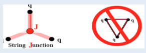
Baryon number transport at LHC energies with the ALICE experiment

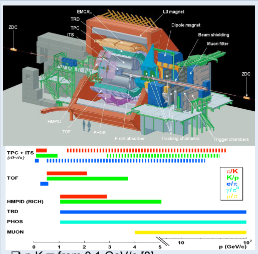
Panos Christakoglou[a,b]
for the ALICE Collaboration
[a]NIKHEF
[b]Utrecht University

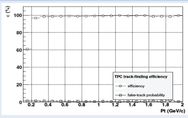
Motivation

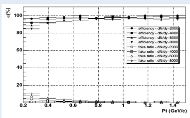
- ❑ Who is the carrier of the baryon number?
  - ○ Many theoretical approaches attempt to address this issue [1-3].
  - ○ LHC's large rapidity gap between the incoming protons (y_p = ±9.6) will give us the opportunity to distinguish between different models.
- ❑ One expects an asymmetry ~0% (~no baryon transported from the fragmentation region to the mid-rapidity).
- ❑ Within the Kopeliovich picture the baryon asymmetry is expected to be significant.
  - ○ Probability to transport BN is constant with rapidity [2].
- ❑ Veneziano's picture predicts a smaller but non-zero asymmetry as well
  - ○ Probability to transport BN is exponentially suppressed [1].
  - ❑ RHIC experiments have seen an excess of protons over antiprotons in p+p and Au+Au collisions that can be attributed to the transport of the BN from the beam [4-6].
  - ❑ The H1 Collaboration initially reported (not published) an asymmetry which is more pronounced at higher multiplicities. Recent results indicate that the Λ asymmetry is compatible with zero within errors [7].

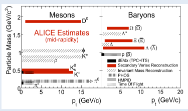


Experimental setup – PID





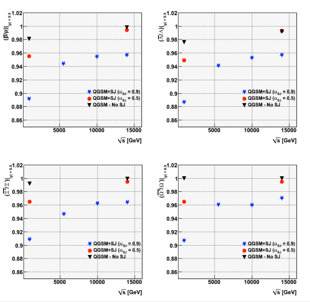




- ❑ p,K,π from 0.1 GeV/c [8]
- ❑ Topological identification (K^0, K^+, K^-, Λ): up to ~ 10 GeV/c [8]
- ❑ Leptons (e, μ), γ, π^0, h:
  - ○ electrons in TRD: p > 1 GeV/c,
  - ○ muons: p > 5 GeV/c,
  - ○ π^0 in PHOS: 1 < p < 80 GeV/c

Model predictions

- ❑ According to [10] the ratios of anti-B to B where calculated based on the QGSM approach with the inclusion of the String Junction (SJ) configuration.
- ❑ With no SJ contribution (ε = 0) results are as close to unity as possible.
- ❑ The inclusion of the SJ (ε = 0.024) with different values of the α_{SJ} (coming from a fit to experimental data), gives predictions that are below unity.



Conclusions

- ❑ An indication of the BN transfer over large rapidity gaps can be extracted from the mid-rapidity ratios of anti-baryons over baryons.
- ❑ ALICE is well equipped to measure protons, lambdas but also cascades over a large momentum range.
- ❑ A first estimate of the proton ratio can be extracted with ~100K events.
  - ○ Correction to be applied: everything that does not cancel out in the ratio (absorption & feed down)
- ❑ A first estimate of the Λ ratio can be extracted with ~300K events.
  - ○ A clean sample can be extracted by applying some basic topological cuts (DCA, pointing angle,…)
  - ❑ Difficult to extract the ratios for cascades soon! We need ~ 10M events for Ξs and 100M events for Ωs to reach 3-4 GeV/c.

Acknowledgments

Special thanks go to Helene Ricaud, Marek Chojnacki, Boris Hippolyte, Mikolaj Krzewicki and Antonin Maire for their valuable contributions.

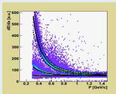
Protons

Particle Identification

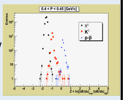
Bayesian approach
Using either fixed or momentum dependent a priori probabilities.

$$w(i|s) = \frac{r(s|i)C_i}{\sum_{k=e,\mu,\pi,\ldots} r(s|k)C_k}$$

N-σ approach
Define an N-σ area around the proton band



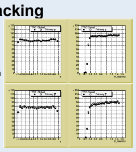
STAR approach
Based on the variable Z = ln[$(dE/dx)_{exp.}$/$(dE/dx)_{BB}$]. Using momentum bins



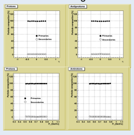
and a convolution of Gaussian fits to extract the (anti)proton yields.

Tracking

- ❑ Standalone TPC approach
  - ○ Momentum determination, vertex calculation and PID from the TPC
- ❑ Hybrid TPC approach
  - ○ Momentum determination and PID from the TPC
  - ○ Vertex calculation from the SPD
  - ○ Additional track constrain by requesting ITS clusters.
- ❑ Global tracking



Hybrid TPC approach

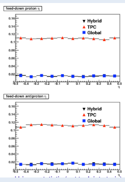


Purity: 98%
Contamination: 2%

Almost 80% of this contamination is attributed to the products of the weak decay of the Λ hyperons ➔ need for corrections!

Corrections

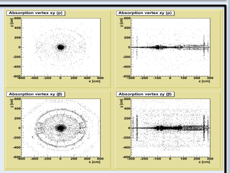
Feed-down



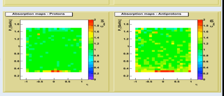
Extract the feed-down corrections by:
- ❑ Estimating the pT distributions of (mainly) Λs
- ❑ Knowing the B.R.
- ❑ Calculating the reconstruction efficiencies of secondary (anti)protons

Absorption

Production vertex of secondaries having a(n) (anti)proton as a mother

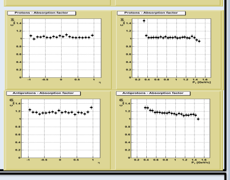


Absorption maps vs η and pT



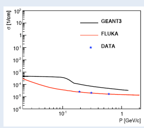
Correction factors

The correction for protons is at the level of 5% whereas the corresponding factor for the antiprotons can reach the 20% level.



Systematic Uncertainties

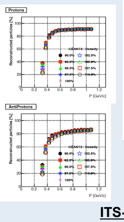
Cross section

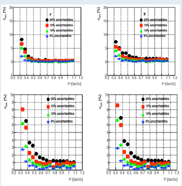


- ❑ The systematic error from this source comes from the spread of the cross section values for real data.
- ❑ By getting a maximum value of δσ=200 mb (4x the max value of data [9]) we obtain a systematic error on the yields which is σ_{syst} = 0.2%

Material budget

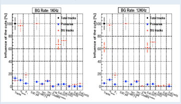
Vary the material budget between ±10% from the nominal value





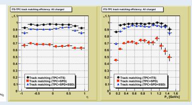
The systematic error on both the ratio and the asymmetry is below 1% for a material uncertainty of 15% (P > 0.5 GeV/c).

Beam gas events

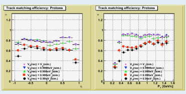


- ❑ After applying the normal track quality criteria we exclude:
  - ○ 99.9% of beam gas tracks with the ITS refit constrain
  - ○ 99% of beam gas tracks with a 3σ DCA cut.
- ❑ The (anti)protons resulting from BG events can be further reduced if we take into account the V0 detector trigger (BG rejection - not tested in this simulation)

ITS-TPC track matching



- ❑ The preferred detector configuration for these measurements is the combination TPC-SSD-SPD.
- ❑ In a realistic scenario, in addition to the residual misalignment the TPC vdrift will influence matching.
- ❑ Typically vdrift varies by ~1% from run to run



Λ Hyperons

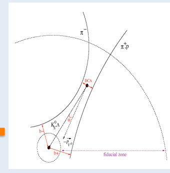
Λ^0(uds)

m = 1115.683 ± 0.006 MeV/c²

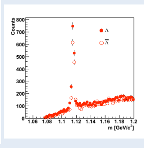
<τ> = (2.632 ± 0.020)x10^{-10} s

cτ = 7.89 cm

Λ -> $p\pi^-$ (~64 %)
-> $n\pi^0$ (~35.8 %)
-> nγ (~1.75x10^{-3} %)

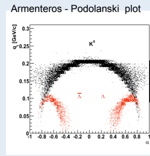


$$m_{inv} = \sqrt{(E_1+E_2)^2 - (\vec{p}_1+\vec{p}_2)^2}$$

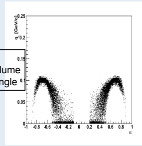


- ❑ The study of (anti)Λs can be easier than the one of the (anti)protons.
- ❑ We do not need PID information but only rely on the topology of the decay.
- ❑ By applying basic topological cuts we can select a clean (anti)Λ sample.

Armenteros - Podolanski plot

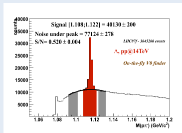


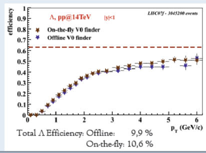
DCA
Fiducial volume
Pointing angle

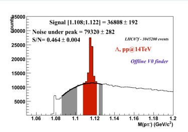


Two V^0 finders during reconstruction
- ❑ "Offline": after track finding
  - ○ Combining two tracks depending on vertex topology criteria (DCA).
- ❑ "On-the-fly": during track finding
  - ○ Checking the likelihood of having a V^0 when adding clusters to a track

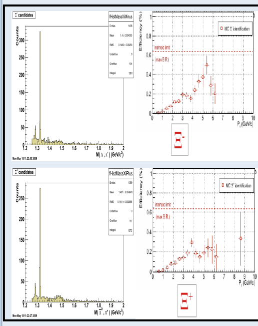
Possibility to cross-check with two different methods
- ❑ "Offline": less efficient / needs tracks for rerunning.
- ❑ "On-the-fly": more efficient but more background / needs clusters for rerunning.



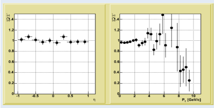




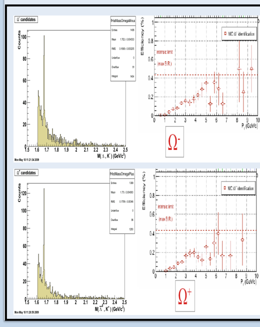
Cascades (Ξs – Ωs)



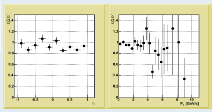
Pure MC info taking into account the B.R.



Statistics needed: ~10M events to reach ~3-4 GeV/c



Pure MC info taking into account the B.R.



Statistics needed: ~100M events to reach ~3-4 GeV/c

References

[1] G.C. Rossi, G. Veneziano, Nucl. Phys. **B123**, (1977) 507;
G.C. Rossi, G. Veneziano, Phys. Rep. **63**, (1980) 149.
[2] B.Z. Kopeliovich, B.G. Zakharov, Phys. Lett. **B211**, (1988) 221;
B.Z. Kopeliovich and B. Zakharov, Z. Phys. **C43** (1989) 241.
B.Z. Kopeliovich, B. Povh, Phys. Lett. **B446**, (1999) 321.
[3] C. Merino *et al.*, Eur.Phys.J. **C54** (2008) 577.
[4] C. Adler *et al.* [STAR Collaboration], Phys. Rev. Lett. **86**, (2001) 4778.
[5] I.G. Bearden *et al.* [BRAHMS Collaboration], Phys. Rev. Lett. **87**, (2001) 112305;
I.G. Bearden *et al.* [BRAHMS Collaboration], Phys. Rev. Lett. **90**, (2003) 102301;
I.G. Bearden *et al.* [BRAHMS Collaboration], Phys. Lett. **B607**, (2005) 42-50.
[6] B.B. Back *et al.* [PHOBOS Collaboration], Phys. Rev. **C71**, (2005) 021901.
[7] A. Falkiewicz for the H1 Collaboration, arXiv:0810.4036
[8] B. Alessandro *et al.* [ALICE Collaboration], J. Phys. **G30**, (2004) 1517;
B. Alessandro *et al.* [ALICE Collaboration], J. Phys. **G32**, (2006) 1295.
[9] G. Bendiscioli and D.Kharzeev, Riv.Nuovo Cim.**17N6**, (1994) 1.
[10] C. Merino *et al.*, arXiv:0906.2659.