First Look at the pA Pilot Run

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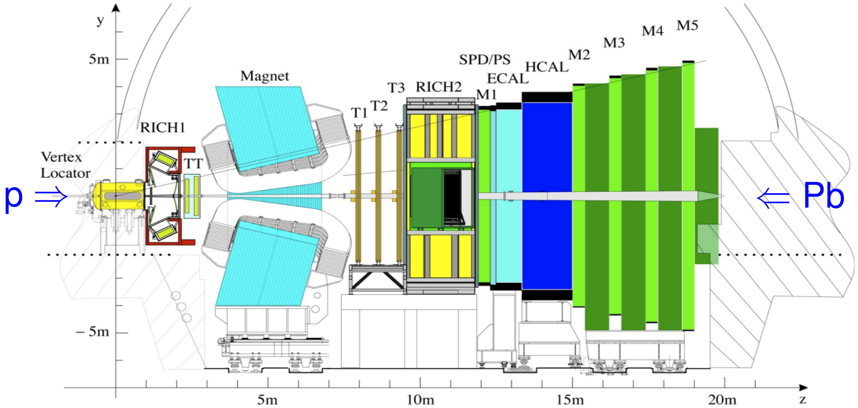
– on behalf of the LHCb Collaboration –

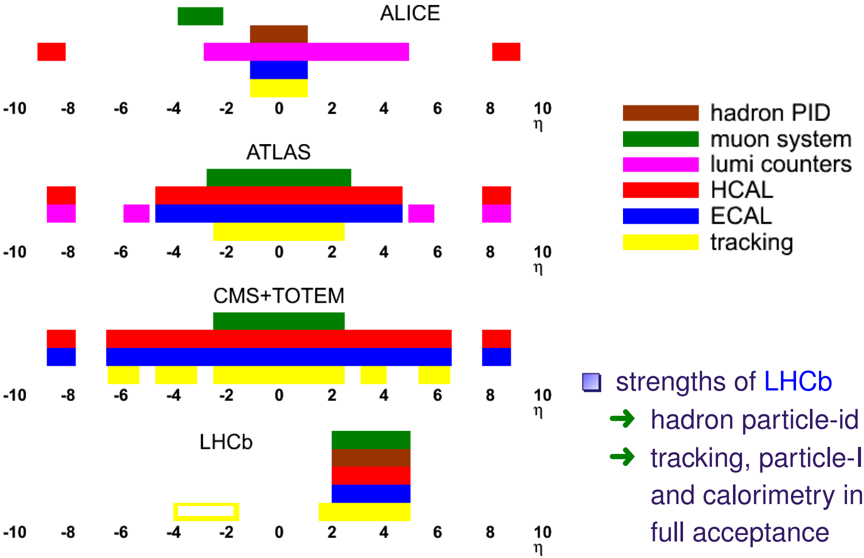
- Introduction
- Running Conditions
- Inelastic pPb Cross-Section
- Multiplicities
- Strangeness and Charm
- Summary and Outlook

1. Introduction



- forward spectrometer $15 < \Theta < 300\,\mathrm{mrad}$
- two configurations for proton-nucleus collisions: $pA \neq Ap$
- pilot run: p ⇒ (VELO) ... (MUON) ⇐ Pb

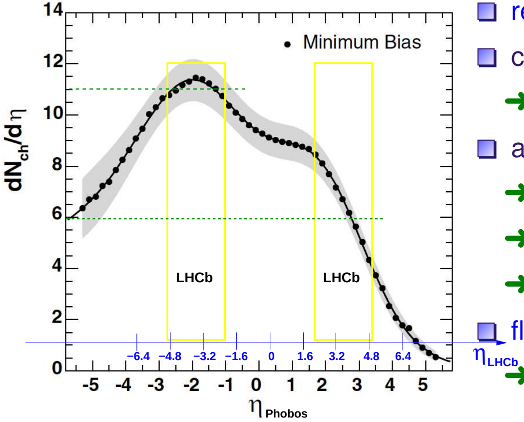
Comparison of Angular Coverage



- strengths of LHCb
  - ➜ hadron particle-id
  - ➜ tracking, particle-ID and calorimetry in full acceptance

Expected occupancies

➜ *extrapolate from d-Au measurements by RHIC/Phobos*

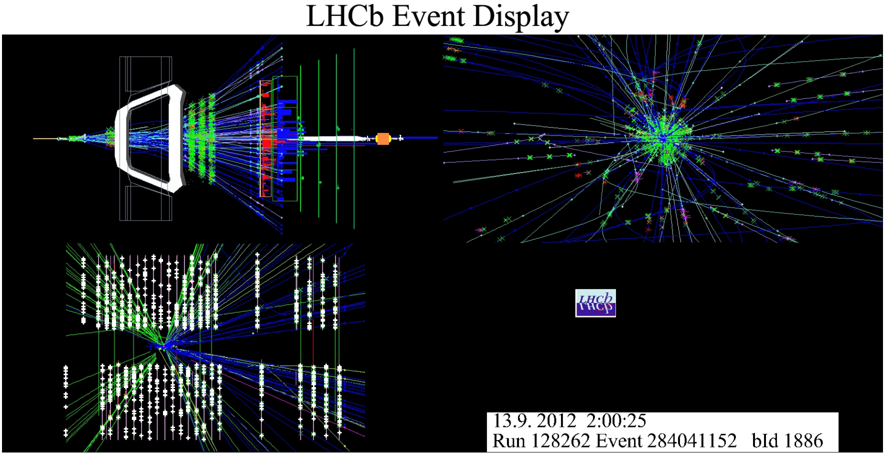


(data from PRL 93(2004)0823901)

- rescaling of rapidity range
- consider pA and Ap
  - ➜ different track densities
- average pPb occupancies
  - ➜ $\approx 3\times$ pp occupancies
  - ➜ p-side: 30% below average
  - ➜ Pb-side: 30% above average
- fluctuations: up to $3\times$ more
  - ➜ expected to be manageable

LHCb performance at high multiplicities

➜ *tracks from a pA interaction in LHCb*

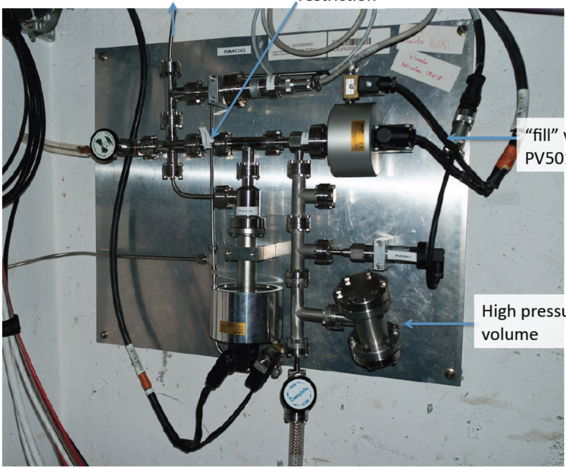


➜ what about physics?

2. Running Conditions

- standard detector operation
- dedicated high efficiency trigger scheme
  - ➜ nobias trigger on 1% of BX with beam
  - ➜ standard hardware minimum bias trigger on all BX
  - ➜ software trigger on all BX with beam to veto empty events
  - ➜ efficiency of combined trigger:
    - ✔ 99% for single track from the luminous region
    - ✔ 100% for two or more tracks
- two running conditions
  - ➜ $\sim$ 90 min running with normal background conditions
  - ➜ $\sim$ 3 h running with “SMOG” system
    - ✔ Ne-injection to measure beam-profile/luminosity (JINST 7 P01010)
    - ✔ increase beam-gas interaction rate by factor $\sim$ 100

System for Measuring Overlap with Gas



Subtraction of beam-gas background

- low luminosity pA running affected by beam-gas interactions
  - ➜ small but visible effect under normal condition
  - ➜ large effect when SMOG is active
- perform beam-gas subtraction:
  - ➜ measure observables with BX1 (beam 1 only), BX2 (beam 2 only) and BX3 (colliding beams) and calculate

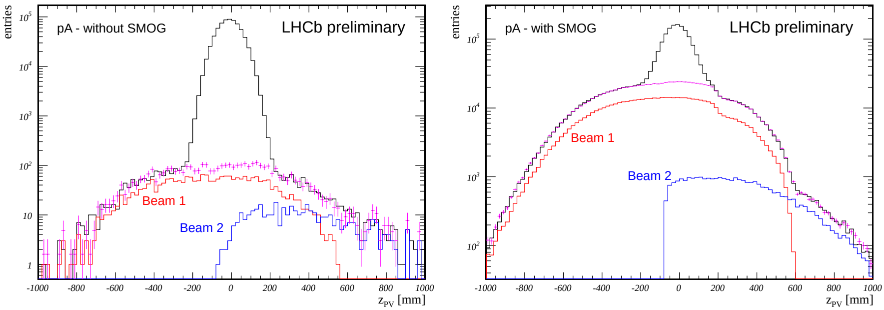
$$BX3 - a_1 BX1 - a_2 BX2 \quad \text{with} \quad a_1 = 1.606 \quad a_2 = 1.518$$

  - ➜ a_1 and a_2 from PV z-distribution for $|z| > 300\,\mathrm{mm}$
  - ➜ common determination from data w/ and w/o SMOG
  - ➜ same weights apply also for other observables

illustration of beam-gas subtraction ➜

Beam-gas subtraction for z_{PV}

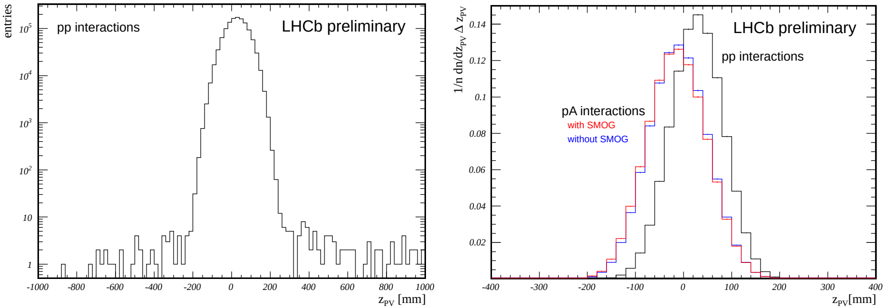
→ *primary vertex z-position: pA-interactions w/ and w/o SMOG*



- visible beam-gas contributions - well described by BX1 and BX2
- small corrections for normal running conditions
- sizeable corrections for SMOG running

Comparison of primary vertex positions

→ z-positions of primary vertices in pp and pA



- after beam-gas subtraction pA very similar with and w/o SMOG
- differences in luminous region between pA and pp
- luminous region in $|z_{PV}| < 200$ mm for pA and pp

physics →

3. Inelastic proton-lead cross-section

➜ *cross-section to be determined:*

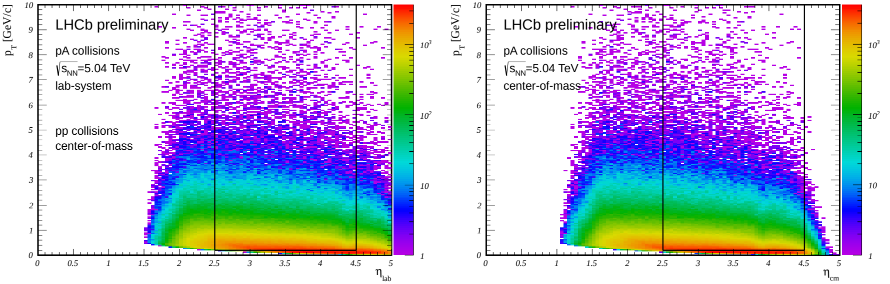
Inelastic pPb cross-section for producing at least one charged track in the pseudorapidity range $2.5 < \eta_{cm} < 4.5$ and $p_T > 0.2\,\mathrm{GeV}/c$ in the nucleon-nucleon center-of-mass system.

- count events with at least one charged track from the luminous region in the range $2.5 < \eta_{cm} < 4.5$ and $p_T > 0.2\,\mathrm{GeV}/c$
- integrated luminosity to convert event count ➜ cross-section
- analysis steps
  - ➜ beam-gas subtraction
  - ➜ correction for track finding efficiency
  - ➜ pileup is below the permille-level and is ignored
  - ➜ trigger efficiency taken as $100 \pm 1\%$
  - ➜ no impact of spurious- or multiply reconstructed tracks

details ➜

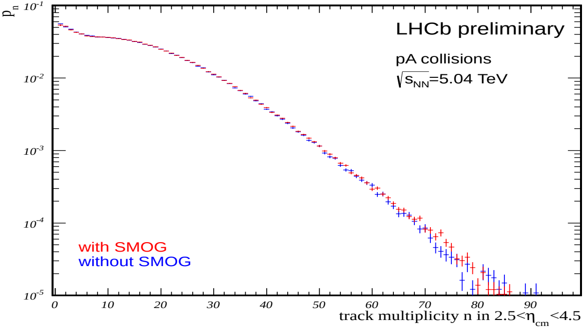
Boost to nucleon-nucleon center-of-mass

- neglect the effect of the crossing-angle
- transform pseudorapidity with assumption of pion mass
  - ➜ phase space coverage and fiducial regions



- ➜ cms-system cut applies for pA (lab-system cut would apply for pp)
- ➜ fiducial cuts stay clear of the spectrometer's momentum cutoff
  - ✘ no acceptance at small p_T and small η

➜ *raw multiplicity distribution after beam-gas subtraction*



- excellent agreement with and without SMOG
- stable event count as a function of the tracking efficiency ε
  - ➜ n-track event kept with probability $p_n = 1 - (1 - \varepsilon)^n$
  - ➜ event count efficiency estimate $\varepsilon_{ev} = 0.98 \pm 0.02$

Preliminary result

→ *raw event counts after beam-gas subtraction:*

data set	event counts	luminosity [μb^{-1}]	σ [b]
w/o SMOG	738928 ± 867	$0.3607 \pm 0.0188\%$	$2.049 \pm 0.002 \pm 0.107$
w/ SMOG	1156961 ± 2449	$0.5685 \pm 0.0296\%$	$2.035 \pm 0.007 \pm 0.106$

- larger uncertainties for SMOG data from beam-gas subtraction
- final result, taking . . .
  - → efficiency correction into account
  - → systematic errors into account
  - → the non-SMOG measurement as the nominal result

$$\sigma_{inel}(2.5 < \eta_{cm} < 4.5,\ p_T > 0.2\,\mathrm{GeV}/c) = 2.09 \pm 0.12\,\mathrm{b}$$

  - → error completely dominated by systematics
  - → systematics dominated by 5.2% luminosity error
- compare with expectation: $\sigma_{pp} \cdot A^{2/3} \sim 60\,\mathrm{mb} \times 207^{2/3} \approx 2.1\,\mathrm{b}$

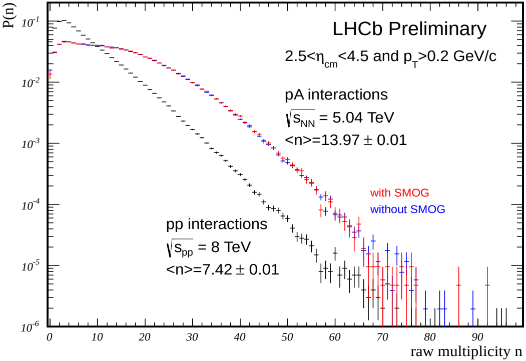
4. MULTIPLICITIES

➜ *compare uncorrected track multiplicities in pp and pA*

- prompt tracks per event in fiducial region
  - ➜ $2.5 < \eta_{cm} < 4.5$ and $p_T > 0.2\,\mathrm{GeV}/c$
- use high luminosity 8 TeV pp data recorded with a nobias trigger
- look at events with a single reconstructed PV to have same pileup
- count tracks coming from the luminous region
- note: at this point no correction for . . .
  - ➜ spurious- or multiply reconstructed tracks
  - ➜ tracks from decays and secondary interactions
  - ➜ tracking efficiencies
  - ➜ different kinematics in lab-system
  - ➜ different nucleon-nucleon center-of-mass energies
  - ➜ effect of pileup on vertex counting

Preliminary result

→ *comparison of uncorrected multiplicity distributions*



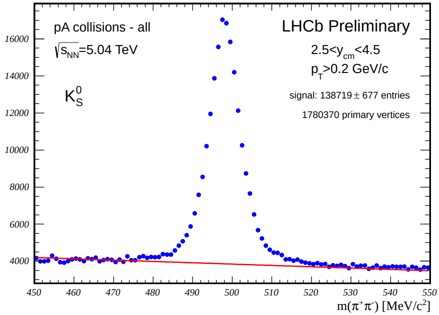
- good agreement for pA data with and without SMOG
- roughly double multiplicity in pA vs pp for same kinematic region
- expect corrections to increase pA/pp multiplicity ratio by O(10%)

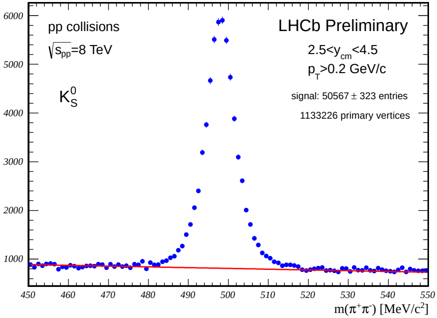
→ *peak hunting in full data sample . . .*

- search for two particle decays
  - → V^0 production - i.e. $K_S^0, \Lambda, \bar{\Lambda}$
  - → ϕ-meson production
  - → D^0 production
  - → J/ψ production
- identical analysis for pp and pA events
  - → single PV in $|z_{PV}| < 200$ mm
  - → no constraint on luminous region for tracks
  - → beam-gas subtraction
  - → geometric analysis for V^0
  - → use of RICH particle-ID for ϕ and D^0
  - → use of MUON-system for J/ψ-search
- determine signals for $2.5 < y_{cm} < 4.5$ and $p_T > 0.2$ GeV/c

K_S^0-signal

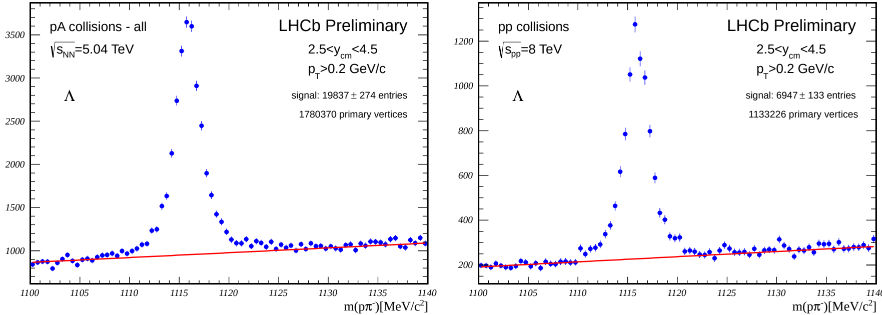
➜ *beam-gas subtracted raw signals in selected kinematical region*





- yield from excess over linear background
- $R(K_S^0) = (K_s^0$/pA-vertex)/(K_S^0/pp-vertex)$= 1.745 \pm 0.014_{\rm stat}$
- expect the corrections discussed before to increase $R(K_S^0)$ by O(7%)

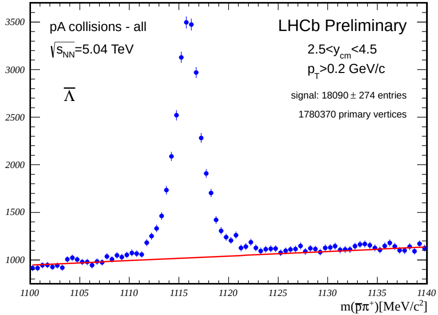
→ *beam-gas subtracted raw signals in selected kinematical region*

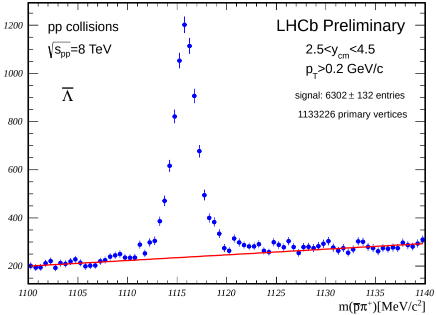


- yield from excess over linear background
- $R(\Lambda) =$ (Λ/pA-vertex)/(Λ/pp-vertex)$= 1.818 \pm 0.043_{\mathrm{stat}}$
- expect the corrections discussed before to increase $R(\Lambda)$ by O(7%)

$\bar{\Lambda}$-signal

→ *beam-gas subtracted raw signals in selected kinematical region*

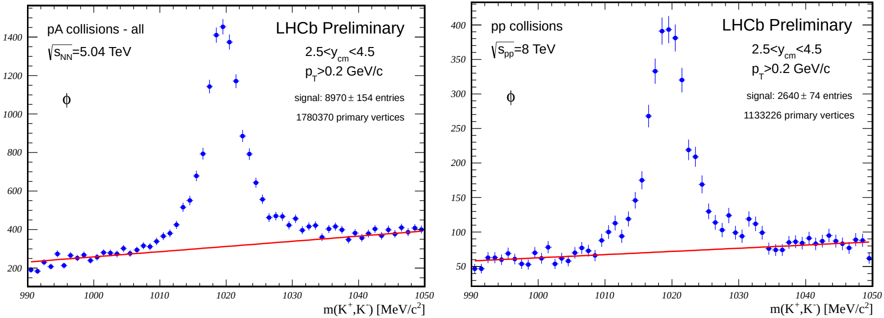




- yield from excess over linear background
- $R(\bar{\Lambda}) = (\bar{\Lambda}$/pA-vertex)/($\bar{\Lambda}$/pp-vertex)$= 1.827 \pm 0.047_{\mathtt{stat}}$
- expect the corrections discussed before to increase $R(\bar{\Lambda})$ by O(7%)

ϕ-signal

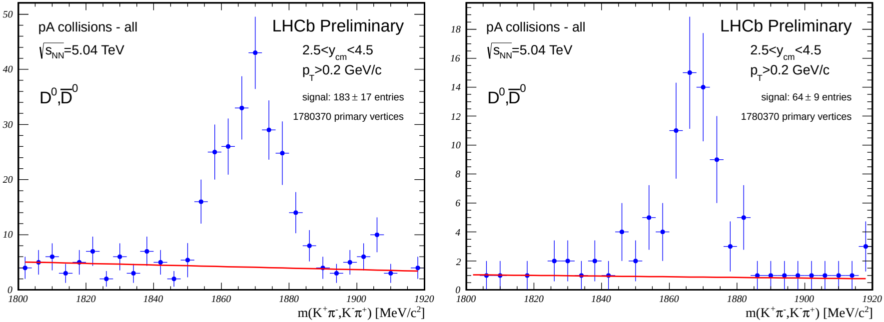
➜ *beam-gas subtracted raw signals in selected kinematical region*



- yield from excess over linear background
- $R(\phi)$ = (ϕ/pA-vertex)/(ϕ/pp-vertex)= $2.163 \pm 0.071_{stat}$
- expect the corrections discussed before to increase $R(\phi)$ by O(7%)

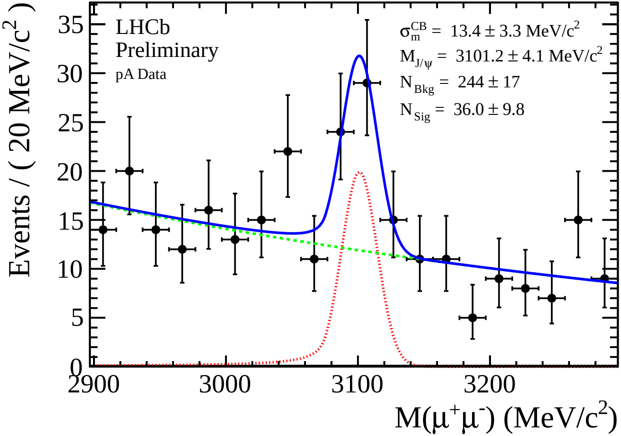
D^0-signal - sum of charge conjugate states

➜ *beam-gas subtracted raw signals in selected kinematical region*



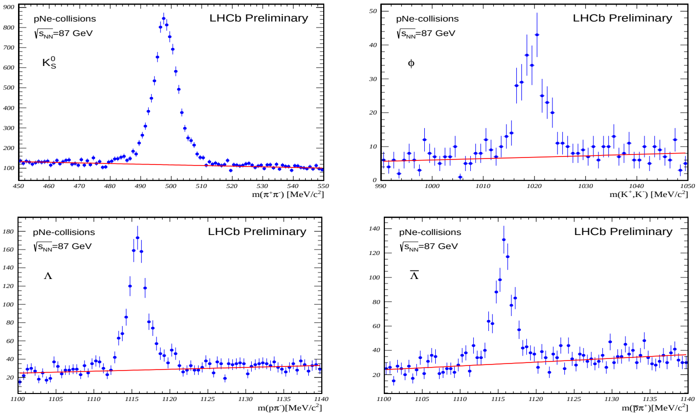
- yield from excess over linear background
- $R(D^0) = (D^0$/pA-vertex)/(D^0/pp-vertex)$= 1.820 \pm 0.307_{\mathtt{stat}}$
- expect the corrections discussed before to increase $R(D^0)$ by O(7%)

➜ *first look: close to 4σ significance*



➜ SMOG-data to study strangeness production in pNe collisions

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



6. Summary and Outlook

➜ *findings from a first look at the pA data:*

- pilot run data correspond to about $1\,\mu\mathrm{b}^{-1}$
- pA pilot run promises excellent prospects for pA physics at LHCb
- inelastic pPb cross-section measurement: $\sigma_{\mathrm{LHCb}} = 2.09 \pm 0.12\,\mathrm{b}$
- pA multiplicities in p-hemisphere about $2\times$ larger than in pp
  - ➜ both for inclusive production and for heavier short lived particles
- strangeness signals observed for K^0_S, Λ-hyperons, and ϕ-mesons
- open and hidden charm seen in D^0- and J/ψ-mesons
- expectations for the 2013 pA-run
  - ➜ 1000 times more statistics
  - ➜ pA and Ap collision
  - ➜ flip B-field to check systematics

LHCb Event Display