Physics perspectives in AFTER@LHC (A Fixed Target Experiment at LHC)

Laure Massacrier,

Institut de Physique Nucléaire d'Orsay

CNRS/IN2P3

Current members for the study group of the AFTER@LHC project
http://after.in2p3.fr/after/index.php/Current_author_list

M. Anselmino (Torino), R. Arnaldi (Torino), S. J. Brodsky (SLAC), V. Chambert (IPN), C. Da Silva (Los Alamos), J.P. Didelez (IPN), M. G. Echevarria (Barcelona), E. G. Ferreiro (USC), F. Fleuret (LLR), Y. Gao (Tsinghua), B. Genolini (IPN), C. Hadjidakis (IPN), I. Hrivnacova (IPN), V. Kartvelishvili (Lancaster), D. Kikola (Warsaw University of Technology), A. Klein (Los Alamos), U. Kramer (Karlsruhe), A. Kurepin (Moscow), A. Kusina (LPSC), J. P. Lansberg (IPN), L. Massacrier (IPN), I. Lehmann (Darmstadt), C. Lorcé (IPN), R. Mikkelsen (Aarhus), A. Nass (Julich), C. Pisano (Pavia), C. Quintans (Lisbon), F. Rathmann (Julich), I. Schienbein (LPSC), M. Schlegel (Tubingen), E. Scomparin (Torino), J. Seixas (Lisbon), H. S. Shao (CERN), A. Signori (VA,USA), E. Steffens (Erlangen), N. Topilskaya (Moscow), B. Trzeciak (CTU), U. I. Uggerhøj (Aarhus), R. Ulrich (Karlsruhe), A. Uras (IPNL), Z. Yang (Tsinghua), A. Zelenski (BNL)

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OUTLINE

- What is AFTER@LHC ?
- Main kinematical features
- General Physics Motivations
- Possible technical implementations at the LHC and projected luminosities
- A selection of projected performances for several probes:
  - Charged and identified particles
  - Quarkonia and Open Heavy Flavours
  - Drell-Yan

WHAT IS AFTER@LHC ?

AFTER@LHC is a proposal for a multi-purpose fixed target experiment using the multi-TeV proton or heavy ion beams of the LHC, with 3 main physic objectives:

- Advance our understanding of the **large-x gluon, antiquark and heavy-quark content in the nucleon and nucleus**
- Advance our understanding of the **dynamics and spin of gluons inside (un)polarised nucleons**
- Study **heavy-ion collisions** between SPS and RHIC energies towards large rapidities

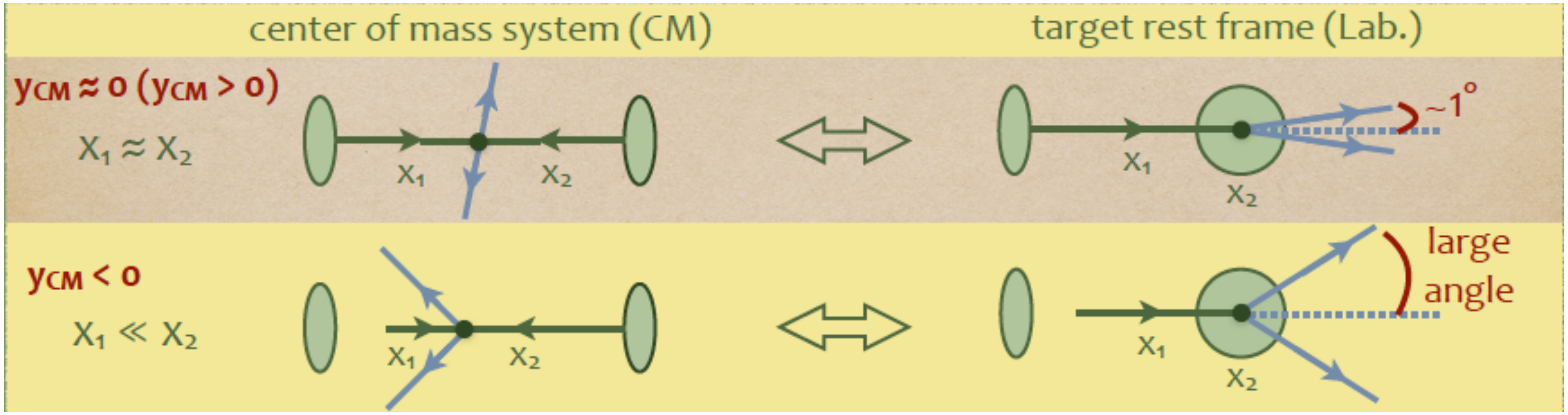
Advantages of the fixed-target mode wrt to collider mode:

- Accessing **the high Feynman x_F** domain ($x_F = p_z/p_{zmax}$)
- Achieving **high luminosities** thanks to dense targets
- Easier **to change the target** type (≠ atomic mass)
- Possibility to **polarize the target**

In **parasitic** mode with the most energetic beam ever, **without affecting the LHC performances**

Two main possibilities:
- **Internal (solid or gazeous) target + existing detector (ALICE/LHCb)**
- New beam line + new detector

MAIN KINEMATICAL FEATURES



- Entire CM forward hemisphere ($y_{CM} > 0$) within $0° < \theta_{lab} < 1°$

- Backward physics ($y_{CM} < 0$) : larger angle in the laboratory frame (lower occupancies)
  Access to parton with momentum fraction $x_2 \rightarrow 1$ in the target

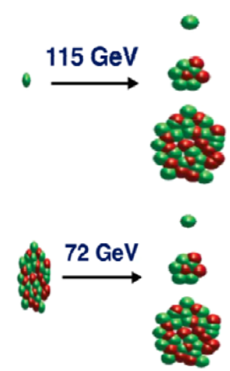
Energy range

7 TeV proton beam on a fixed target

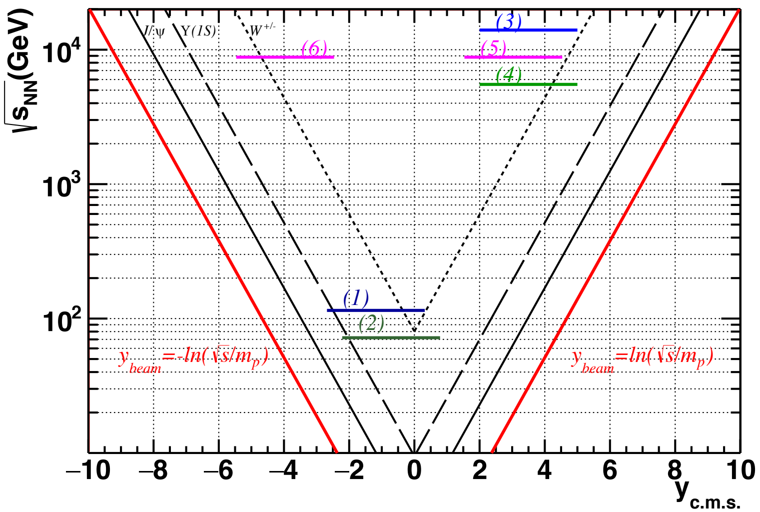
c.m.s. energy:	$\sqrt{s} = \sqrt{2m_N E_p} \approx 115\,\mathrm{GeV}$	**Rapidity shift:** $y_{c.m.s.} = 0 \rightarrow y_{lab} = 4.8$
Boost:	$\gamma = \sqrt{s}/(2m_N) \approx 60$	

2.76 TeV Pb beam on a fixed target

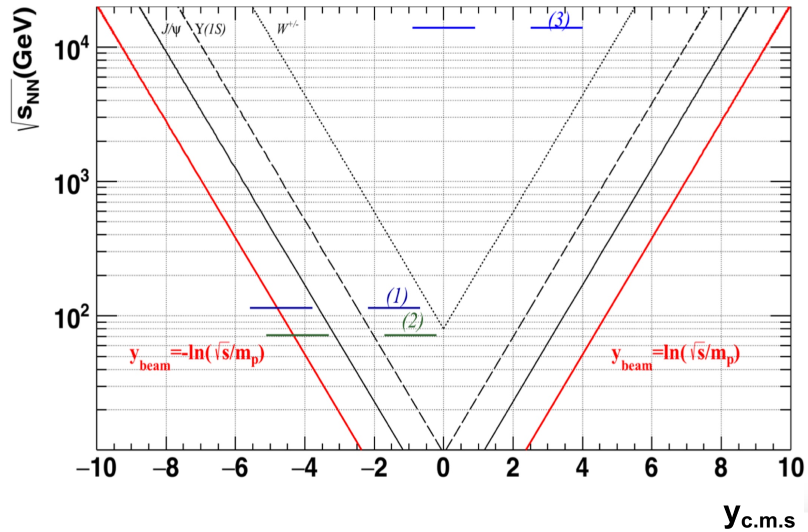
c.m.s. energy:	$\sqrt{s_{NN}} = \sqrt{2m_N E_{Pb}} \approx 72\,\mathrm{GeV}$	**Rapidity shift:** $y_{c.m.s.} = 0 \rightarrow y_{lab} = 4.3$
Boost:	$\gamma \approx 40$	



MAIN KINEMATICAL FEATURES (ALICE AND LHCb LIKE DETECTORS)



Acceptance of the LHCb detector
$2 < \eta_{lab} < 5$



Acceptance of the ALICE detector
MUON : $2.5 < \eta_{lab} < 4$
TPC : $-0.9 < \eta_{lab} < 0.9$

(1) pA collisions in fixed target mode, $\sqrt{s_{NN}}$ = 115 GeV
(2) PbA collisions in fixed target mode, $\sqrt{s_{NN}}$ = 72 GeV
(3) pp collisions in collider mode, $\sqrt{s}$ = 14 TeV

} Assuming $Z_{target} = 0$

- ❑ LHCb and ALICE muon arm access the mid- to backward- rapidity region ($y_{c.m.s} < 0$)
- ❑ ALICE central barrel probes very backward region (end of phase space)

PHYSICS MOTIVATIONS: STUDY THE HIGH-x FRONTIER

- Advance our understanding of the high-x gluon, antiquark and heavy-quark content in the nucleon and nucleus
  - Structure of nucleon and nuclei at high-x poorly known
  - Some longstanding puzzles:
    - The origin of the EMC effect in nuclei is not understood
      → Study a possible gluon EMC effect is essential
    - The Existence of a possible non-perturbative source of *c* or *b* quarks in the proton
      → Important for high-energy neutrino and cosmic ray physics
  - Search and study rare proton fluctuations where one gluon carries most of the proton momentum to test QCD in a new limit never explored

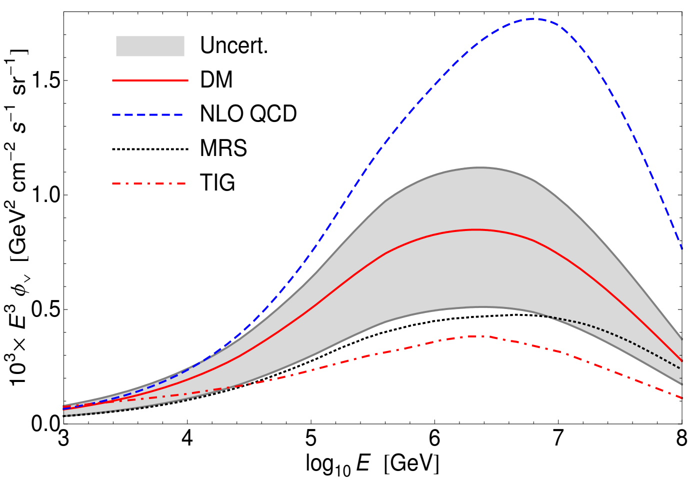
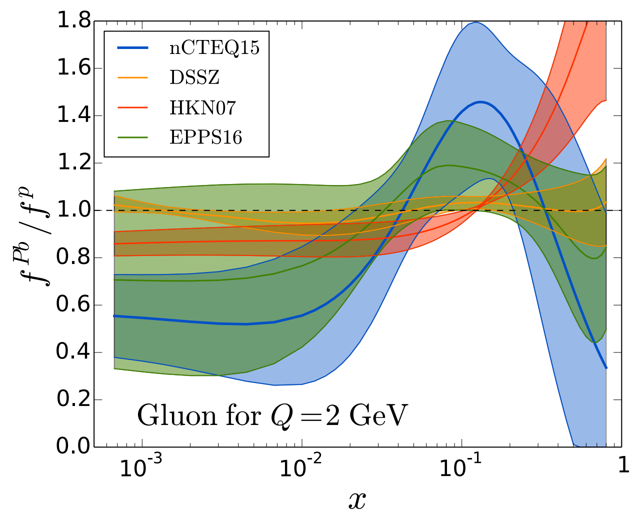


Illustration of the QCD uncertainties (QCD corrections, PDF uncertainties,…) on the prompt muon neutrino fluxes



Gluon density in Pb nuclei

PHYSICS MOTIVATIONS: UNRAVELING THE SPIN OF THE NUCLEON

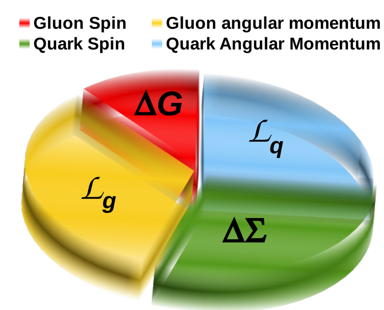
- Advance our understanding of the dynamics and spin of quarks and gluons inside polarised (and unpolarised) nucleons
  - Limited understanding of the nucleon spin structure, especially the quarks and gluons Orbital Angular Momentum (OAM) contributions

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + \mathcal{L}_g + \mathcal{L}_q$$

Spin of quarks /antiquarks ($\frac{1}{2}\Delta\Sigma$)

Spin of gluons (ΔG)

Orbital angular momentum of quarks and gluons ($\mathcal{L}_g + \mathcal{L}_q$)

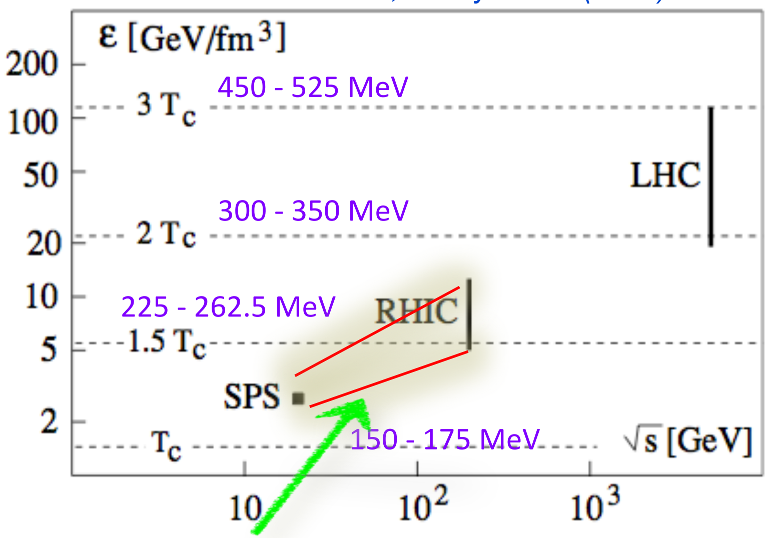


- First hint by COMPASS that $\mathcal{L}_g \neq 0$
- Access information on the orbital motion of the partons inside bound hadrons via Single Spin Asymmetry measurements (Sivers effect)
- Test TMD factorization formalism → sign change of A_N between SIDIS and DY
- Determination of linearly polarised gluons in unpolarised protons (Boer Mulders effect)

PHYSICS MOTIVATIONS: HEAVY ION COLLISIONS TOWARD LARGE RAPIDITIES

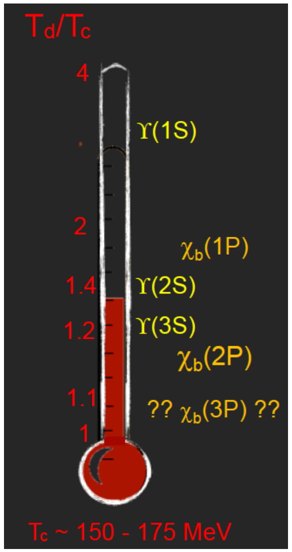
- QGP studies between SPS and RHIC energies (with eg. quarkonia)

Satz, J. Phys. G32 (2006) R25

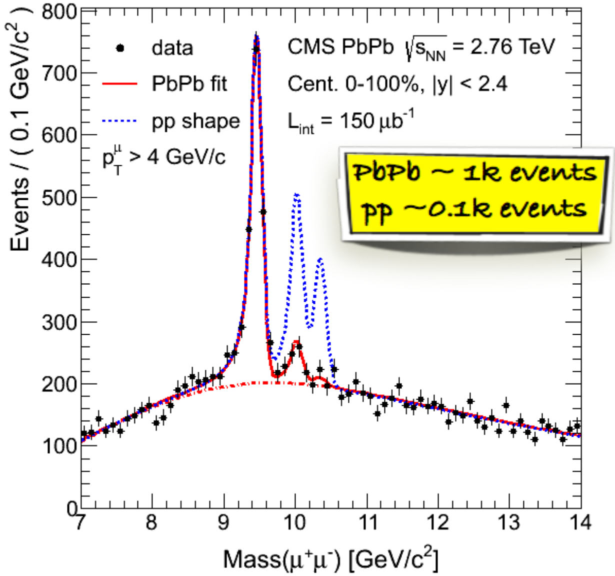


AFTER in PbA
$\sqrt{s_{NN}}$ ~ 72 GeV

Mocsy et al, Int. J. Mod. Phys. A28 (2013) 1340012



Dissociation temperature from lattice QCD (+hydro)



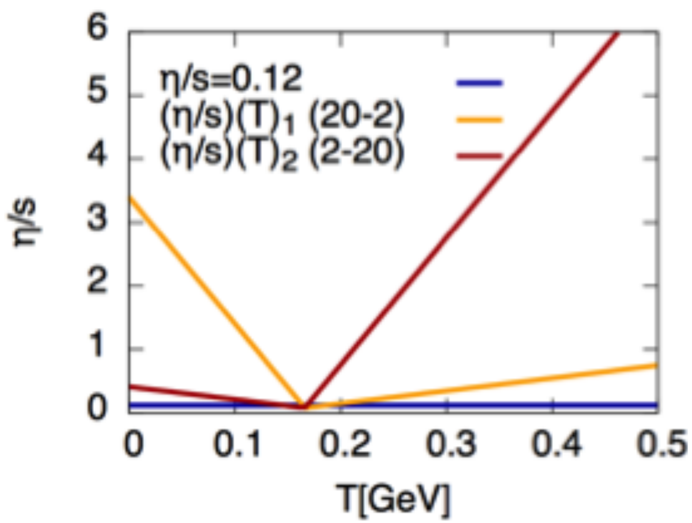
Phys. Rev. Lett. 109 (2012) 222301

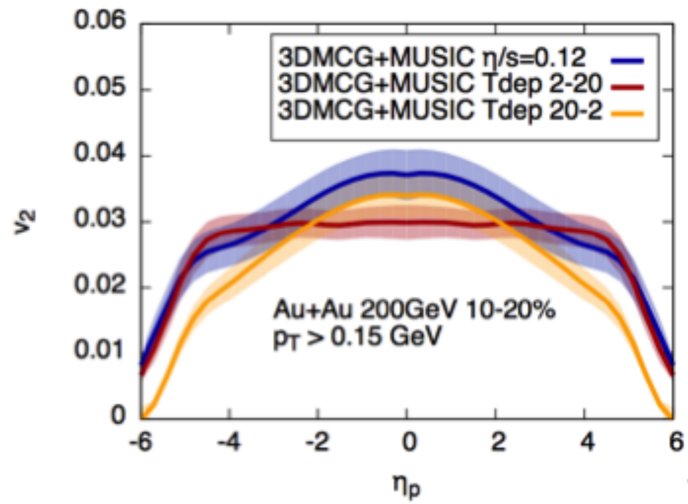
- A complete set of heavy-flavour studies (as a function of rapidity and system size)
  → Calibration of the quarkonium thermometer in AA collisions
- At AFTER@LHC energy, Υ(3S) and Υ(2S) are expected to melt
- Enough statistics to perform the same study as CMS at low energy
- Ψ(2S), χ_c, correlations of J/ψ + J/ψ, J/ψ + D also at reach

PHYSICS MOTIVATIONS: HEAVY ION COLLISIONS TOWARD LARGE RAPIDITIES

- ❑ Explore the longitudinal expansion of QGP formation

→ Particle yields and v_N measured at large rapidities powerful tool to access the medium shear viscosity and temperature





Phys. Rev. Lett. 116, 212301 (2016)

- ❑ Test collectivity in small systems with heavy quarks (v_2 of D mesons in p-Pb)

- ❑ Study heavy quarks energy loss mechanisms (collisional/radiative)
  - High precision measurement of D meson suppression in AA collisions versus p_T and y
  - R_{AA} and v_2 of D mesons → transport properties of the QGP

- ❑ Test the factorization of Cold Nuclear Matter effects
  - Use probe insensitive to Quark Gluon Plasma formation: Drell Yan

POSSIBLE TECHNICAL IMPLEMENTATIONS AT THE LHC

Internal (solid or gazeous) target + existing detector (ALICE/LHCb)

- Various ways of making fixed target collisions at the LHC:

  - Internal **Gas** target:
    - Currently validated by the LHCb collaboration with the SMOG system
    - Caveat: AFTER is not necessarily SMOG! (higher pressure, polarisation…)
      → Indeed several possibilities: gas jet, storage cell gas target
      → Need dedicated pumping systems
    - Benefit from the full p and Pb fluxes: 3.4×10^{18} p/s, 3.6×10^{14} Pb/s

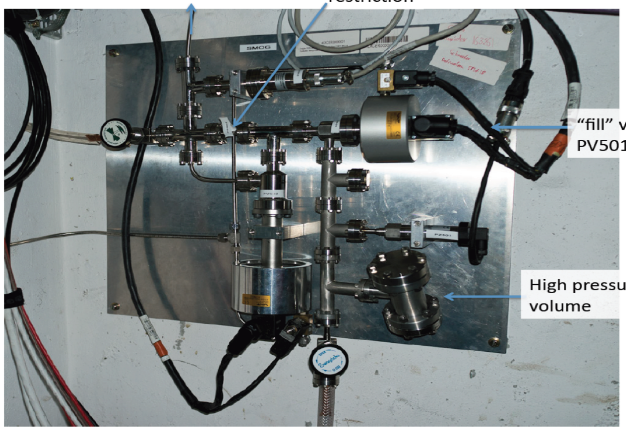
  - Internal **Wire/Foil** target (directly in the beam halo):
    - Used by Hera-B on the 920 GeV p beam and by STAR at RHIC

  - **Beam splitted** via **bent crystal:**
    - LHC beam halo is recycled:
      - Proton flux: ~ 5×10^8 p/s, Lead flux: ~ 2×10^5 Pb/s
    - Halo particles deflected by a bent crystal onto a solid target inside an experiment
    - Need to absorb the particles not interacting with the target

→ Similar luminosities can be reached with an internal gas target or a crystal based solution

INTERNAL GAS TARGET (SMOG @ LHCb)

SMOG: System for Measuring Overlap with Gas



- ❑ Low density noble gas injected (He, Ne, Ar so far) into LHCb Vertex Locator
- ❑ Benefit from the full LHCb beam without decrease of the beam lifetime:
  - Due to limited gas pressure (1.5 x 10^{-7} mbar)
- ❑ Limited running time, no polarization of the target, only noble gases

Typical integrated luminosity:
- p-Ar collisions at $\sqrt{s_{NN}}$ = 115 GeV (2015), ~ 17h of data taking, -20 cm < Z < 20 cm
- **L_{int} ~ 3.75 nb^{-1}**

INTERNAL GAS TARGET (GAS JET OPTION)

- ❑ Polarised H-jet polarimeter (used at RHIC)
  - Used to measure the proton beam polarisation
  - 9 vacuum chambers → 9 stages of differential pumping
  - Polarised free atomic beam source (ABS)
- ❑ Target Areal density
  - Polarised inlet Hydrogen flux: 1.3x10^{17} H/s, higher flux for ^{3}He
  - θ_{target} = 1.2 x 10^{12} atoms/cm^2 → ~ 7.5 x SMOG

- ❑ Integrated luminosity over one LHC year
  - **L_{int} (pH) = 45 pb^{-1}**

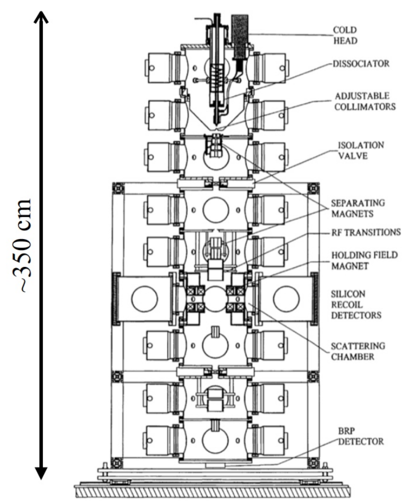
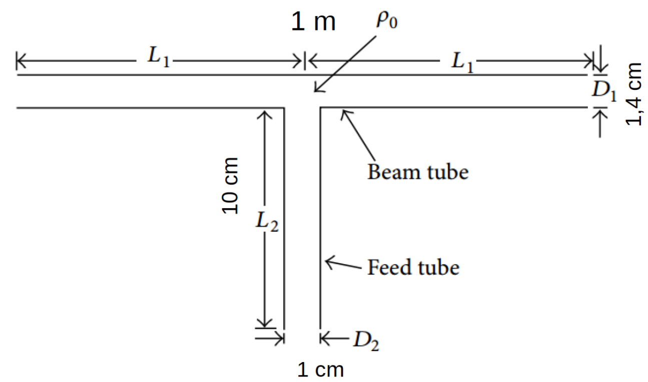


Fig. 1. H-jet polarimeter general layout.

Zelenski et al. NIM A 536 (2005) 248

INTERNAL GAS TARGET (HERMES TARGET LIKE OPTION)

- Openable storage cell:
  - Beam tube: 1000 mm length
  - 14 mm radius (50 mm open position)
- Benefit from higher pressure in the target cell
- Dedicated pumping system [turbo molecular pumps]
- Polarised H, D, ^{3}He can be injected (P ~80%)
- Unpolarised heavy gas can also be injected



Adv. High Energy Phys. 2015 (2015) 463141

E. Steffens, PoS (PSTP2015) 019

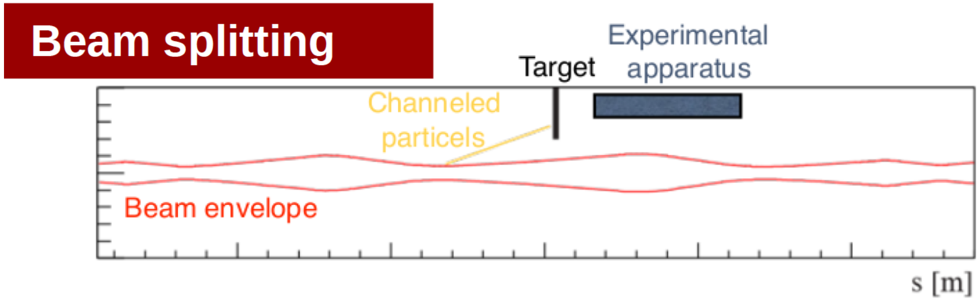
Beam	Target Gas	inlet flux [s^{-1}]	θ_{target} [cm^{-2}]	$\mathcal{L}$ [$cm^{-2}s^{-1}$]	$\sigma_{MB}^{Beam-Target}$	beam fraction used over a fill
p	$H^{\uparrow}$	$6.5 \cdot 10^{16}$	$2.5 \cdot 10^{14}$	$0.92 \cdot 10^{33}$	39 mb	0.4%
p	$D^{\uparrow}$	$5.2 \cdot 10^{16}$	$2.9 \cdot 10^{14}$	$1.1 \cdot 10^{33}$	71 mb	0.9 %
p	$^3He^{\uparrow}$	$1.0 \cdot 10^{16}$	$6.8 \cdot 10^{13}$	$0.25 \cdot 10^{33}$	96 mb	0.3 %
p	H_2	$2.8 \cdot 10^{17}$	$1.6 \cdot 10^{15}$	$5.8 \cdot 10^{33}$	39 mb	2.5%
p	{Ne, Ar, Kr, Xe}	$1.3 \cdot 10^{15}$	$6.44 \cdot 10^{13}$	$2.34 \cdot 10^{32}$	{0.4,0.6,1.0,1.3} b	{1.0,1.6,2.6,3.4} %
Pb	$H^{\uparrow}$	$6.5 \cdot 10^{16}$	$2.54 \cdot 10^{14}$	$1.18 \cdot 10^{29}$	1.8 b	9.3%
Pb	Xe	$1.3 \cdot 10^{15}$	$6.44 \cdot 10^{13}$	$3 \cdot 10^{28}$	6.2 b	8.1%

→ x 200 free gas-jet!

→ Gas pressure limited by beam lifetime

Typical integrated luminosity over a year:
- p-H collisions at $\sqrt{s_{NN}}$ = 115 GeV → **L_{int} ~ 10 fb^{-1}**
- Pb-H collisions at $\sqrt{s_{NN}}$ = 72 GeV → **L_{int} ~ 100 nb^{-1}**

BEAM SPLITTING USING BENT CRYSTALS



S. Redaelli, Physics Beyond Colliders, CERN, 06/09/2016

- ❑ Bent crystals initially for collimation purposes
- ❑ Can be used to deflect the beam halo onto an internal solid target
- ❑ First preliminary setups studied for both LHCb and ALICE
- ❑ Luminosities considering a 5mm-thick targets:

LHC beam	Target species	Density ρ [g cm^{-3}]	M [g mol^{-1}]	Thickness [mm]	θ_{Target} [cm^{-2}]	beam flux [s^{-1}]	$\mathcal{L}$ [cm^{-2}s^{-1}]
p	Solid H	0.088	1	5	$2.6 \cdot 10^{22}$	5×10^8	$1.3 \cdot 10^{31}$
p	C	2.25	12	5	$5.6 \cdot 10^{22}$	5×10^8	$2.8 \cdot 10^{31}$
p	Ti	4.43	48	5	$2.8 \cdot 10^{22}$	5×10^8	$1.4 \cdot 10^{31}$
p	W	19.25	184	5	$3.1 \cdot 10^{22}$	5×10^8	$1.6 \cdot 10^{31}$
Pb	Solid H	0.088	1	5	$2.6 \cdot 10^{22}$	10^5	$2.6 \cdot 10^{27}$
Pb	C	2.25	12	5	$5.6 \cdot 10^{22}$	10^5	$5.6 \cdot 10^{27}$
Pb	Ti	4.43	48	5	$2.8 \cdot 10^{22}$	10^5	$2.8 \cdot 10^{27}$
Pb	W	19.25	184	5	$3.1 \cdot 10^{22}$	10^5	$3.1 \cdot 10^{27}$

Typical integrated luminosity over a year:
- p-H collisions at $\sqrt{s_{NN}}$ = 115 GeV → **L_{int} ~ 0.1 fb^{-1}** (÷100 internal gas target)
- Pb-H collisions at $\sqrt{s_{NN}}$ = 72 GeV → **L_{int} ~ 3 nb^{-1}** (÷30 internal gas target)

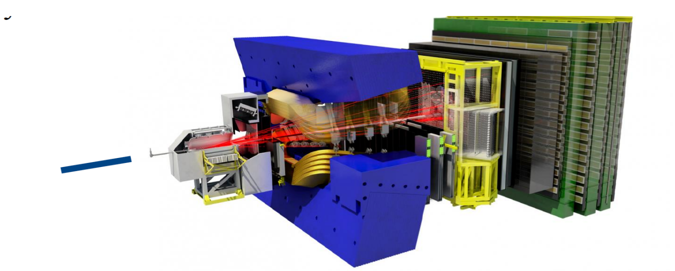
- ❑ Similar luminosities as the internal gas target case at reach by increasing the target lenght

A SELECTION OF PROJECTED PERFORMANCES FOR SEVERAL PROBES

LHCb-like

$\sqrt{s_{NN}}$ = 115 GeV, L_{int} (p-H) = 10 fb^{-1} / year
$\sqrt{s_{NN}}$ = 115 GeV, L_{int} (p-Xe) = 100 pb^{-1} / year
$\sqrt{s_{NN}}$ = 72 GeV, L_{int} (Pb-Xe) = 30 nb^{-1} / year
(Ref at same energy: L_{int} (p-H) = 250 pb^{-1}
L_{int} (p-Xe) = 2 pb^{-1})

$2 < \eta < 5$



HERMES-type polarized target + LHCb – like acceptance and performance

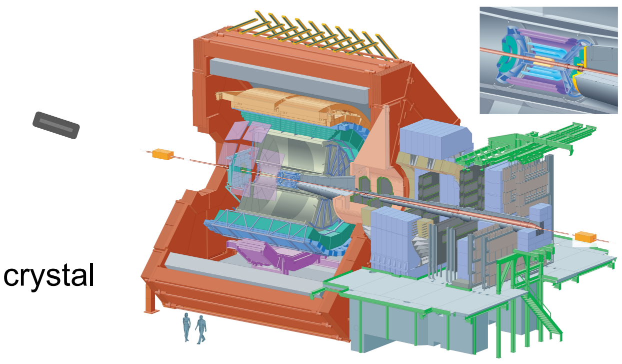
Resolution, efficiencies, microvertexing, particle ID, μ ID, electromagnetic and hadonic cal.

ALICE-like

$\sqrt{s_{NN}}$ = 72 GeV, L_{int} (Pb-Pb) = 1.6 nb^{-1} / year

$-0.87 < \eta^{TPC} < 0.95$

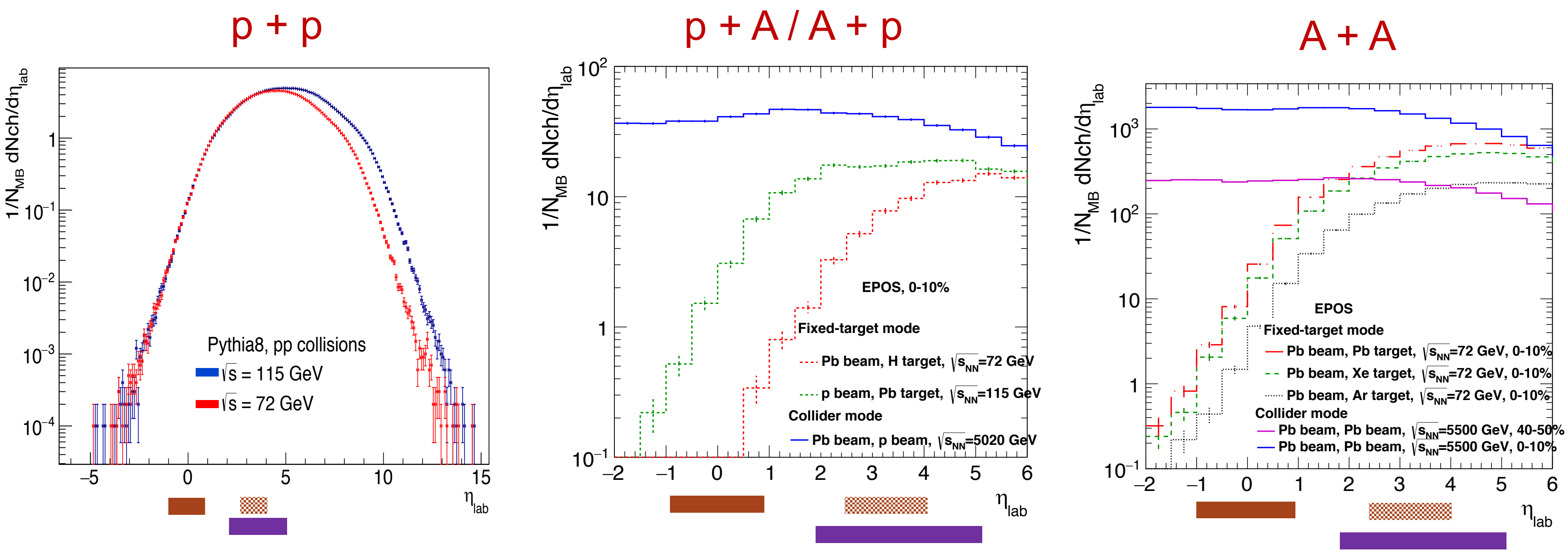
Bent crystal



+ internal solid target:
  Z ~ 13 cm from IP (A side)
+ ALICE like acceptance

CHARGED PARTICLE MULTIPLICITIES

Adv.High Energy Phys. 2015 (2015) 986348

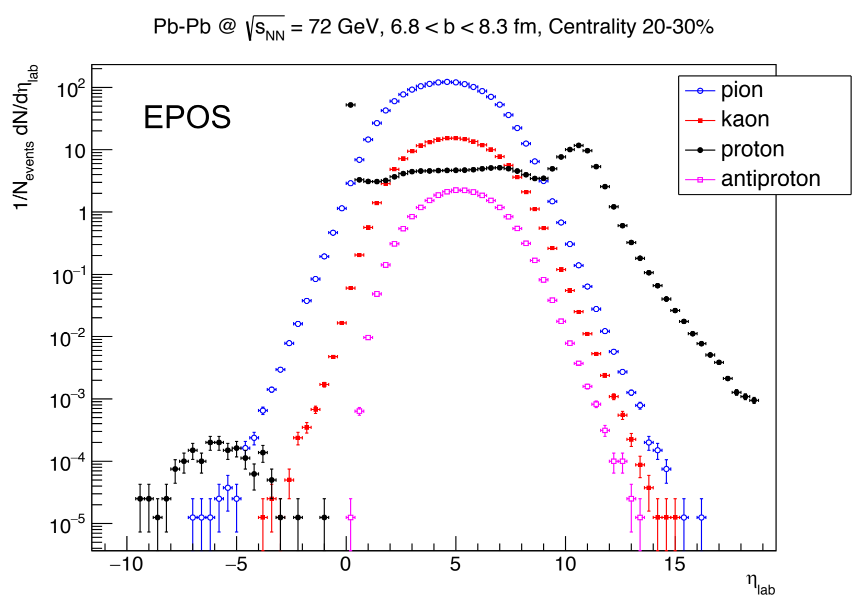


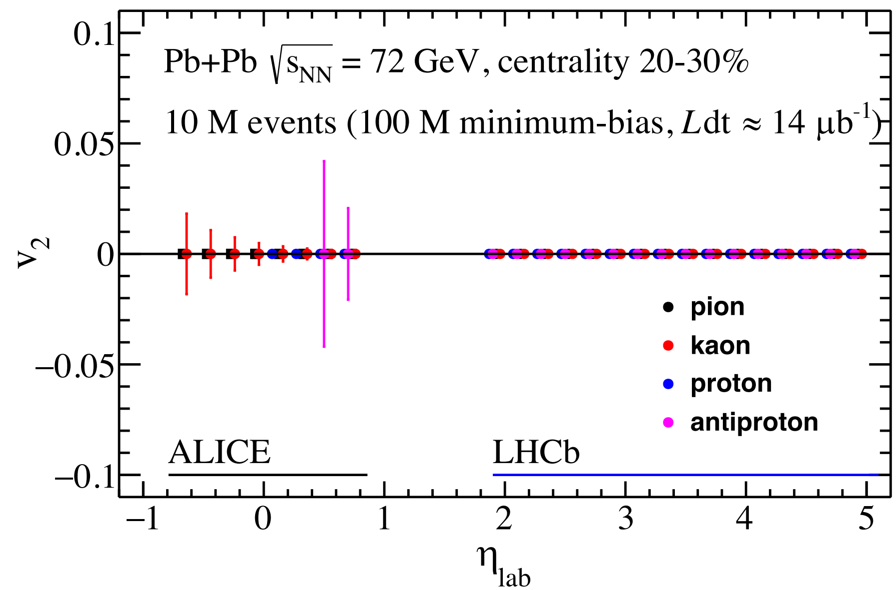
- Charged particles can be studies in a wide rapidity range, down to the phase space limit with the ALICE central barrel detector
- Multiplicities in pA/AA fixed target mode, always smaller than the multiplicity in collider mode at $\sqrt{s_{NN}}$ ~ 5 TeV → not an issue for an ALICE-like detector
- Multiplicities in most central fixed target Pb-Xe, Pb-Pb collisions above multiplicity in Pb-Pb collisions (centrality 40-50%) in the LHCb acceptance
  → Need to evaluate the new multiplicity reach of LHCb after LS2

ALICE central barrel (TPC)
ALICE muon arm
LHCb

STUDY THE TEMPERATURE DEPENDENCE OF η/S WITH THE FLOW OF IDENTIFIED PARTICLES

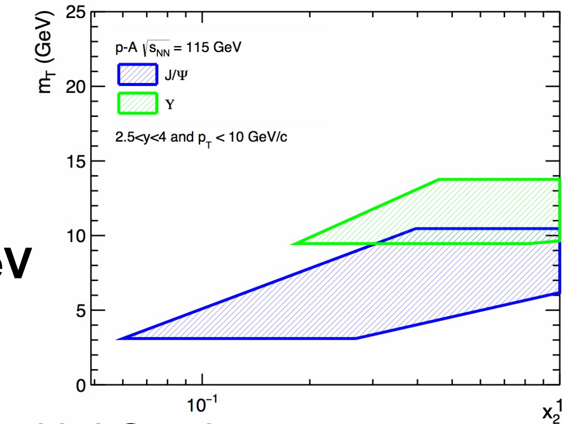
- Particle yields and v_n measured at large rapidities powerful to measure medium shear viscosity and temperature
- Identified charged particles can be studied in a wide rapidity range down to the phase-space limit
- At large rapidities, statistical accuracy on v_2 measurement better than percent for pions and protons, 2% accuracy for kaons, and 5% accuracy for antiprotons in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 72 GeV, centrality range 20-30%. Collection of 100M minbias events considered (~ few hours of data taking)





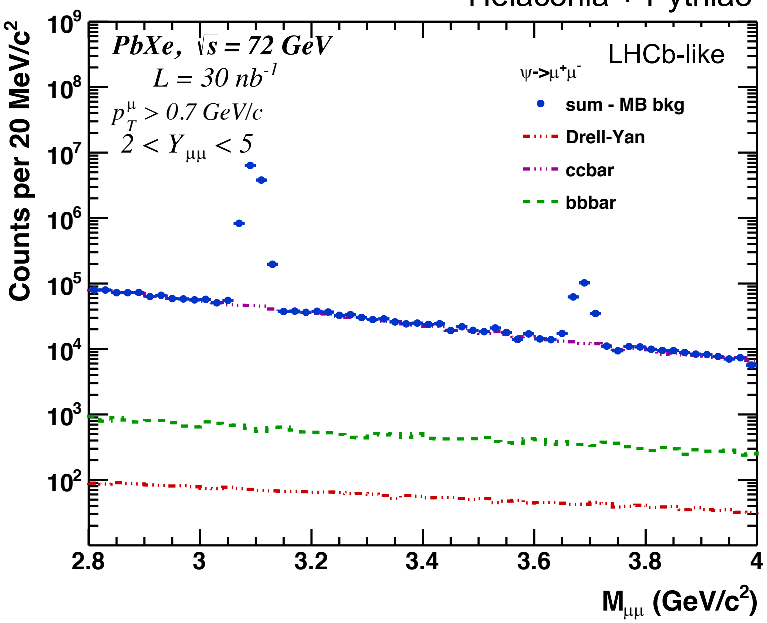
PROBING CNM EFFECTS AND QGP WITH QUARKONIA

- Probe large gluon x_2 in the target (in particular with Υ(1S))
- Constrain gluon anti-shadowing, EMC effects and other CNM effects with pA collisions. Study color screening from QGP in AA collisions
- **Wide rapidity coverage, p_T up to ~ 15 GeV and down to 0 GeV**
- Full background simulations show very good prospects for all systems (including AA) with LHCb-like performances

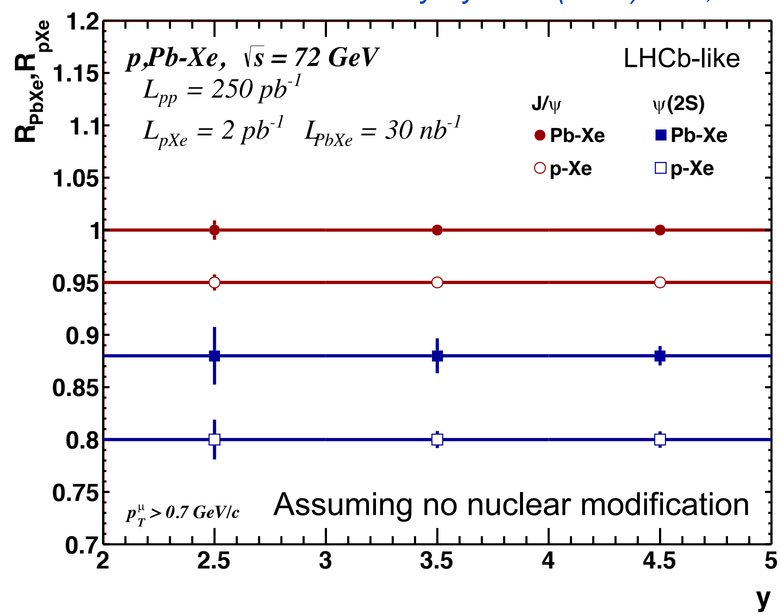


- 1 year of PbXe collisions, combinatorial background subtraction with LS pairs
- Few days of pXe and pH collisions at same energy
- Ψ(2S) measurement in PbXe with a statistical accurancy from ~10% ($4 < y_{lab} < 5$) to ~ 30% ($2 < y_{lab} < 3$)

Helaconia + Pythia8



Few Body Syst. 58 (2017) no.5, 148

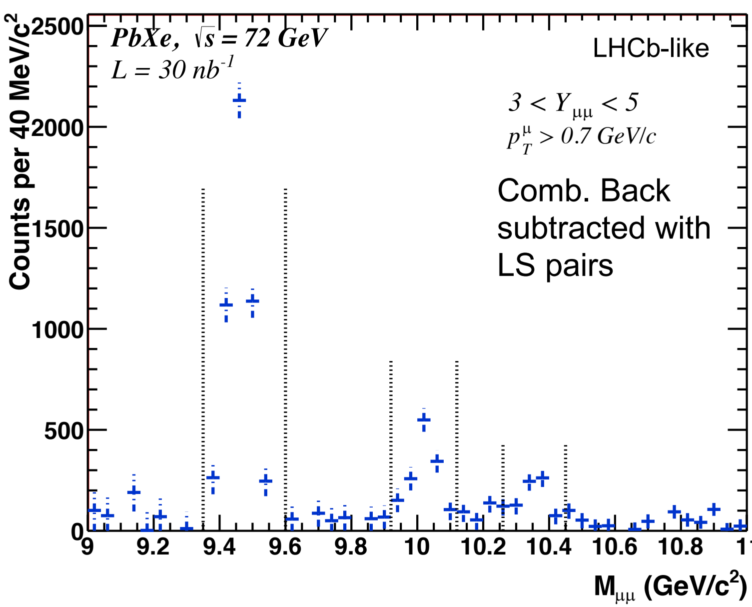


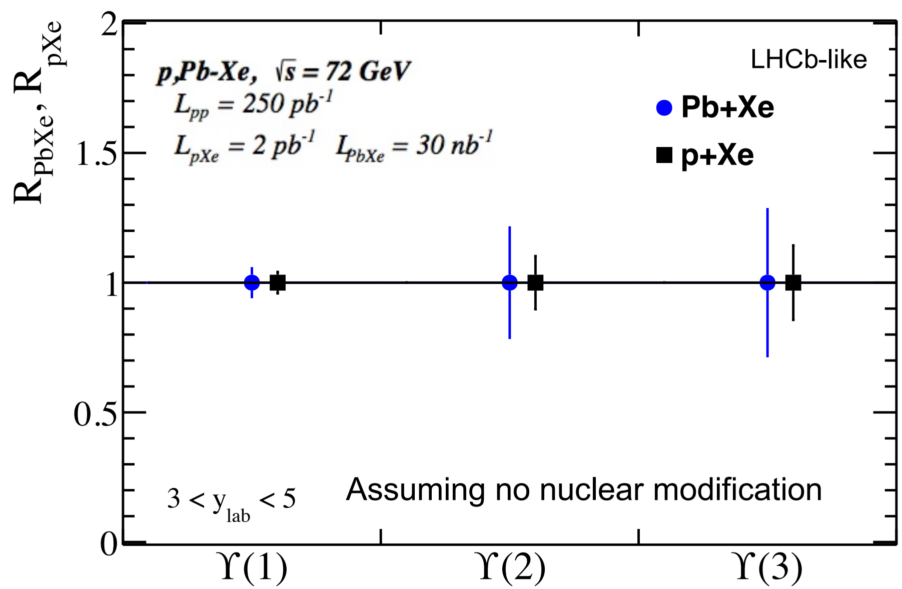
PROBING CNM EFFECTS AND QGP WITH QUARKONIA

- Determination of thermodynamic properties of QGP + CNM effects with Υ(nS) production in pp, pA, AA
- Search for the phase transition with Υ(nS) suppression as a function of rapidity and system size. Good calibration of the QGP thermomether (no $b\bar{b}$ recombination expected)
- Large Υ(nS) yields in one LHC year of PbXe data taking with LHCb-like performances (~ 450 Υ(3S))
- Statistical accuracy of ~7% on Υ(1S) R_{AA} measurement

Yields		signal	S/B
$\Upsilon(1S)$	pp	1.33×10^3	29.0
	pXe	1.39×10^3	7.8
	PbXe	4.33×10^3	1.8×10^{-1}
$\Upsilon(2S)$	pp	2.92×10^2	8.2
	pXe	3.06×10^2	2.2
	PbXe	9.56×10^2	5.0×10^{-2}
$\Upsilon(3S)$	pp	1.37×10^2	10.3
	pXe	1.44×10^2	2.8
	PbXe	4.49×10^2	6.2×10^{-2}

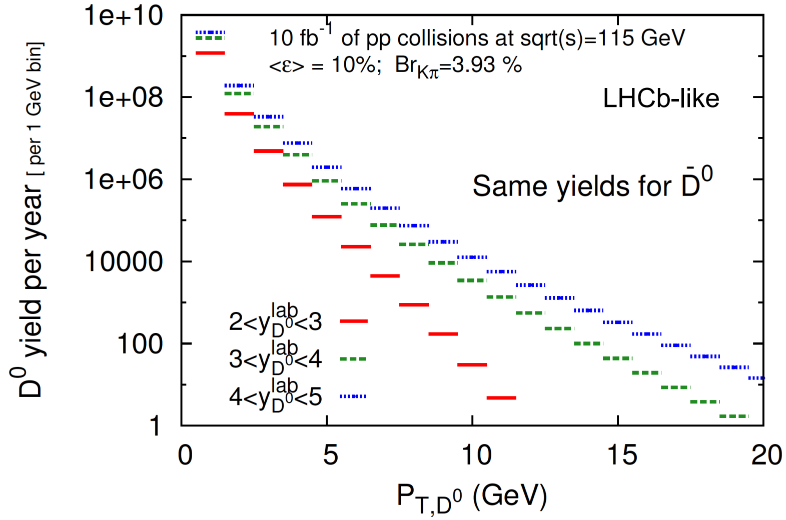
Few Body Syst. 58 (2017) no.5, 148





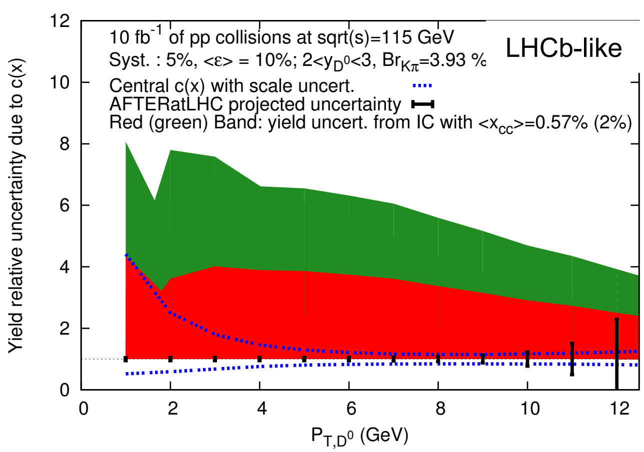
OPEN HEAVY FLAVOURS (D MESONS)

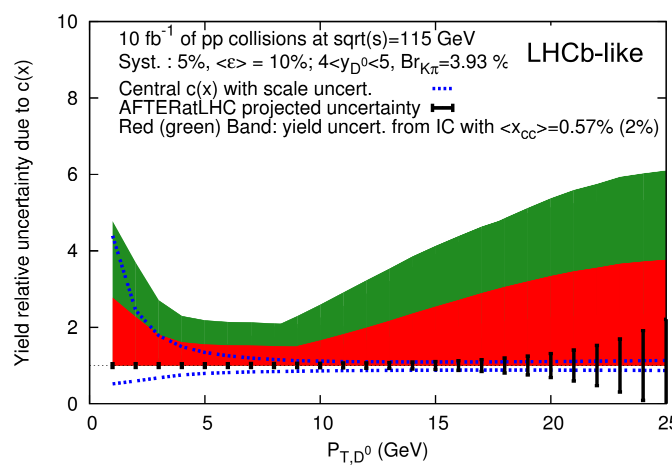
- Extremely good prospects to measure charm:
  - Down to zero p_T → total cross-section
  - Over a wide rapidity coverage: x_F → -1
  - with extremely high statistical precision in pp, pA and AA collisions
- With a LHCb-like detector , background well under control (pAr SMOG data available)



→ Study the large x intrinsic charm (IC) component in the proton

- Intrisic charm modifies significantly D meson yield at large p_T or forward rapidity
- For $p_T \leq 15$ GeV, expected precision of measurement allow to constrain IC models



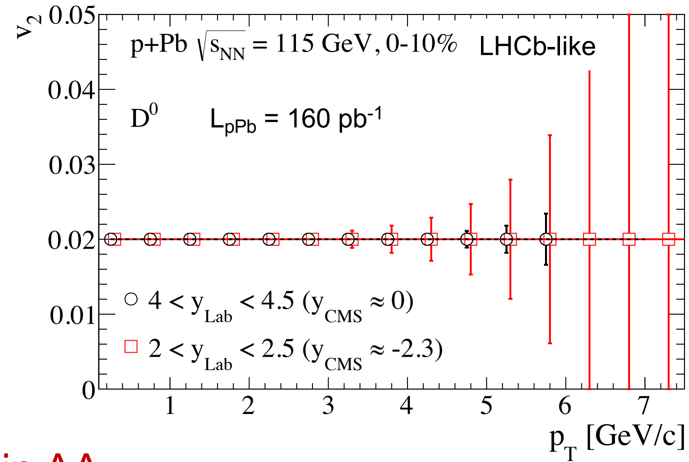


OPEN HEAVY FLAVOURS (D MESONS)

→ Test collectivity in small systems with D mesons in pA

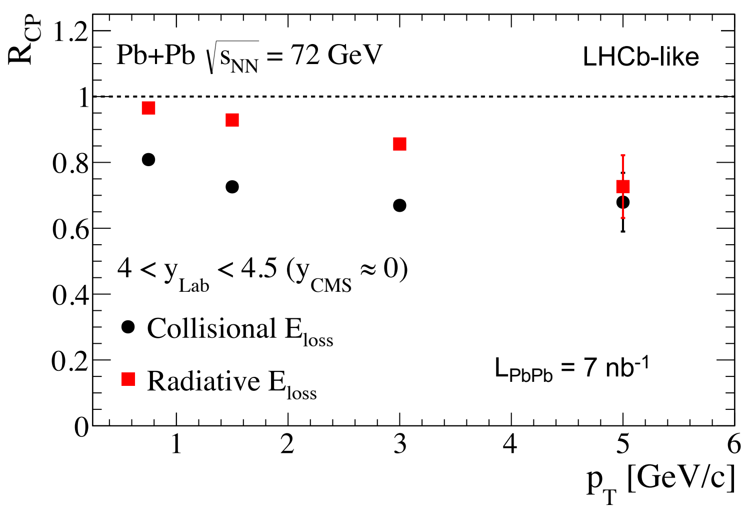
Adv.High Energy Phys. 2015 (2015) 783134

- ❑ Requires high statistics in pA collisions
- ❑ Large D^0 elliptic flow would provide evidence for collective effects if CNM effects under control (Cronin,…) with precise R_{pPb} measurement
- ❑ Good accuracy on D^0 v_2 measurement up to ~ 6 GeV/c for 4 < y_{lab} < 4.5 and up to ~ 5 GeV/c for 2 < y_{lab} < 2.5



→ Study heavy quark E_{loss} mechanisms with D mesons in AA

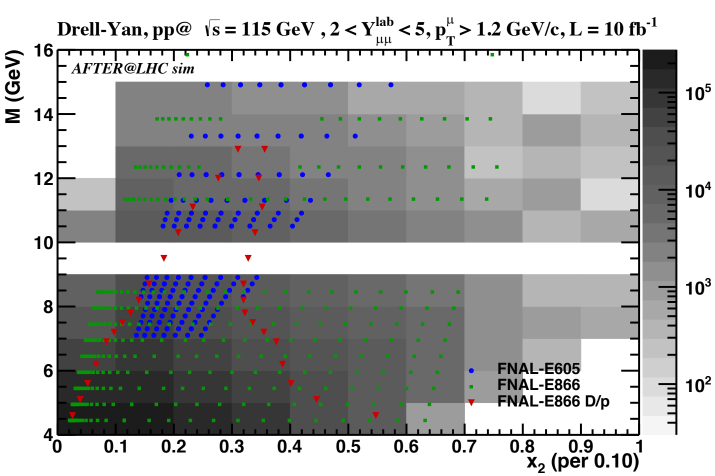
- ❑ Precise suppression measurements of charm and beauty separately versus y and p_T to disentangle collisional versus radiative E_{loss} mechanisms

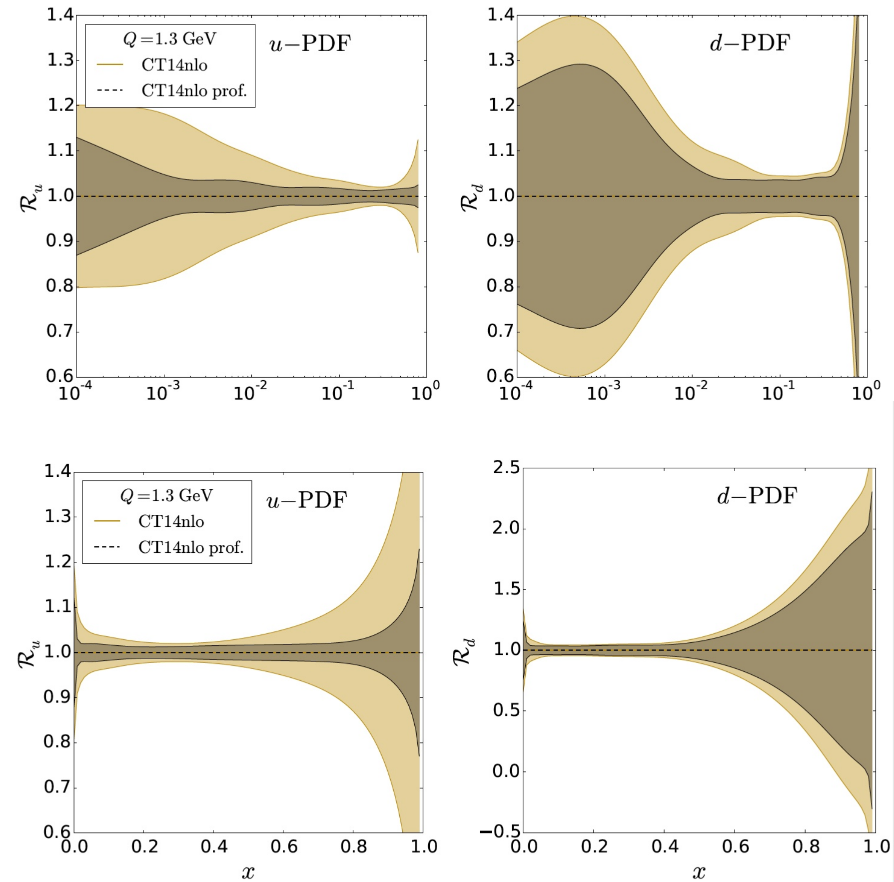


PROBING THE NUCLEON STRUCTURE WITH DRELL-YAN

- With AFTER@LHC, extension of the coverage of the existing Fermilab Drell-Yan data to larger x value. NuSea data limited by statistical precision (100% uncertainty at kinematic boundaries)
- At least 30 events per (M,x_2) bin → improved precision at large-x
- Impact of DY pair measurement on quark PDFs : evaluated with profiling analysis and generating pseudo-data
- Knowledge of valence quark distribution considerably improved for x > 0.4 (effect more pronounced for *u* quark)

LHCb-like *Few Body Syst. 58 (2017) no.4, 139*





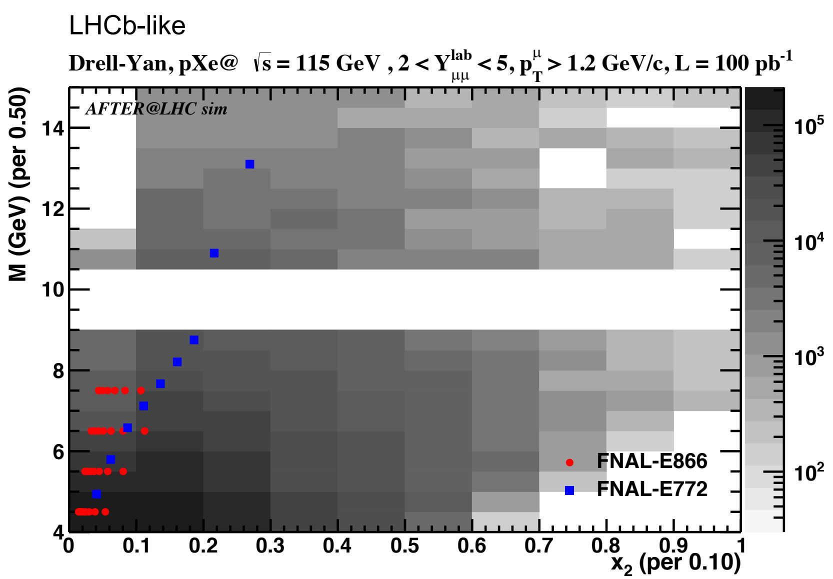
PROBING THE NUCLEAR STRUCTURE WITH DRELL-YAN

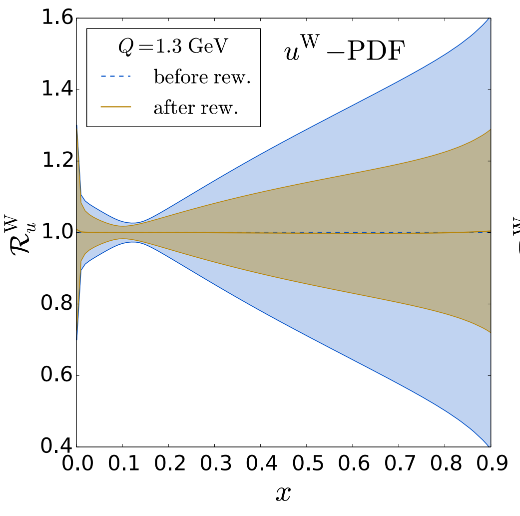
- Unique acceptance (with LHCb-like detector) compared to existing DY pA data (E866 & E772 @ Fermilab) used for nPDF fit. No existing measurements at RHIC

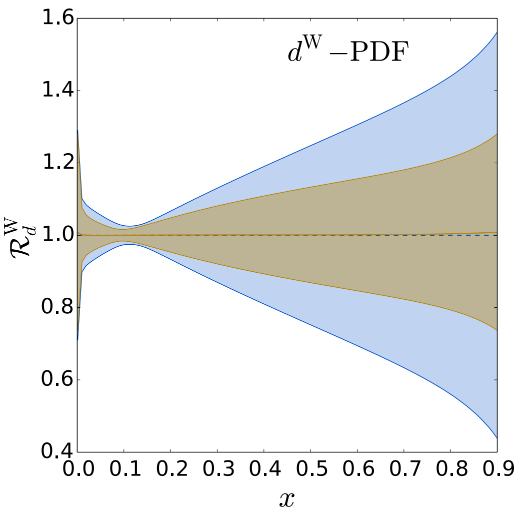
- Extremely large yields up to $x_2 \rightarrow 1$ (pXe simulations) and possibility to study various target species

- Potential impact of DY measurements (pXe, pW) on nPDFs evaluated with reweighting analysis using pseudo data on nuclear ratio R_{pW}, R_{pXe}.

- Significant decrease of the errors fo up and down quark distributions

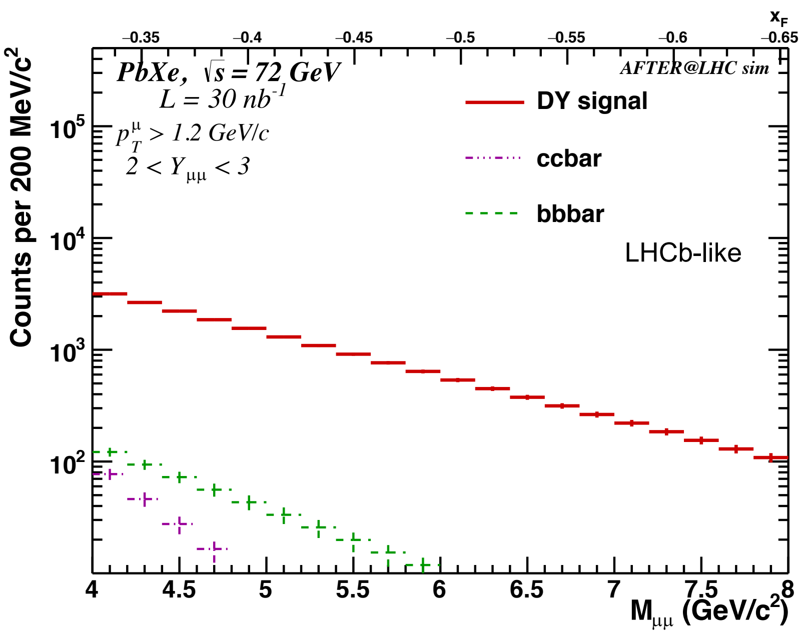






TEST THE FACTORIZATION OF INITIAL STATE EFFECTS IN AA COLLISIONS WITH DRELL YAN

- Drell Yan produced from initial state partons and do not interact with nuclear medium
- Ideal probe to test the extrapolation of initial state effects observed in pA collisions to AA collisions
- Low correlated background from $b\bar{b}$ pairs at AFTER@LHC energies. Combinatorial background can be removed with event mixing techniques
- Signal to background ratio ~ 10^{-2} in most backward rapidity bin



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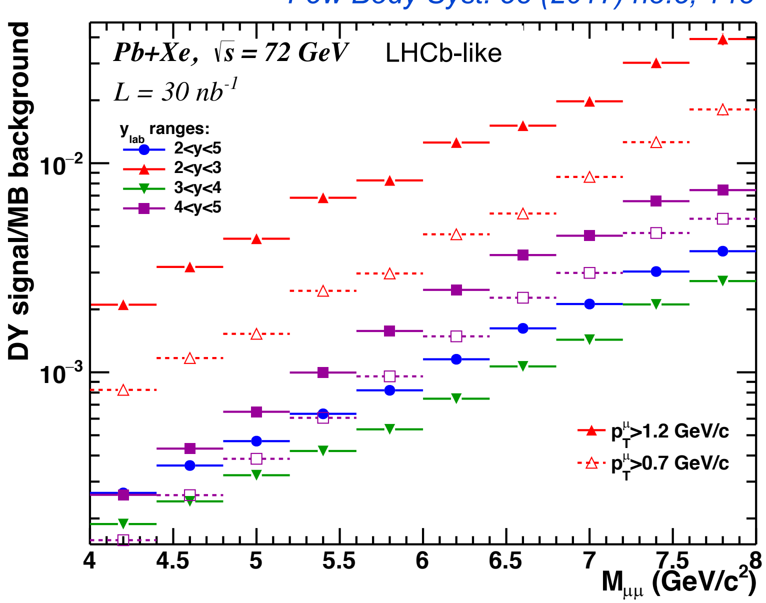


CONCLUSIONS

- Three main physics motivations for a fixed target program at the LHC:
  - Advance our understanding of the high-x gluon, antiquark and heavy-quark content in the nucleon and nucleus
  - Advance our understanding of the dynamics and spin of quarks and gluons inside polarised (and unpolarised) nucleons
  - Study the QGP in heavy-ion collisions towards large rapidities
- Two main ways towards fixed target collisions with the LHC beams and without interfering with other experiments
  - An internal gas target inspired from SMOG@LHCb/HERMES/H-jet@RHIC,…
  - A slow beam extraction with a bent crystal coupled to an internal solid target
  - → Technical implementations are studied inside the Physics Beyond Collider Working Group at CERN
- Projected performances:
  - Accurate v_2 measurement of identified particles expected to access T dependence of η/s
  - Large yields of charmonia and bottomia in pA/AA to measure CNM effects / color screening in the QGP in an energy range between SPS and RHIC
  - A complete set of Open Heavy Flavour measurements foreseen in all systems to study large x intrinsic charm component in the proton, test collectivity in small system and study heavy quark energy loss mechanism in the QGP
  - Abundant Drell-Yan pair production to probe the nucleon and nuclear structure at large x
- An expression of interest to be submitted to the LHCC is beeing written
- AFTER Webpage: http://after.in2p3.fr

BACKUP

RELEVANT LHC PARAMETERS

	proton beam	lead beam
Number of bunches in the LHC	2808	592
Number of particles per bunch	1.15×10^{11}	7×10^{7}
LHC Revolution frequency [Hz]	11245	
Particle flux in the LHC [s^{-1}]	3.63×10^{18}	4.66×10^{14}
LHC yearly running time [s]	10^{7}	10^{6}
Nominal energy of the beam [TeV]	7	2.76
Fill duration considered [h]	10	5
Usable particle flux in the halo (when relevant) [s^{-1}]	5×10^{8}	10^{5}

INTERNAL GAS TARGET (GAS JET OPTION)

- ❑ Polarised H-jet polarimeter (used at RHIC)
  - Used to measure the proton beam polarisation at RHIC
  - 9 vacuum chambers → 9 stages of differential pumping
  - Gas target: polarised free atomic beam source (ABS) cooled down to 80K crossing the RHIC beam

- ❑ Target Areal density
  - Polarised inlet Hydrogen flux: 1.3×10^{17} H/s
  - Higher flux can be obtained for ^3He
  - $\theta_{target} = 1.2 \times 10^{12}$ atoms/cm^2
    → ~ 7.5 x SMOG

- ❑ Instantaneous luminosity
  - $\mathcal{L}_{pH} = 4.5 \times 10^{30}$ cm^{-2} s^{-1} (full LHC flux)

- ❑ Integrated luminosity over one LHC year
  - $\mathcal{L}_{int}$ (pH) = 45 pb^{-1}

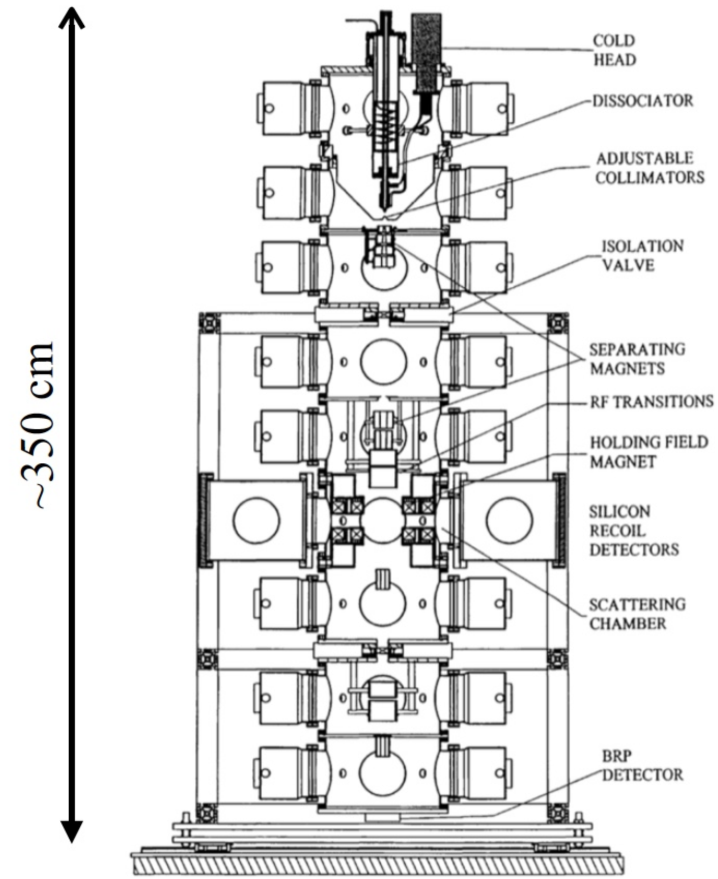
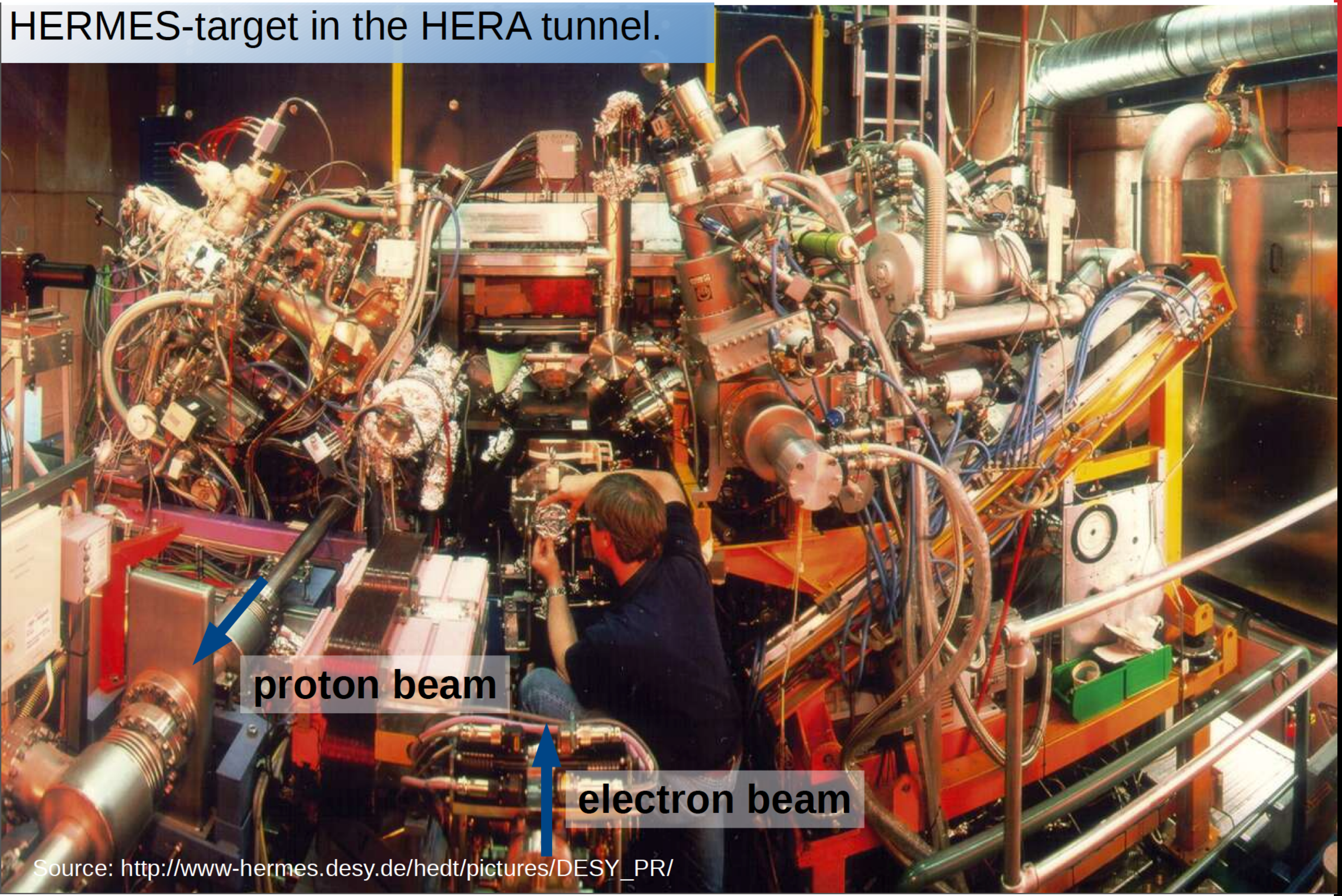


Fig. 1. H-jet polarimeter general layout.

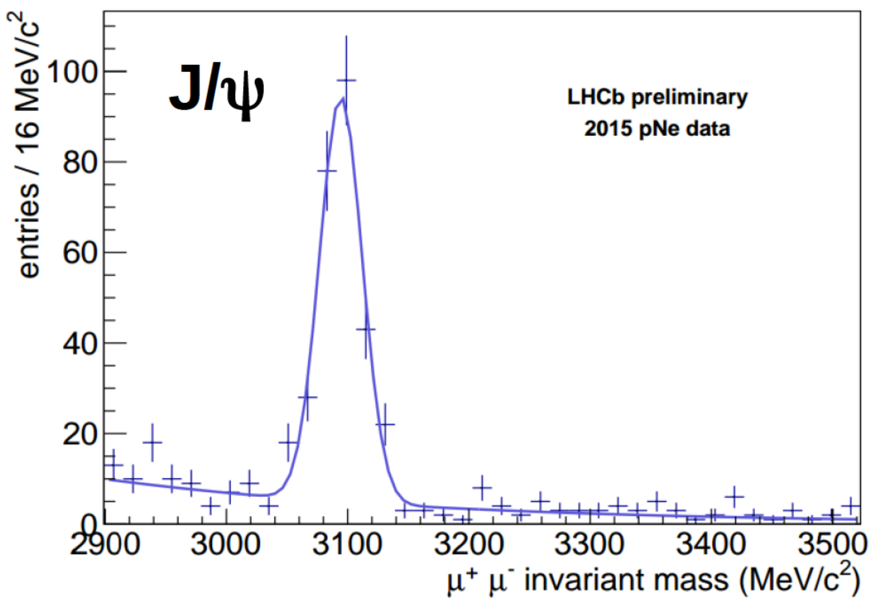
Zelenski et al. NIM A 536 (2005) 248

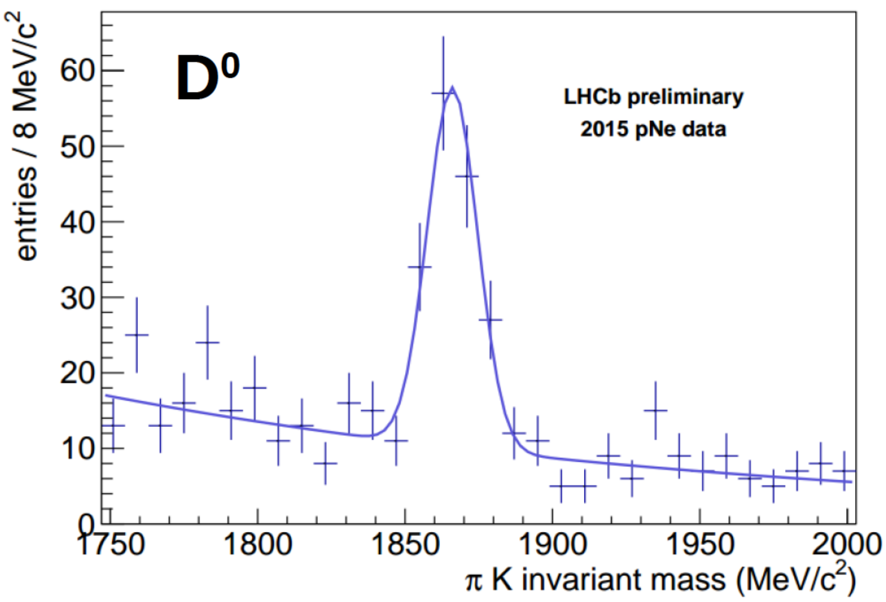
INTERNAL GAS TARGET (HERMES TARGET LIKE OPTION)



INTERNAL GAS TARGET (SMOG LHCb)

- Sucessfull pA and PbA data taking
- Heavy flavour signals from pNe data taking period at $\sqrt{s_{NN}}$ = 110 GeV (~12h)

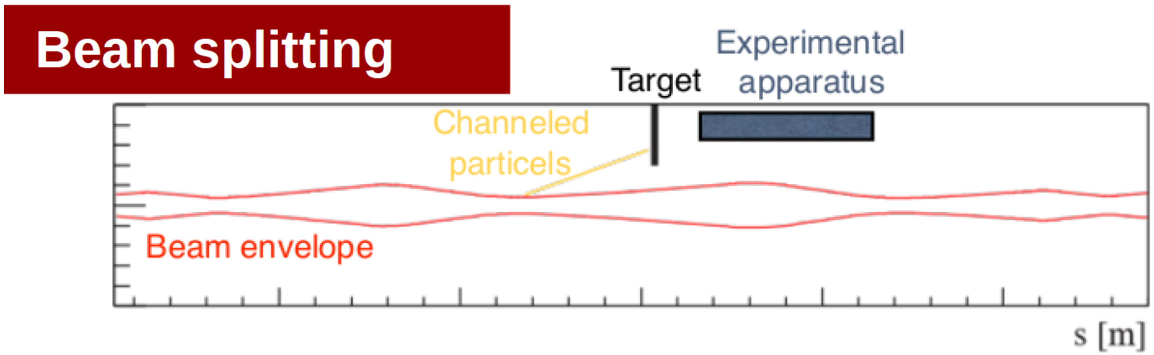




https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015

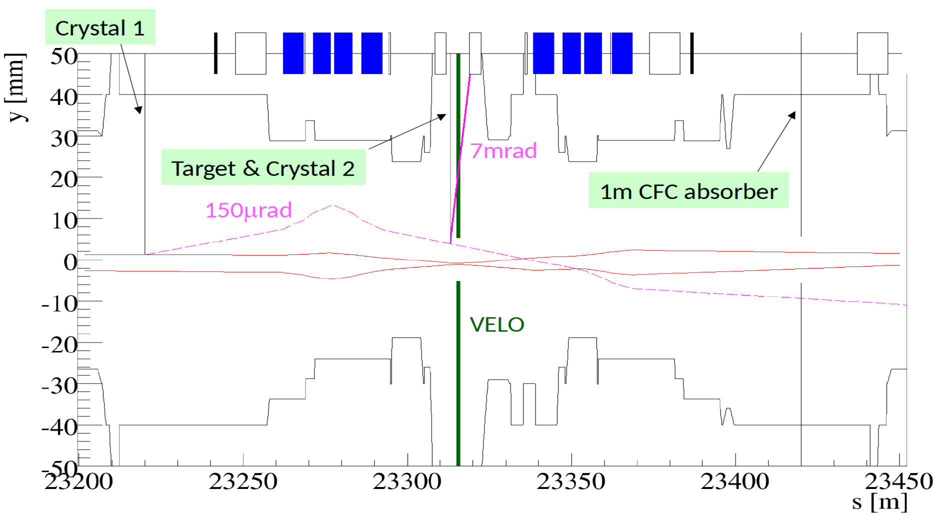
- Good resolution, high signal over background ratio

BEAM SPLITTING USING BENT CRYSTALS

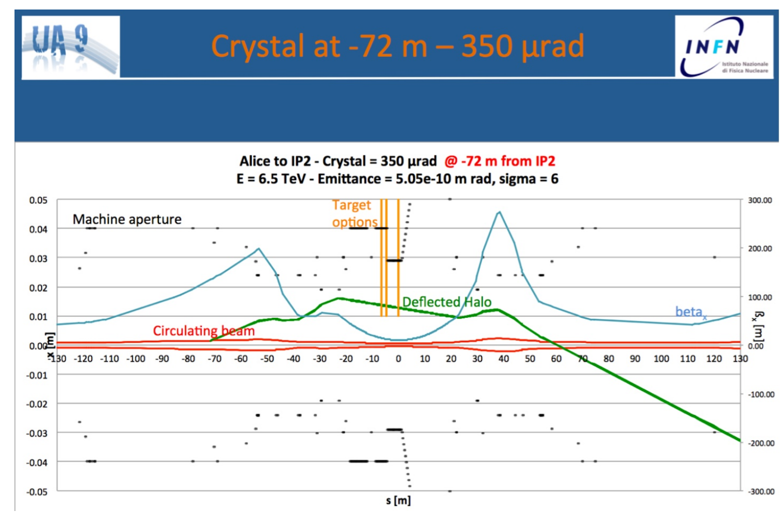


S. Redaelli, Physics Beyond Colliders, CERN, 06/09/2016

- ❑ Bent crystals initially for collimation purposes: deflect the beam halo to reduce beam losses
- ❑ Can be used to deflect the beam halo onto a solid target
- ❑ First preliminary setups studied for both LHCb and ALICE
- ❑ Motivated in LHCb for measuring the magnetic moment of Λ_c and other charm baryons
  → Parasitic operation allowed according to loss map simulations



W. Scandale, PBC, CERN, 06/09/2016 – Setup for LHCb

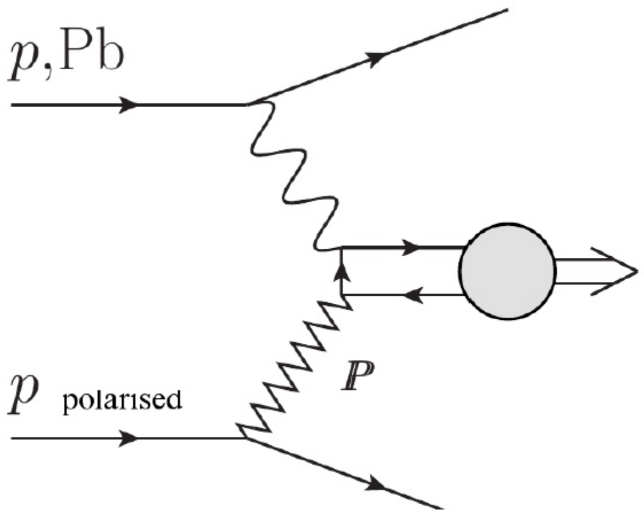


F. Galluccio, W. Scandale – Setup for ALICE

PROSPECTS FOR PHOTOPRODUCTION STUDIES WITH AFTER@LHC

J.P. Lansberg, L. Massacrier, L. Szymanowski, J. Wagner

- $\gamma_{lab}^{p\ beam} \sim 7450\ (E_p = 7000\ GeV)$
- $\gamma_{lab}^{Pb\ beam} \sim 2940\ (E_p = 2760\ GeV)$
- $E_\gamma^{max} \sim \gamma_{lab}^{beam}$ x 30 MeV
- $W_{\gamma p} \sim [5, 100]$ for y_{lab} ~ [0,9]
- Single Transverse Spin Asymmetry measurement $A_N^{\gamma p^\uparrow \to J/\Psi p}$ → access to the GPD E_g and the gluon Orbital Angular Momentum
- Access to pentaquark at very backward rapidity?



Simulations with STARLIGHT generator

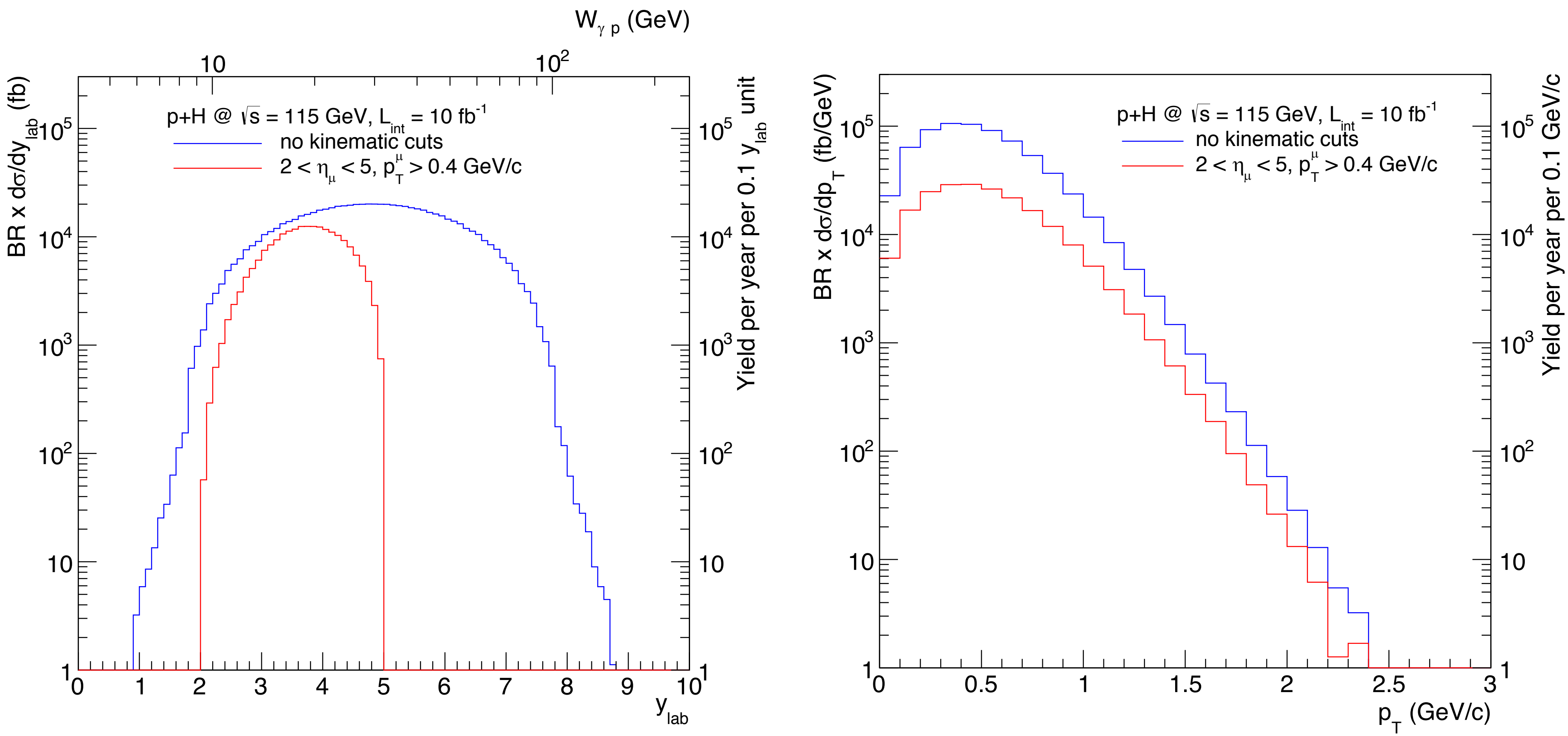
Phys. Rev. C60 (1999) 014903, arXiv:hep-ph/9902259 [hep-ph]

1. Proton-Hydrogen collisions in fixed target mode ($\sqrt{s_{NN}}$ = 115 GeV) for AFTER@LHC;
2. Lead-Hydrogen collisions in fixed target mode ($\sqrt{s_{NN}}$ = 72 GeV) for AFTER@LHC;

	Case 1	Case 2
Photon-emitter	proton	Lead
$\sigma_{J/\psi}^{tot}$ (pb)	1.18×10^3	276.77×10^3
$\sigma_{J/\psi\to l^+l^-}$ (pb)	70.10	16.50×10^3

Sum of 2 contributions, both protons are photon emitters

- J/ψ photoproduction in p-H↑ collisions at $\sqrt{s_{NN}}$ = 115 GeV (dimuon channel)



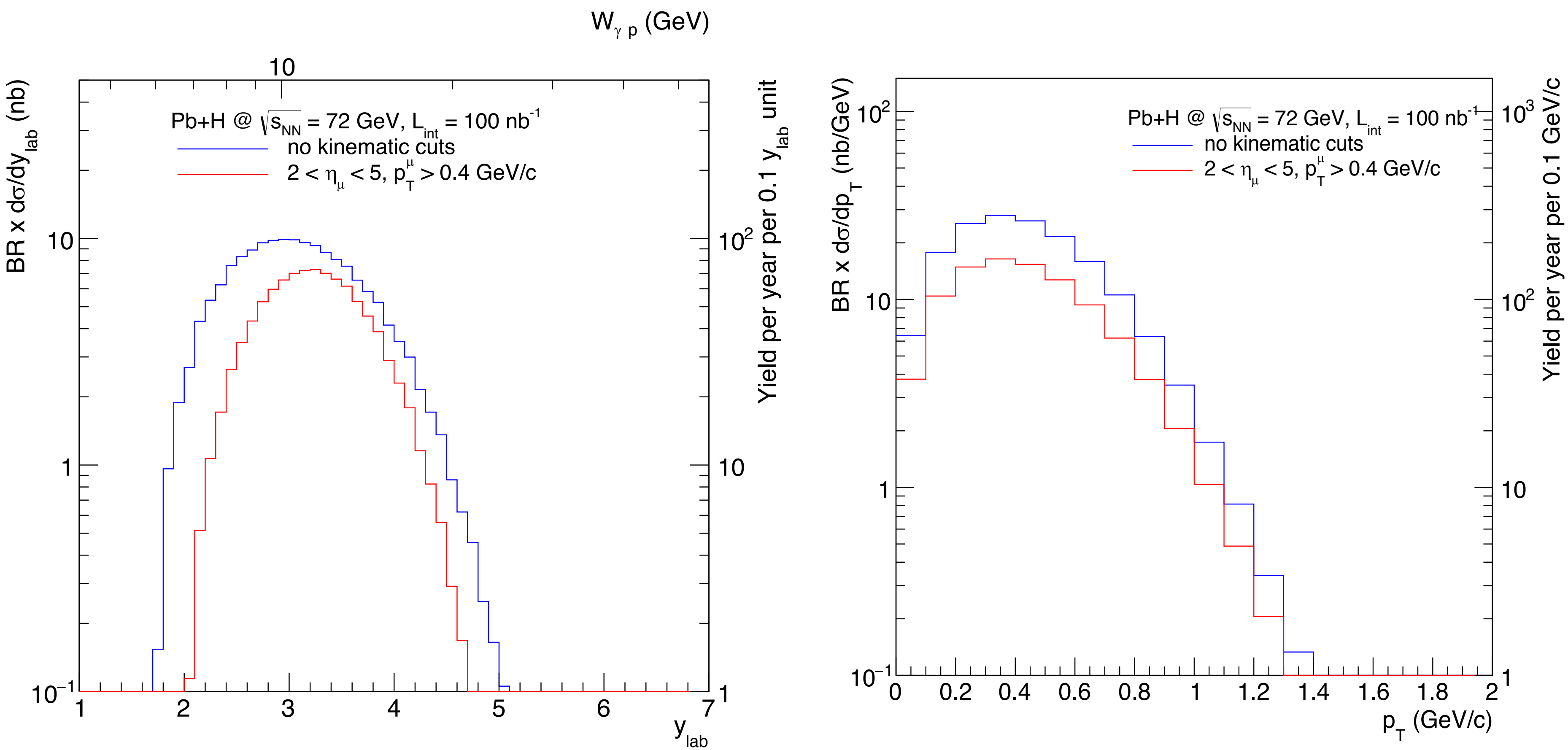
$\sigma_{J/\psi\to\mu^+\mu^-}\left(2<\eta^\mu<5, p_T^\mu > 0.4 \text{ GeV/c}\right) = 20.64$ pb

→ 200000 photoproduced J/ψ emitted in the LHCb acceptance (each p can emit the photon)

→ ~ x20 number of photoproduced J/ψ to be recorded at RHIC for 2017 Run in pp collisions at √s = 500 GeV (L_{int} ~ 400 pb^{-1}) arXiv:1602.03922 [nucl-ex]

PHOTOPRODUCTION PROSPECTS

❑ J/ψ photoproduction in Pb-H↑ collisions at $\sqrt{s_{NN}}$ = 72 GeV (dimuon channel)



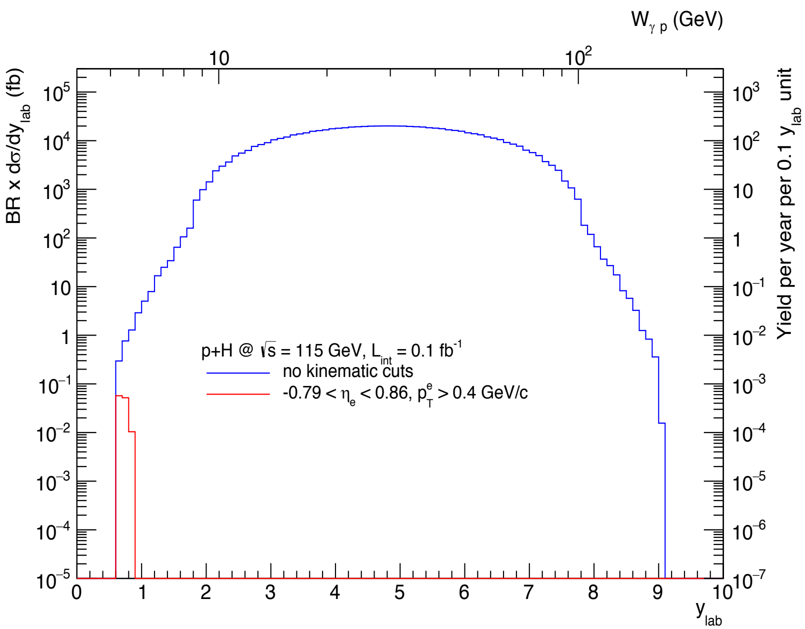
$\sigma_{J/\psi\rightarrow\mu^+\mu^-}\left(2<\eta^\mu<5, p_T^\mu > 0.4 \text{ GeV/c}\right) = 9.81 \times 10^3$ pb

→ 1000 photoproduced J/ψ emitted in the LHCb acceptance (Pb photon emitter)

→ ~ ÷13 number of photoproduced J/ψ to be recorded at RHIC for 2023 Run in Aup collisions at $\sqrt{s_{NN}}$ = 200 GeV (L_{int} ~ 1.75 pb^{-1}) arXiv:1602.03922 [nucl-ex]

FIRST LOOK AT PROJECTED PERFOMANCES FOR ALICE

- J/ψ photoproduction in p-H collisions at $\sqrt{s_{NN}}$ = 115 GeV (dielectron channel)



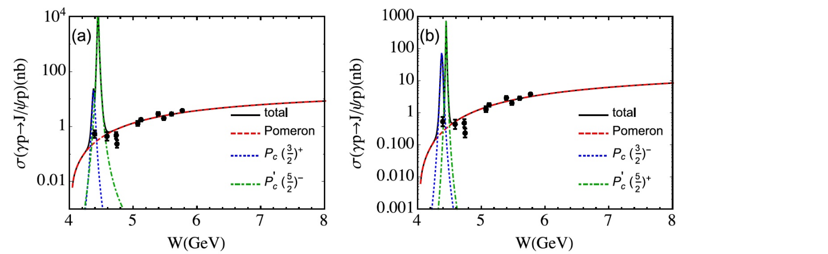
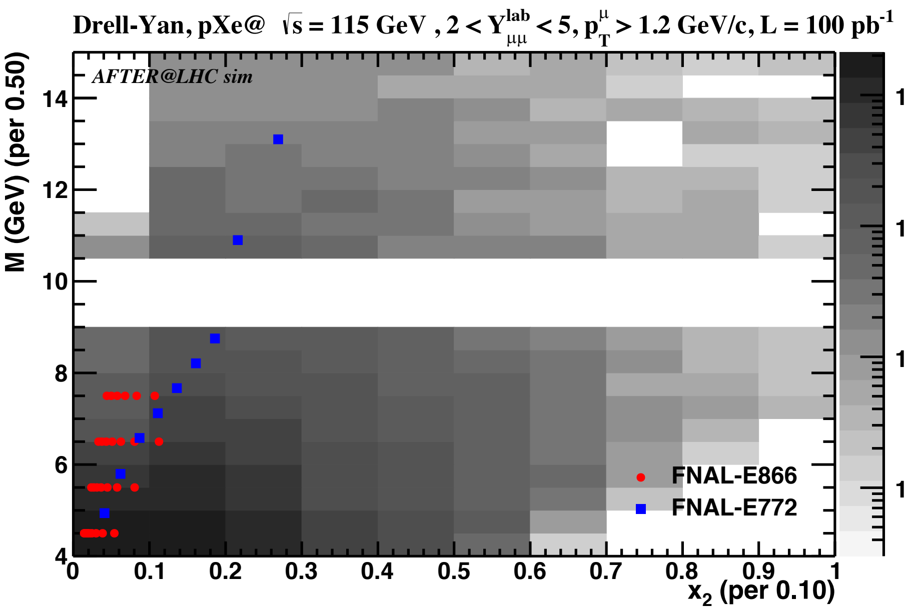


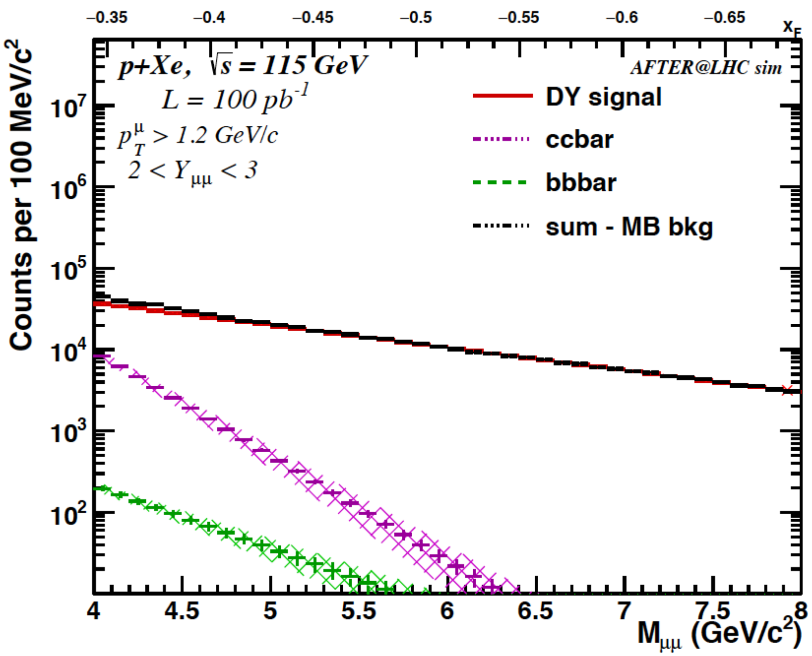
FIG. 3 (color online). The total cross section of $\gamma p \to J/\psi p$ in terms of the c.m. energy. The red dashed, blue dotted, green dot-dashed and black solid curves are the contributions from Pomeron, P_c with spin 3/2, P_c with spin 5/2 and the coherent sum of all. (a) shows $(3/2^+, 5/2^-)$ combination. (b) shows $(3/2^-, 5/2^+)$ combination. The coupling constants [Eq. (21)] between $J/\psi p$ and the two P_c states are extracted by assuming $J/\psi p$ saturates all their total widths. The experimental data are from Refs. [24–26].

Photoproduction of hidden charm pentaquark states P_c^+ (4380) and P_c^+ (4450), PHYSICAL REVIEW D 92, 034022 (2015)
S/B ratios ~ 10^3 – 10^4 depending on the state and coupling

→ ~ 0.001 photoproduced J/ψ emitted per year in the ALICE TPC acceptance
→ Could expect to produce ~ 1-10 pentaquark per year in the ALICE very backward acceptance

DRELL-YAN SIMULATIONS (p + Xe)





QUARKONIA (Pb + Xe)