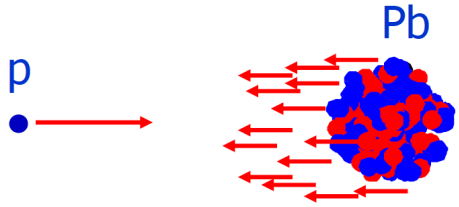
LHCb Results from pA collisions

Michael Schmelling – MPI for Nuclear Physics

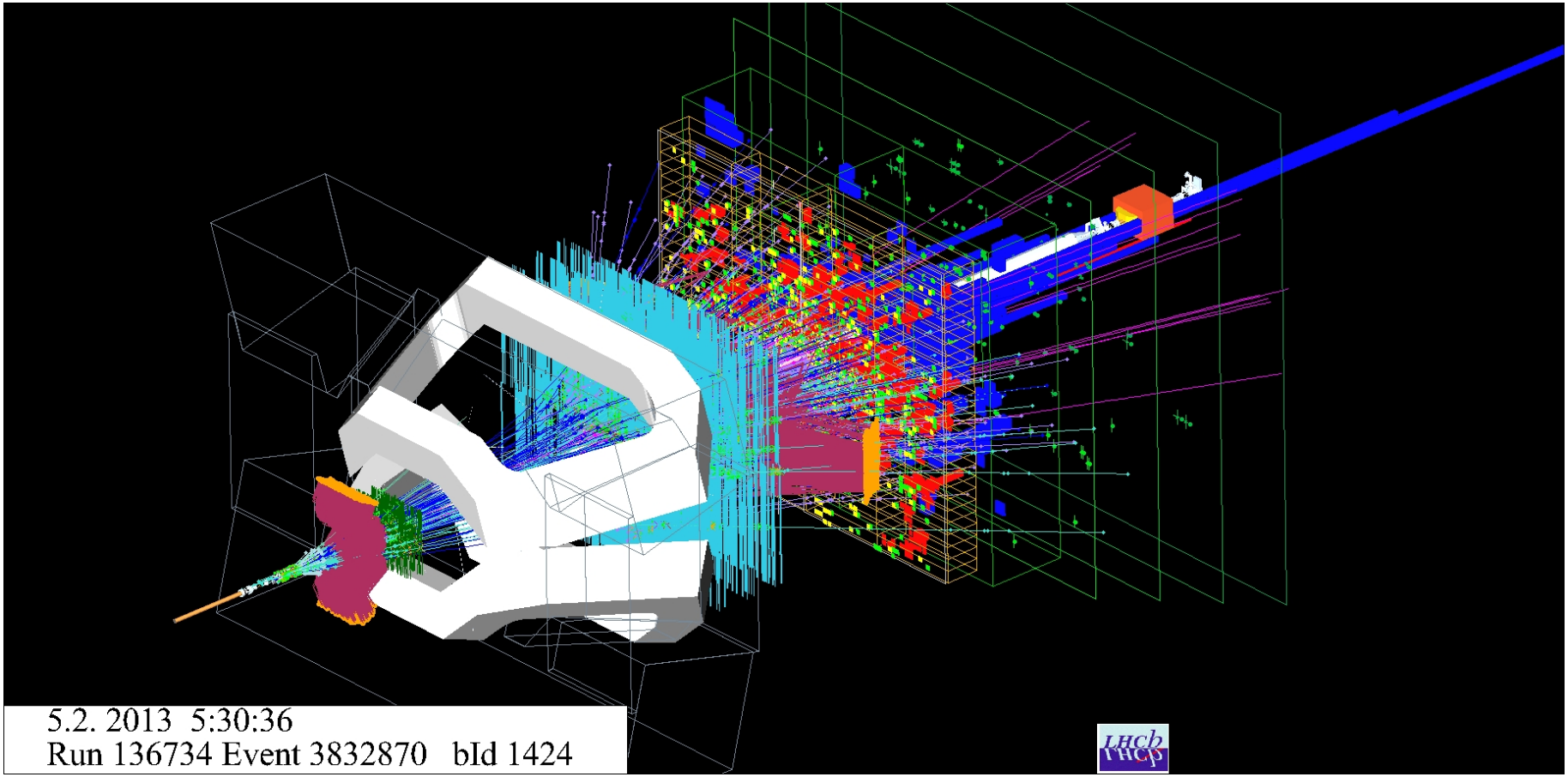
– on behalf of the LHCb collaboration –



❖ physics issues

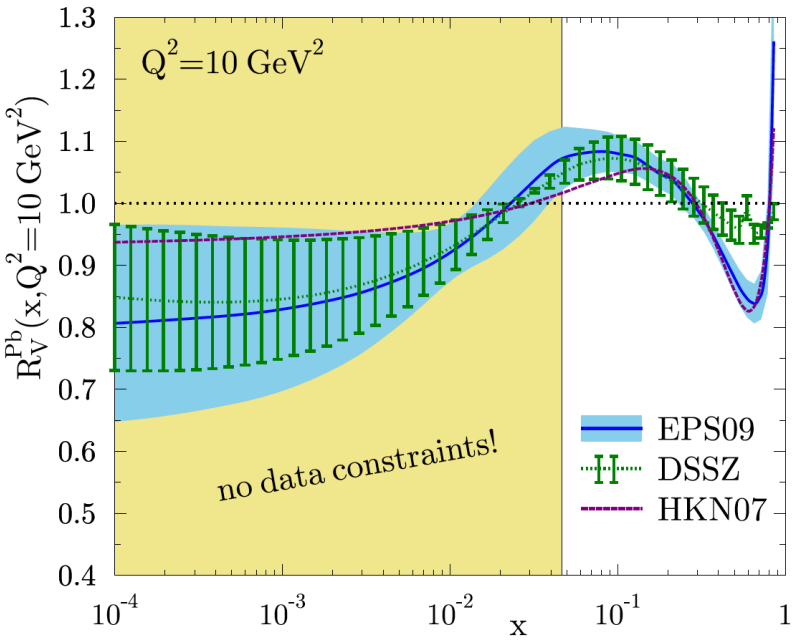
- study nuclear PDFs (parton shadowing)
- (coherent) energy loss in nuclear matter
- disentangle effects by looking at different processes
  - ➜ prompt J/ψ and J/ψ from b
  - ➜ Υ production
  - ➜ Z production
  - ➜ fixed target physics

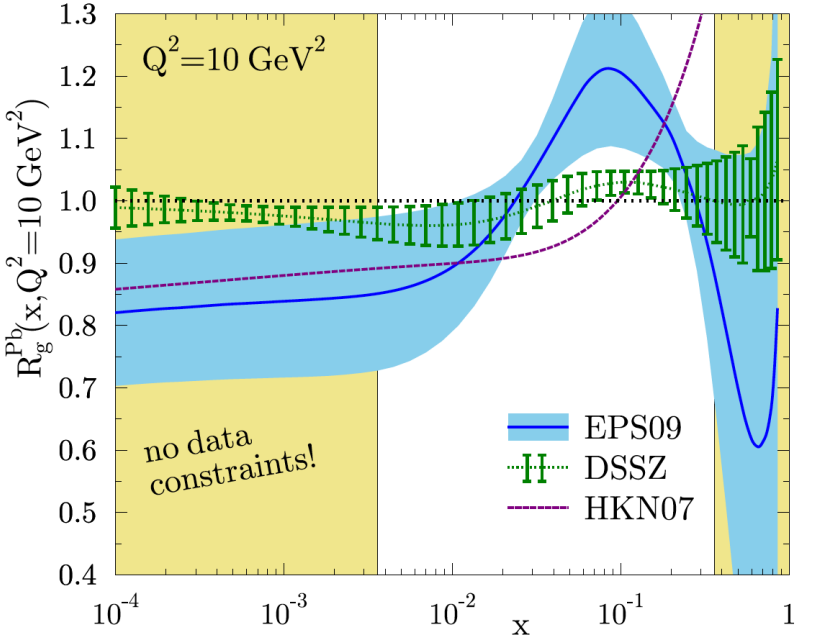
A typical pPb interaction in LHCb



Current knowledge of nuclear PDFs

➜ *ratios: (nuclear PDF)/(nucleon PDF)*





arXiv:1401.2345

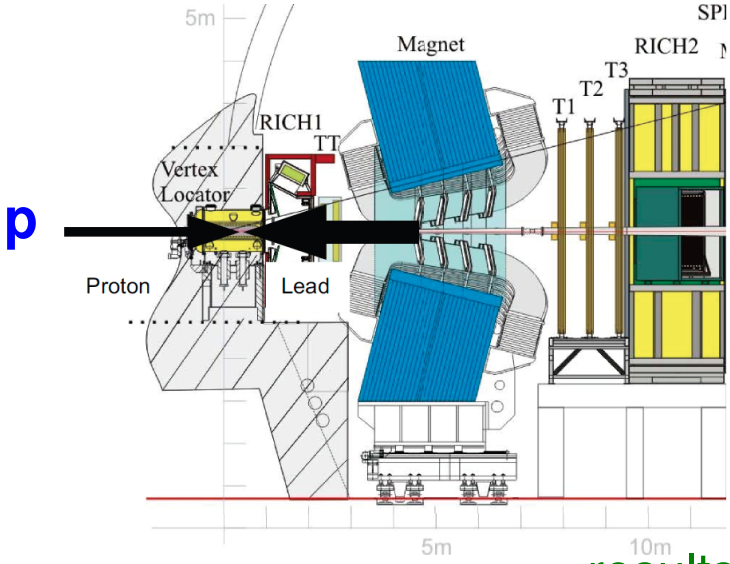
- currently still large unexplored regions
- accessible regions for LHCb in J/ψ, Υ, Z production, approximately...
  - ➜ J/ψ: $1 \cdot 10^{-5} < x < 1 \cdot 10^{-4}$ and $7 \cdot 10^{-3} < x < 7 \cdot 10^{-2}$
  - ➜ Υ: $3 \cdot 10^{-5} < x < 3 \cdot 10^{-4}$ and $3 \cdot 10^{-2} < x < 3 \cdot 10^{-1}$
  - ➜ Z: $2 \cdot 10^{-4} < x < 3 \cdot 10^{-3}$ and $3 \cdot 10^{-1} < x$
  - ➜ fixed target: $x \sim 0.1$

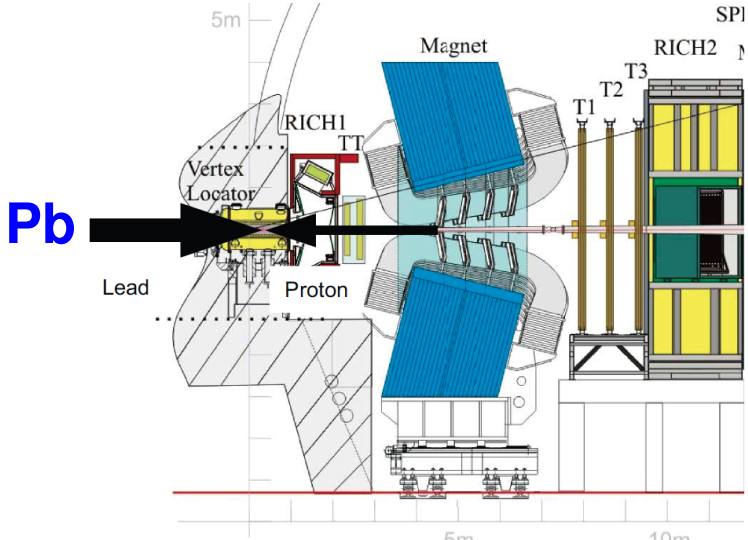
Observables sensitive to nuclear effects

nuclear modification factor: $R_{pA}(y) = \frac{1}{A} \cdot \frac{d\sigma_{pA}/dy}{d\sigma_{pp}/dy}$

forward-backward asymmetry: $R_{FB}(y) = \frac{R_{pA}(+|y|)}{R_{pA}(-|y|)}$

- positive rapidity in direction of the proton
- pp cross-section cancels in R_{FB}
- exploit asymmetric layout of LHCb to measure forward and backward

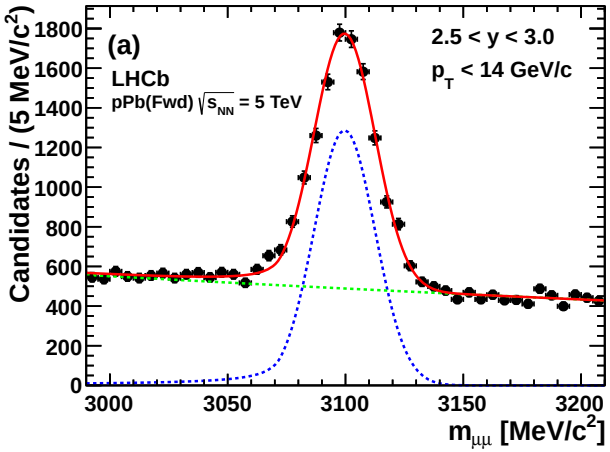


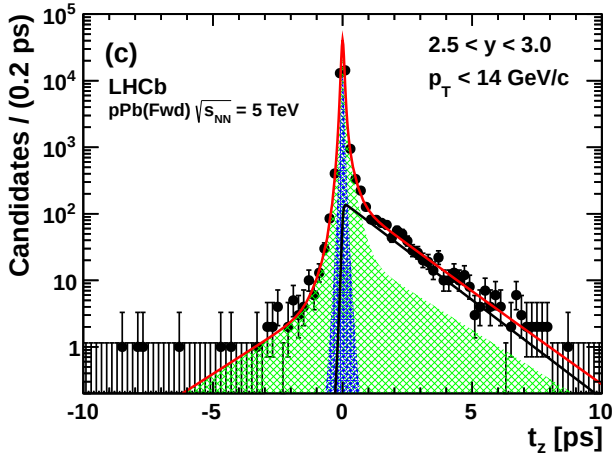


results from $1.6\,\text{nb}^{-1}$ pPb-data recorded in 2013 ➜

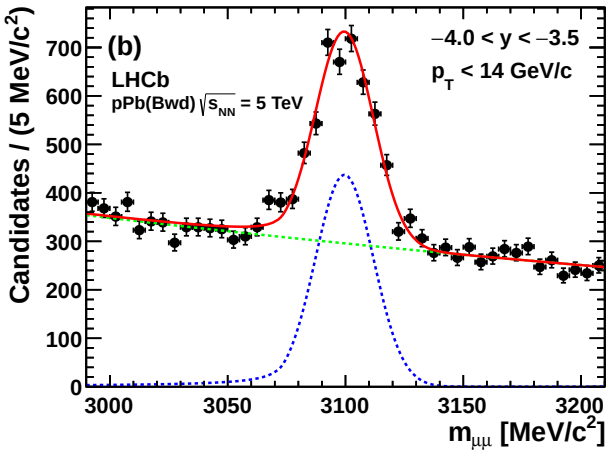
J/ψ production in pA collisions

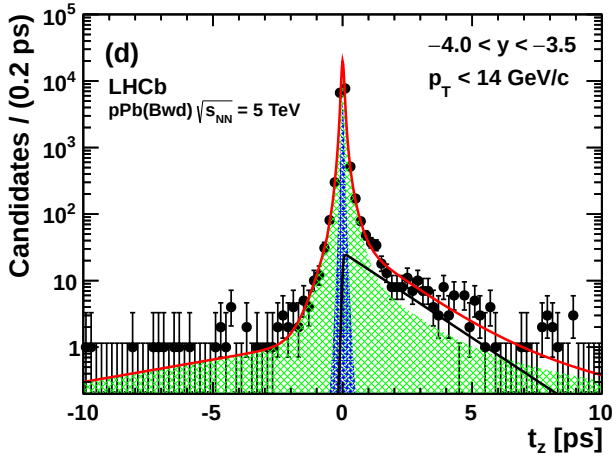
➜ *separate prompt and delayed components by a simultaneous fit of mass and pseudo-proper-time* $t_z = (z_{J/\psi} - z_{PV}) \cdot M_{J/\psi}/p_z$





pA collisions:
forward hemisphere
$2.5 < y < 3.0$
$p_T < 14\,\text{GeV}/c$



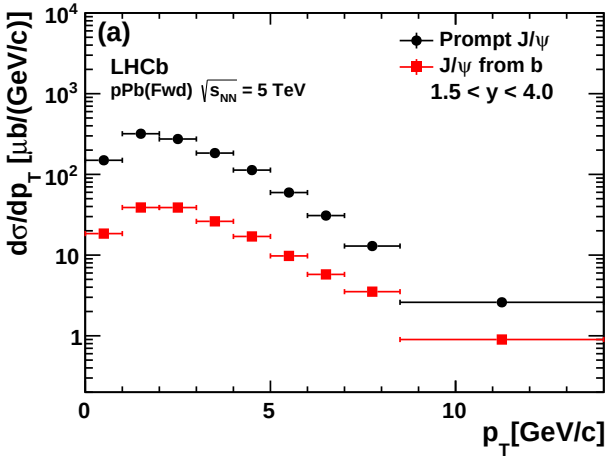


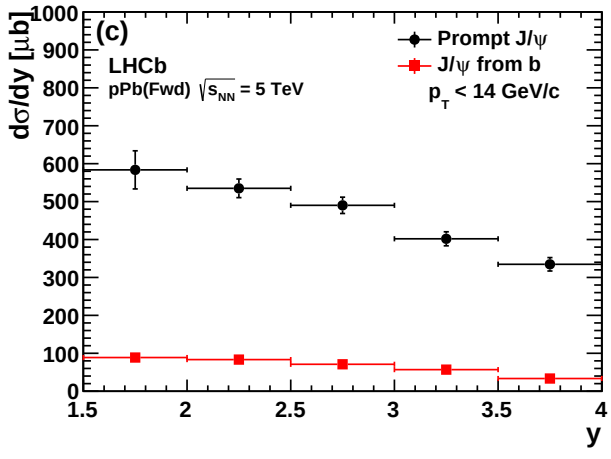
Ap collisions:
backward hemisphere
$-4.0 < y < -3.5$
$p_T < 14\,\text{GeV}/c$

JHEP02(2014)072

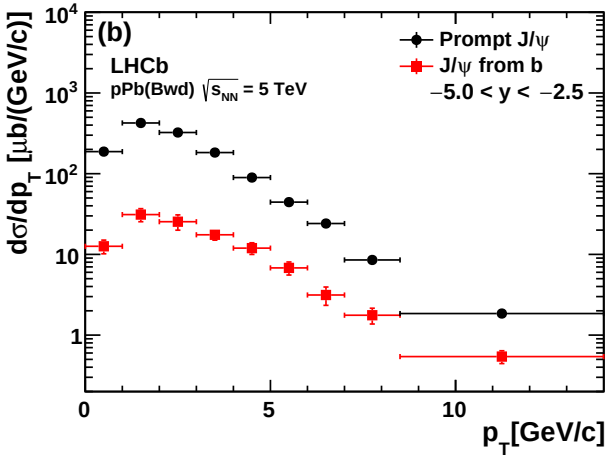
Single differential J/ψ cross-sections

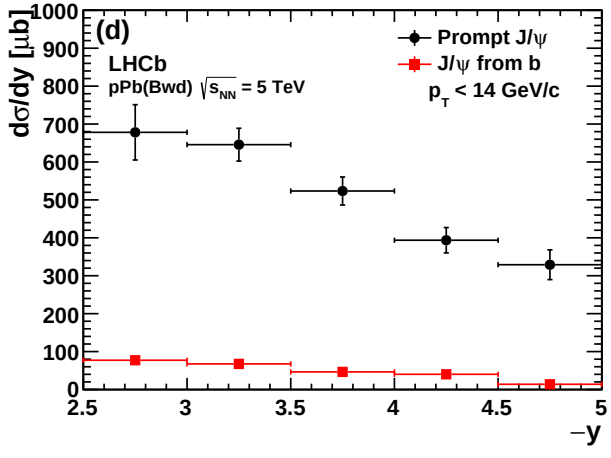
- $\sqrt{s} = 5\,\text{TeV}$, transverse momentum $0 < p_T < 14\,\text{GeV}/c$





pA collisions:
forward hemisphere
$1.5 < y < 4.0$



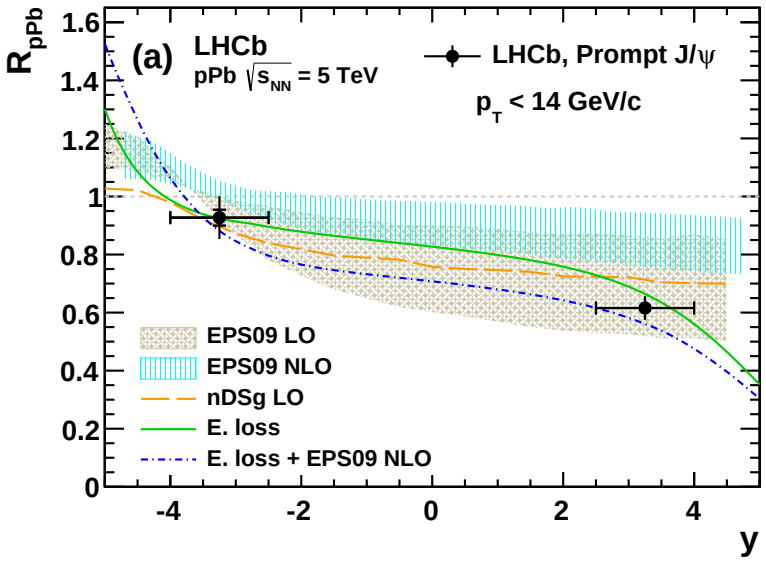


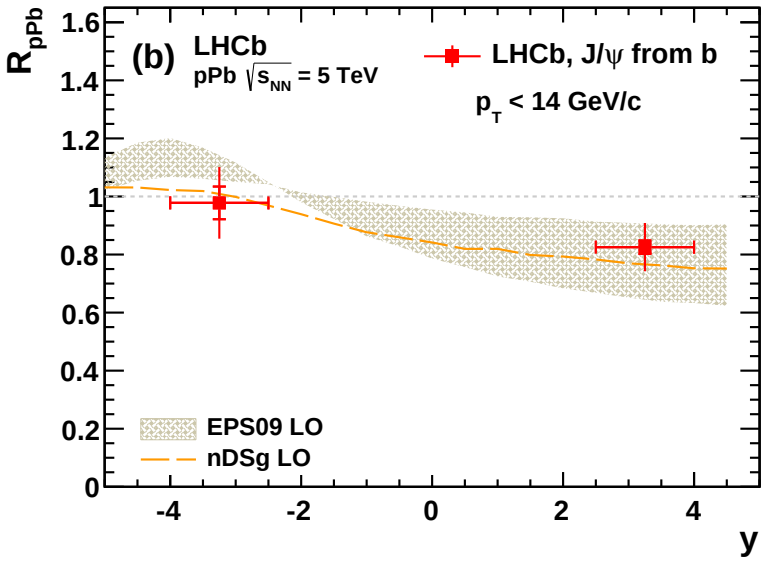
Ap collisions:
backward hemisphere
$-5.0 < y < -2.5$

JHEP02(2014)072

J/ψ results: nuclear modification factors

➜ *common range of forward and backward acceptance:* $2.5 < |y| < 4.0$



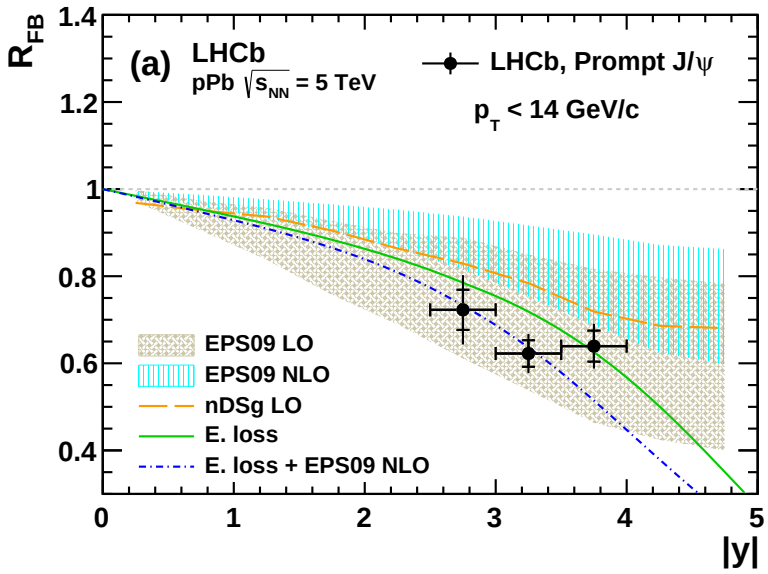


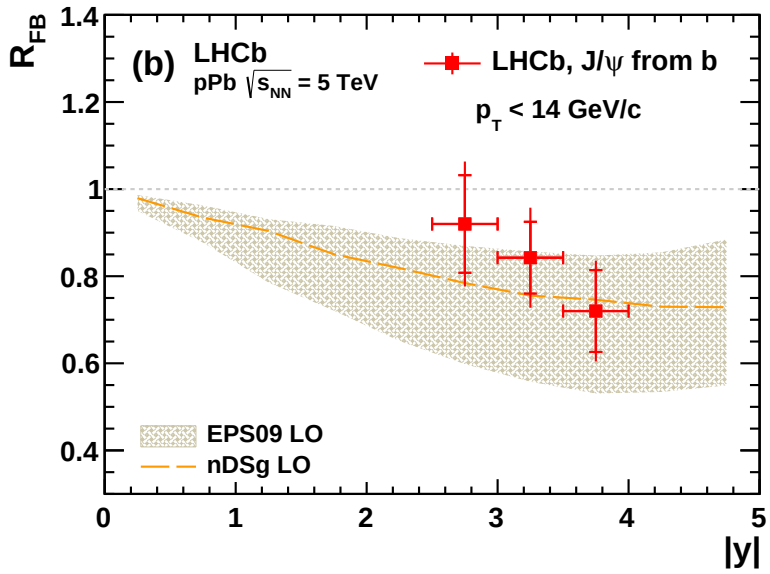
JHEP02(2014)072

- results require interpolation of pp cross-section to $\sqrt{s} = 5\,\text{TeV}$
- $R_{pPb} \neq 1$: the nucleus is not a loose collection of independent nucleons
- tighter bound B-mesons less affected than prompt J/ψ
- energy loss and shadowing are about equally important
- J/ψ data agree with "energy loss + NLO shadowing"

J/ψ results: forward-backward asymmetries

➜ *interpolated pp cross-section not required*





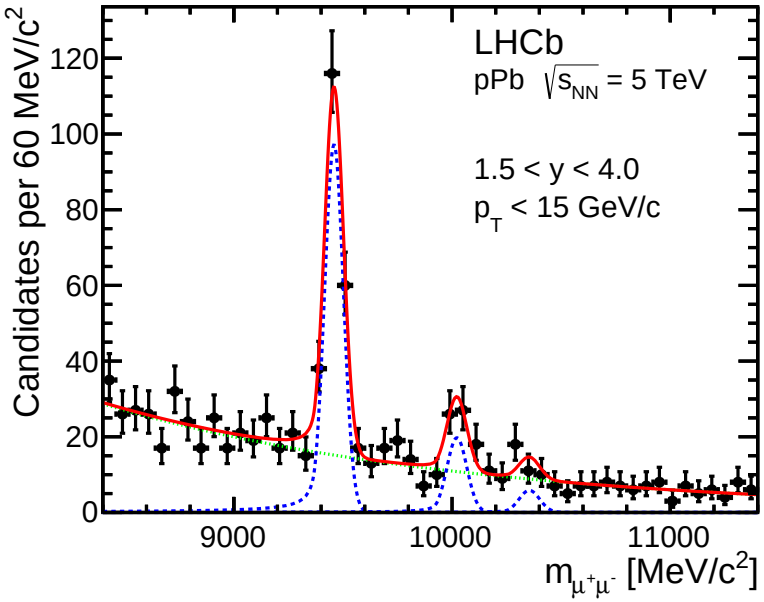
JHEP02(2014)072

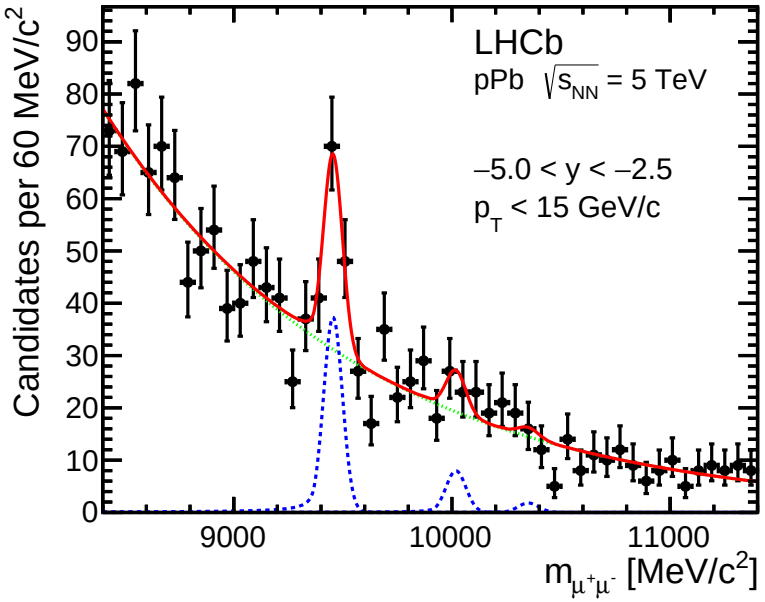
- differential measurement in $|y|$
- same observations/conclusions as for R_{pPb}

➜ study heavier systems

Upsilon production in pA collisions

➜ *statistics limited measurement*





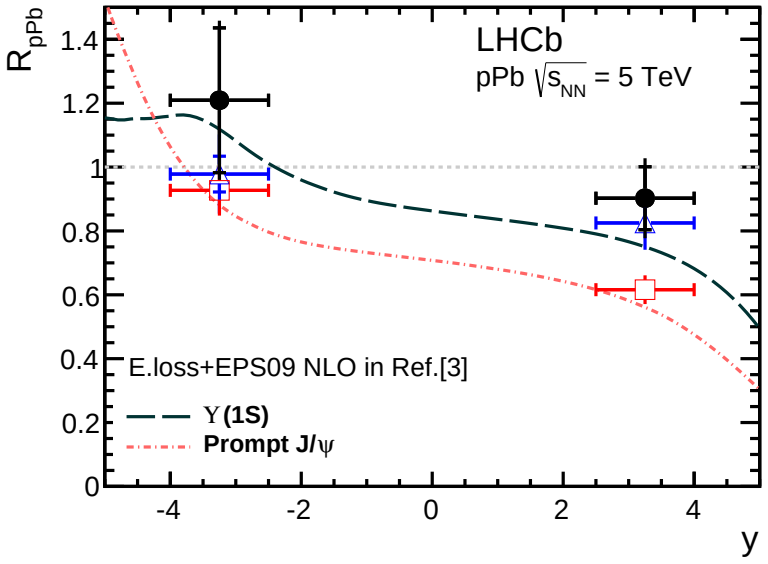
JHEP07(2014)094

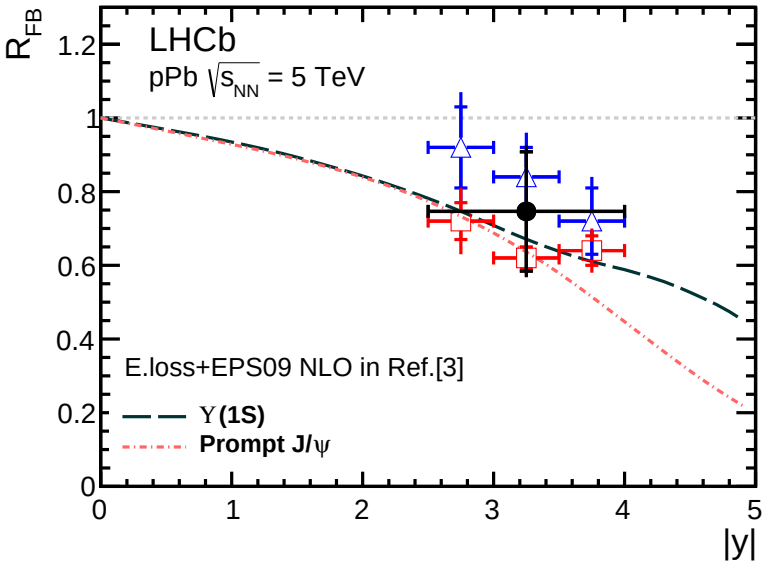
- no differential measurements possible
- kinematic range: $p_T < 15\,\text{GeV}/c$, $1.5 < y < 4.0$ and $-5.0 < y < -2.5$
- study nuclear effects in common rapidity range $2.5 < |y| < 4.0$
- evidence for strong suppression of $\Upsilon(2S)$ and $\Upsilon(3S)$

➜ focus on $\Upsilon(1S)$

Results on Upsilon production

➜ $\Upsilon(1S)$ *nuclear modification factor and forward-backward asymmetry*



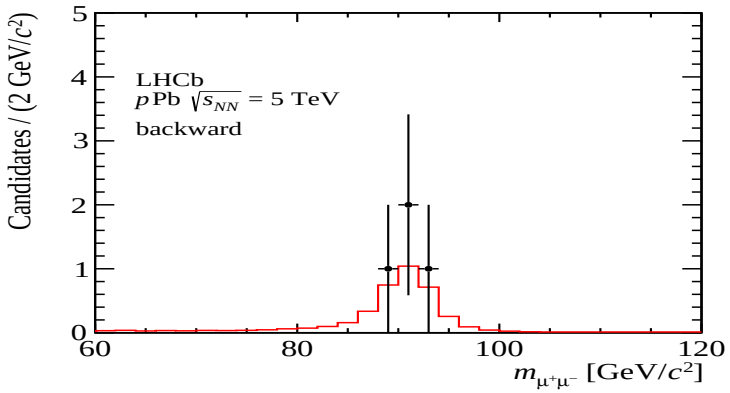


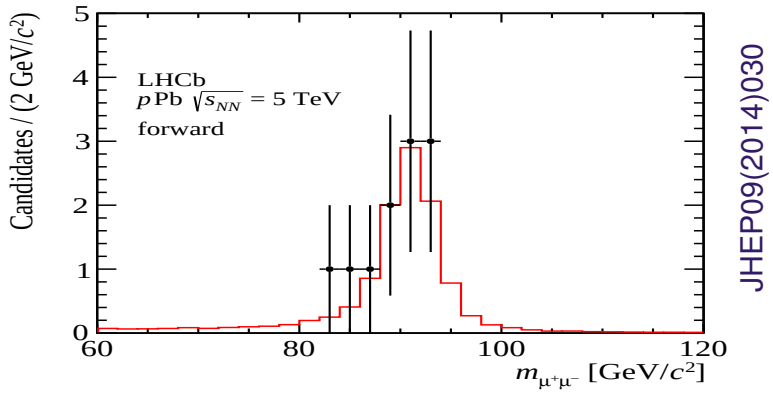
- large uncertainties
- less suppression for Upsilon than for prompt J/ψ production (red symbols)
- backward data consistent with expectations of anti-shadowing
- Upsilon consistent with J/ψ from b (blue symbols)

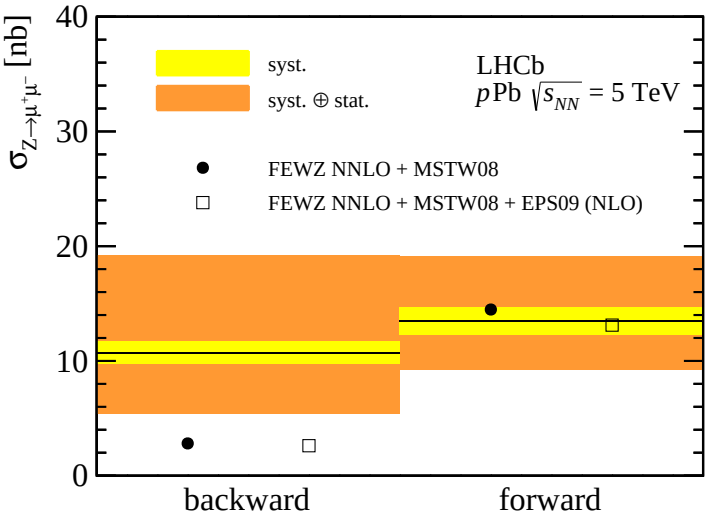
❖ more data needed for firm conclusions

Z production in pA collisions

➜ *clean signals: 4 backward-candidates, 11 forward-candidates*







➜ *muon selection*

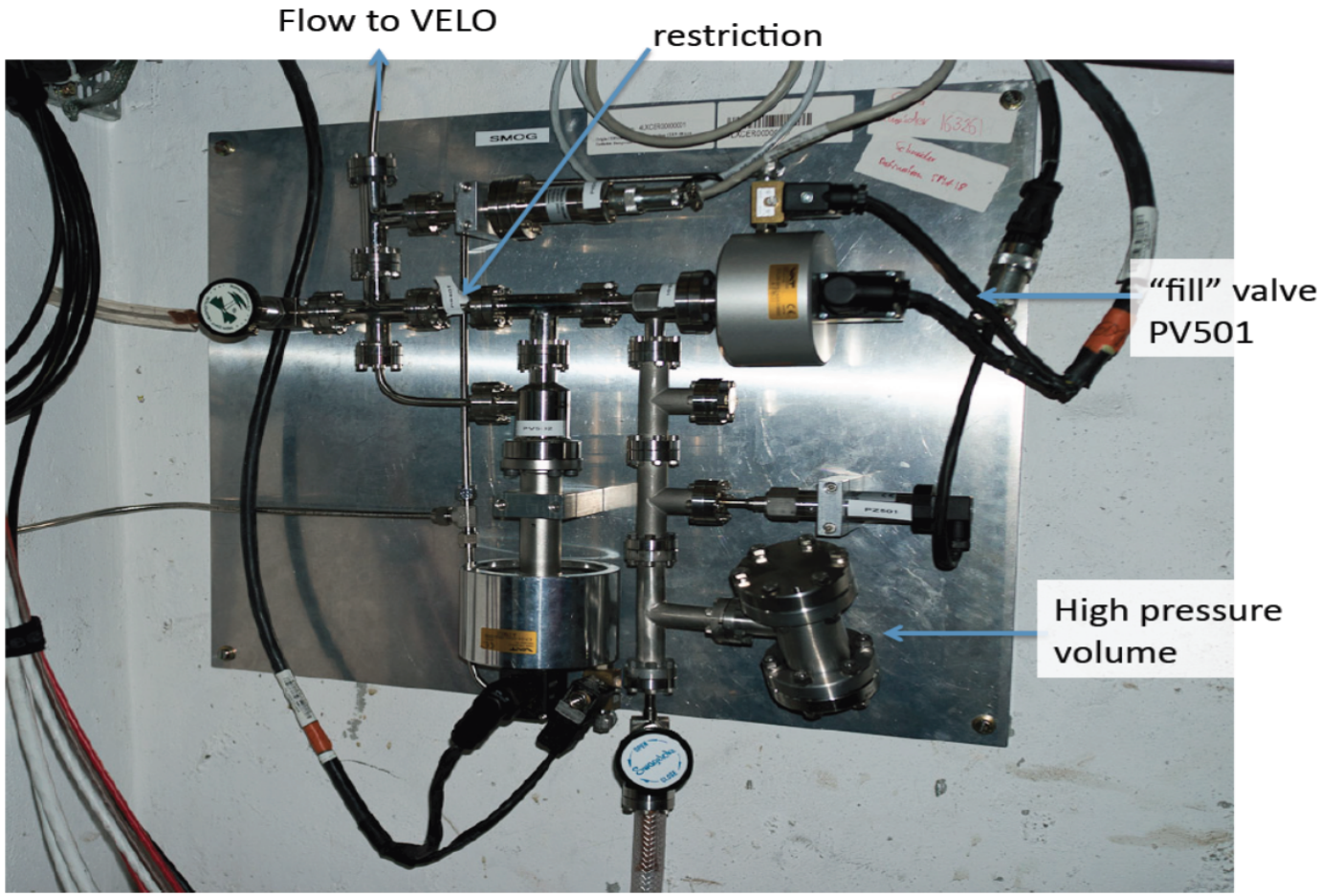
- $p_T > 20\,\text{GeV}/c$, $2.0 < \eta < 4.5$
- $60 < M(\mu^+\mu^-) < 120\,\text{GeV}/c^2$

➜ *cross-section results*

$$\sigma_{\text{fwd}} = 13.5 \pm^{5.4}_{4.0}\,(\text{stat}) \pm 1.2(\text{syst})\,\text{nb}$$

$$\sigma_{\text{bwd}} = 10.7 \pm^{8.4}_{5.1}\,(\text{stat}) \pm 1.0(\text{syst})\,\text{nb}$$

SMOG: System for Measuring Overlap with Gas

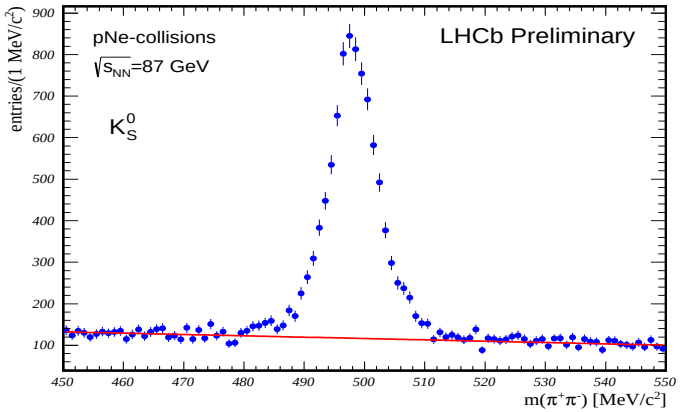


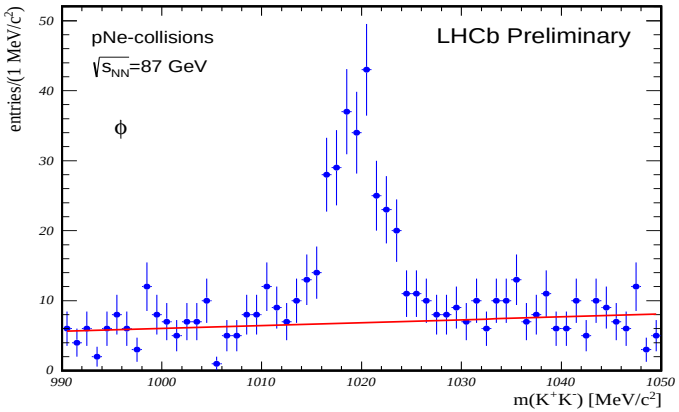
➜ injection of Ne-gas into VELO

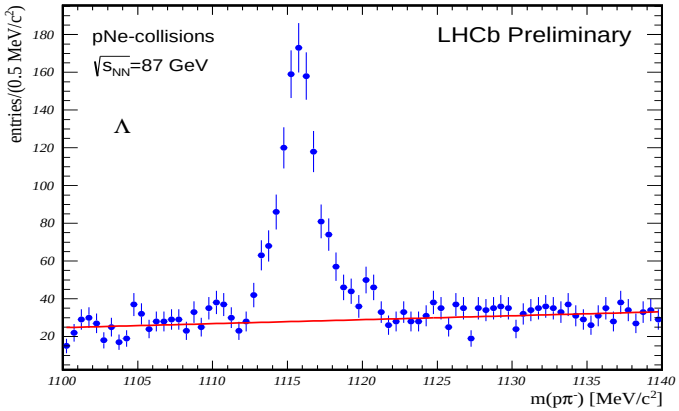
Fixed target strangeness production

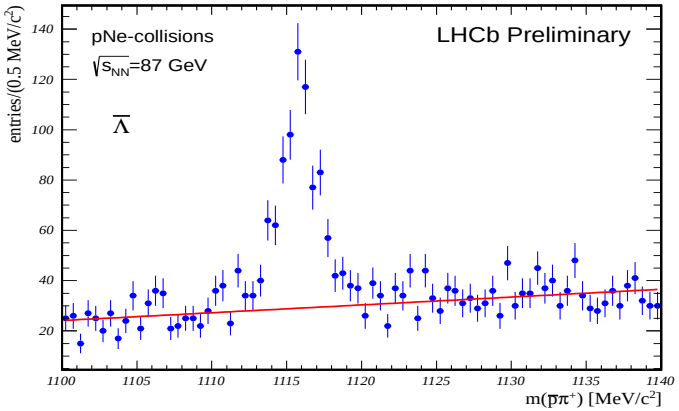
➜ *proton-Neon collisions recorded during the pA pilot run*

- $\sqrt{s_{NN}} = 87\,\text{GeV}$, boost to center-of-mass $\Delta y \approx 4.5$
- LHCb: backward direction in the nucleon-nucleon center-of-mass





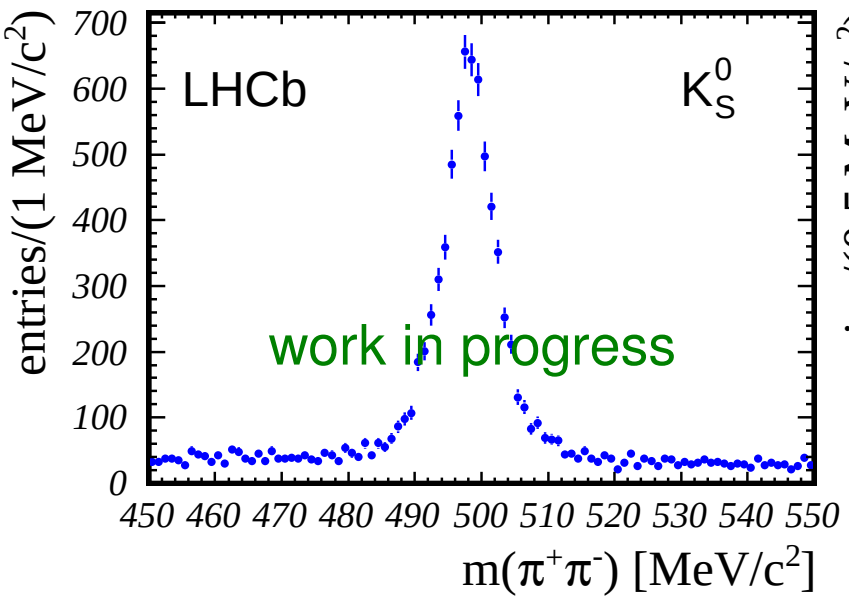


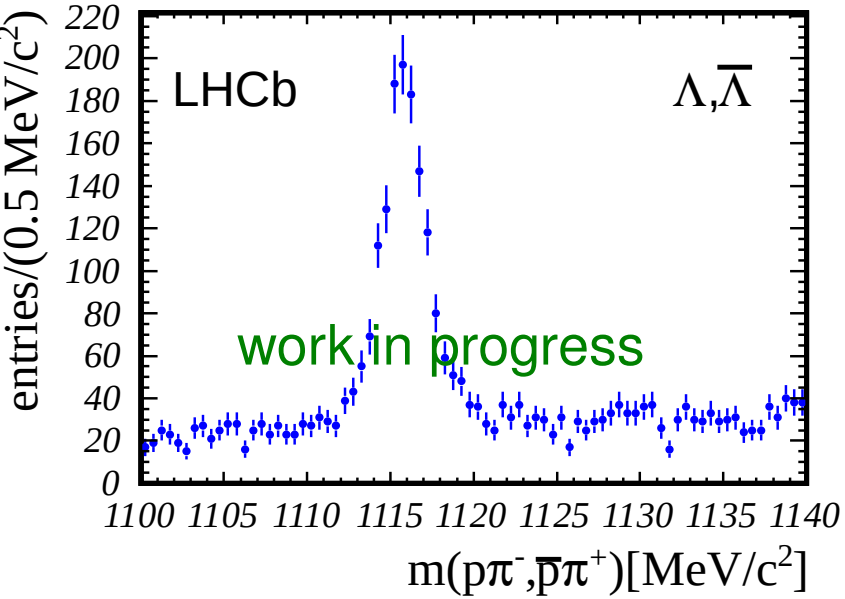


LHCb-CONF-2012-034

➜ *a first look at PbNe collisions*

PbNe-interactions - $\sqrt{s_{NN}}$=54.4 GeV





- O(1/2h) very low luminosity data taking with PbNe interactions
- plots based on 1/4 of available statistics

❖ possibility to study nuclear PDFs at large x!

LHCb Summary

➜ *rich harvest already from 1.6 nb^{-1} pA running*

- initial measurements
  - ➜ production of prompt J/ψ and J/ψ from b
  - ➜ Upsilon production
  - ➜ Z production
  - ➜ first sets of event with fixed target pNe and PbNe collisions
- current limitations
  - ➜ not enough statistics for heavy particles to allow definite conclusions
  - ➜ no pp reference data at $\sqrt{s} = 5\,\text{TeV}$
- more data in pA and pp at the same $\sqrt{s_{NN}}$ would be useful
- in the meantime focus on further analyses of existing data
  - ➜ energy flow, multiplicities, strangeness production, . . .
  - ➜ charm and beauty production cross-section
  - ➜ excited charmonium states
  - ➜ central-exclusive-production