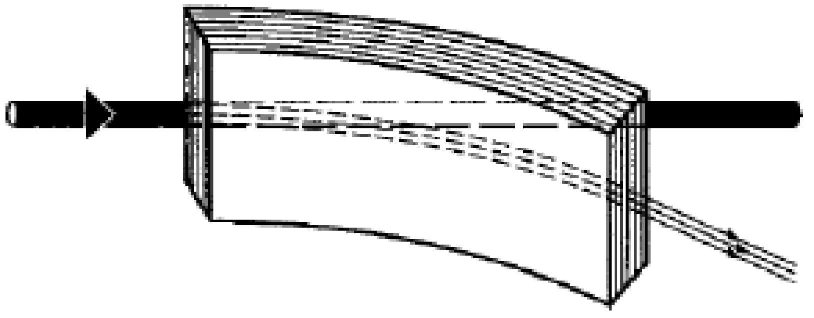
Standard collimation today → Crystal-based collimation
- UA9 (@SPS)
- LUA9 (@LHC)

→ To beam extraction
- CRYSBEAM (@SPS then LHC)
- AFTER@LHC

W. Scandale et al., JINST 6 T10002 (2011)

✓ The LHC beam extraction with "strong crystalline filed"

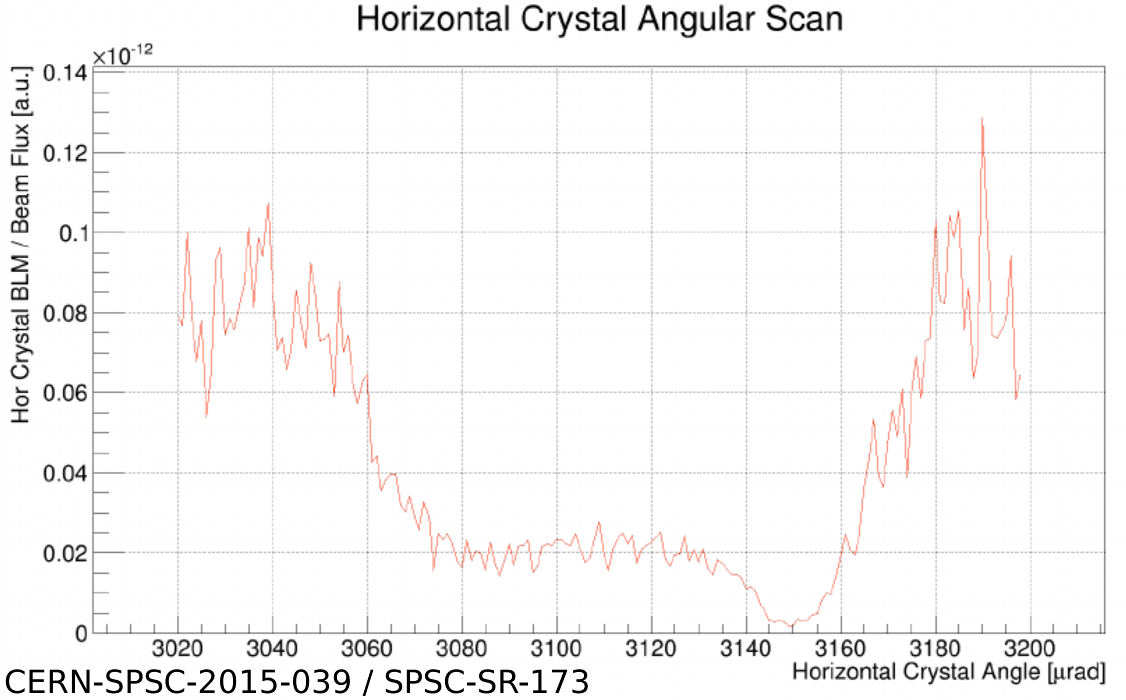
E. Uggerhøj, U.I Uggerhøj, NIM B 234 (2005) 31, Rev. Mod. Phys. 77 (2005) 1131



Deflecting the beam halo at 7σ distance to the beam

Reduce the LHC beam loss

✓ LUA9 test in the LHC complex

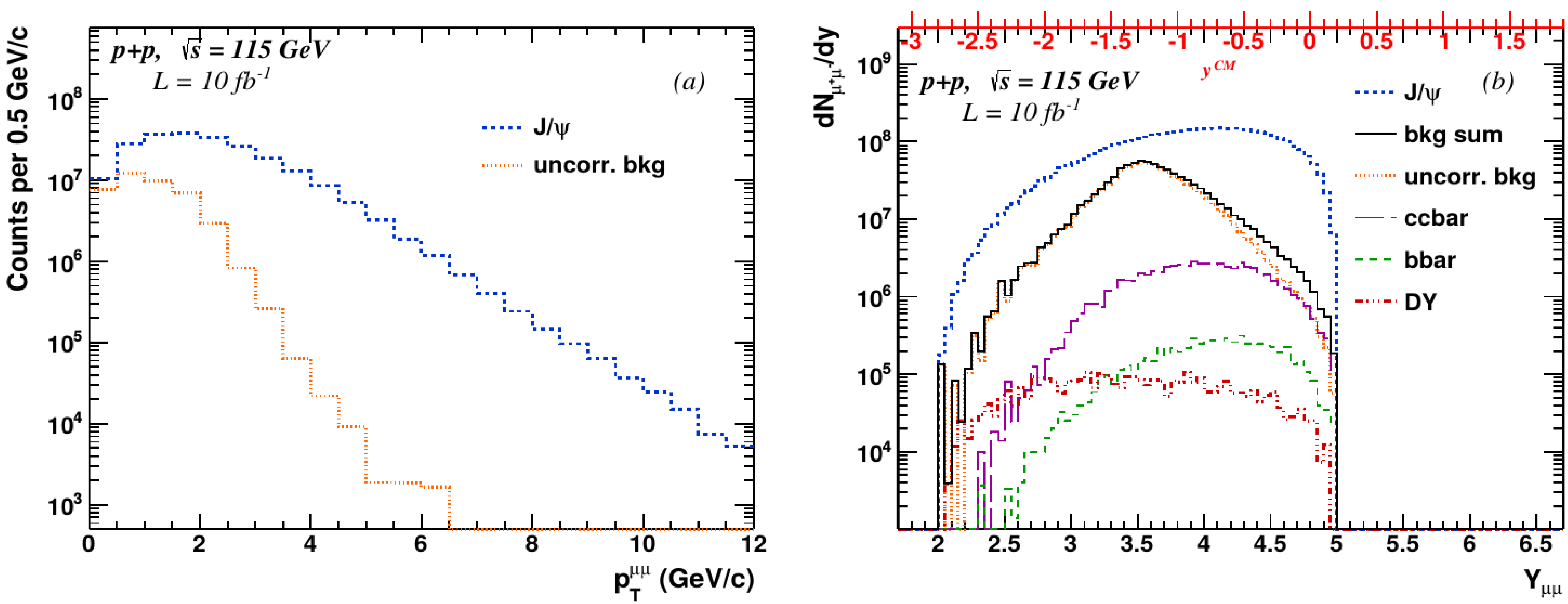


CERN-SPSC-2015-039 / SPSC-SR-173

J/ψ signal simulation with full background

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

$\int L = 10\ fb^{-1}$, **0.5 year of data taking with 1m H_2 target** (in the crystal case)



➔ p_T and rapidity Distributions for the J/ψ and different backgrounds differ.

➔ In more backward or forward rapidity regions, the signal to background ratio increases

Open Heavy Flavour in pA collisions

D. Kikoła

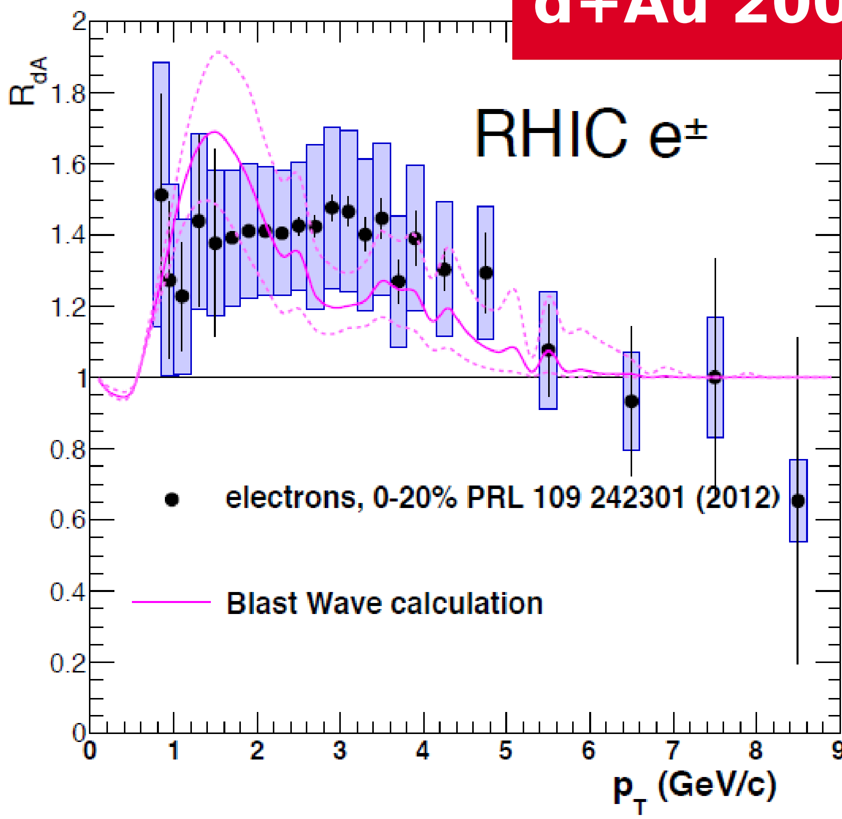
$D^0 \to K^- \pi^+$

- Heavy quarks in pA

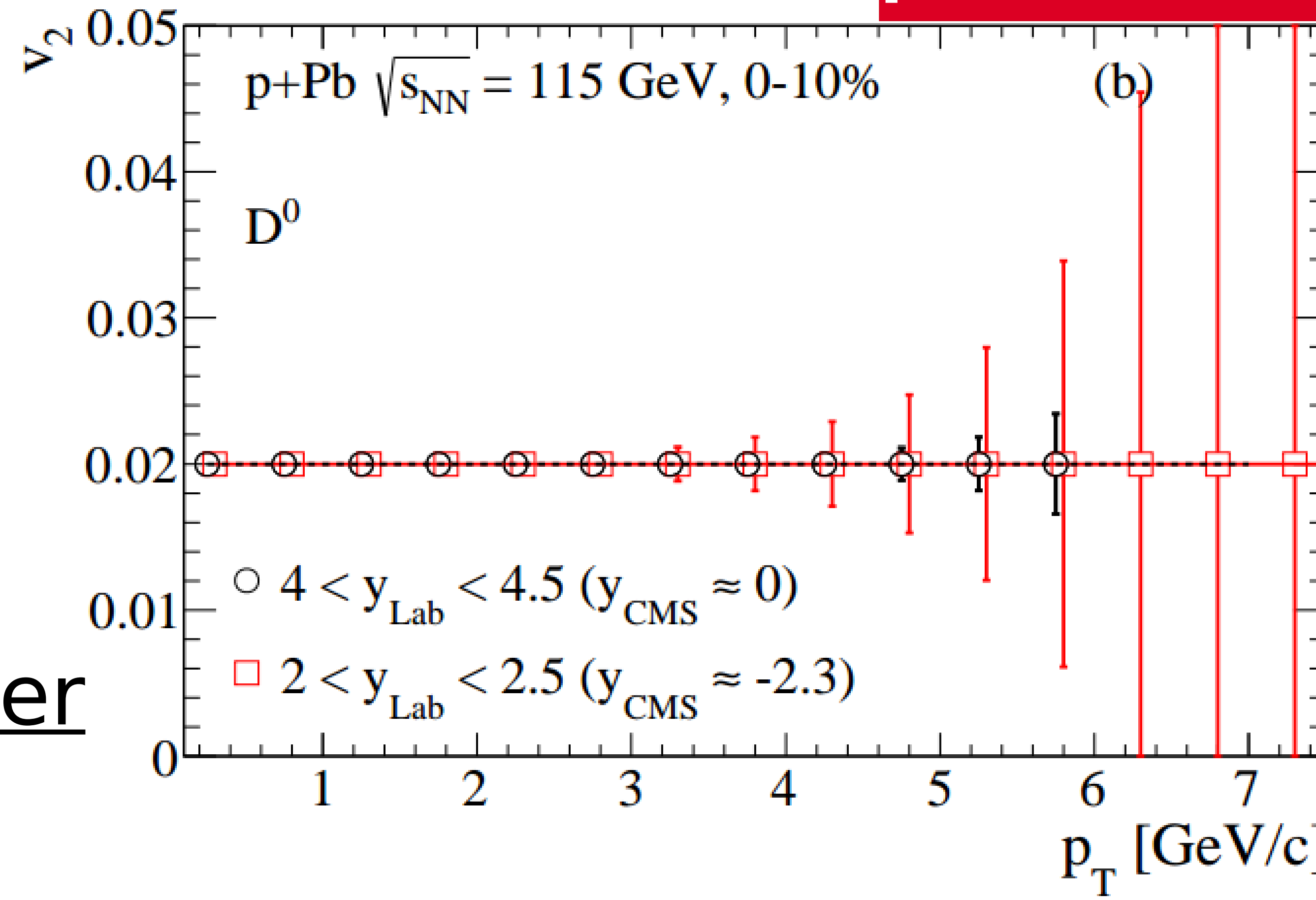
Cronin effect ?
Collective effects (radial flow)?

„Possible evidence for radial flow of heavy mesons in d+Au collisions" Phys. Lett. B731 51-56 (2014)

d+Au 200 GeV



p+A 115 GeV



<u>AFTER → definitive answer</u>