Measuring anti-p XS with a fixed target magnetic spectrometer

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XSCRC2017: Cross sections for Cosmic Rays @ CERN

Introduction

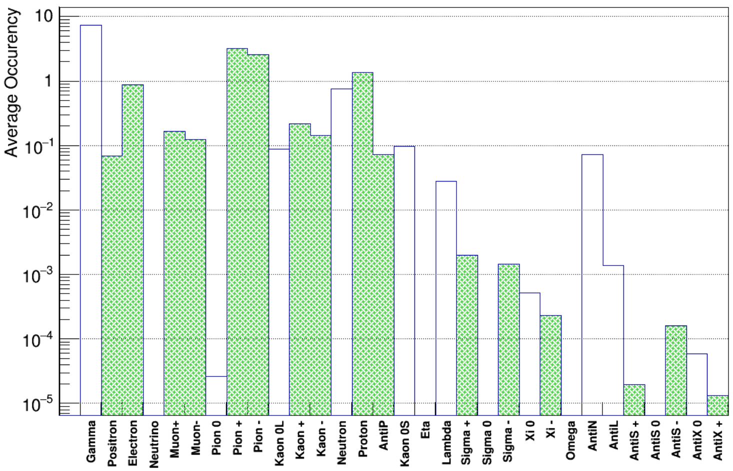
- anti-p production cross section from p-p and p-He interactions is poorly measured and cannot simply constrained from available measurements.
- an accurate prediction of the expected anti-p flux in cosmic rays in the rigidity range from few GeV to several hundreds of GeVs, is interesting to understand cosmic ray an possibly search for signals of new physics
- LHC-b collaboration reported a measurement the anti-p XS from 8 TeV p-He, and foresee a similar measurement with 4TeV protons.
- we want to investigate the possibility to perform a measurement with the SPS protons at 190 and 400 GeV on fixed LH2 and LHe targets, and a magnetic spectrometer

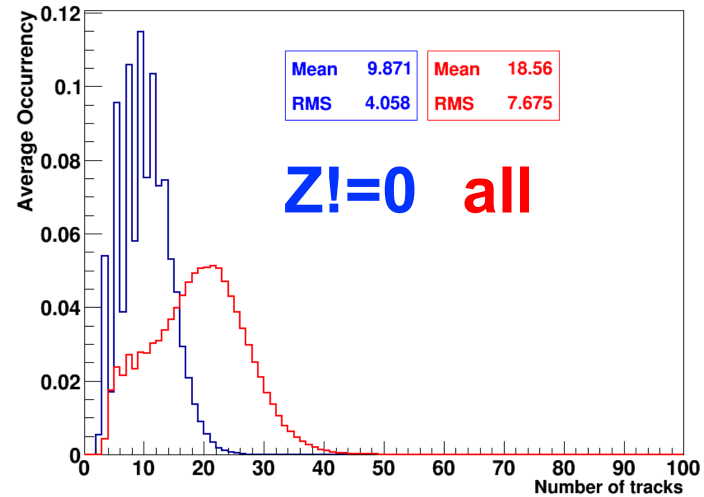
Outline

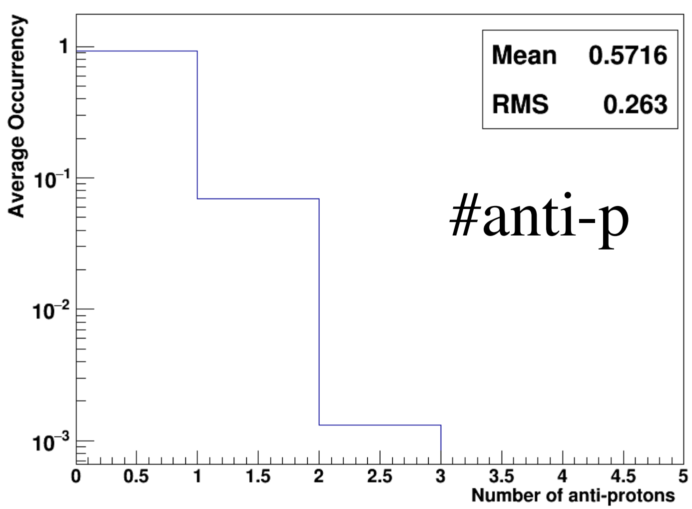
- p-p and p-He events characterization with FLUKA
- Inject FLUKA events on COMPASS simulation and reconstruction
- Study the COMPASS performance in reconstructing the events
- Discuss a possible procedure to measure a double differential anti-p production cross section
- Estimate the expected accuracy of such a measurement

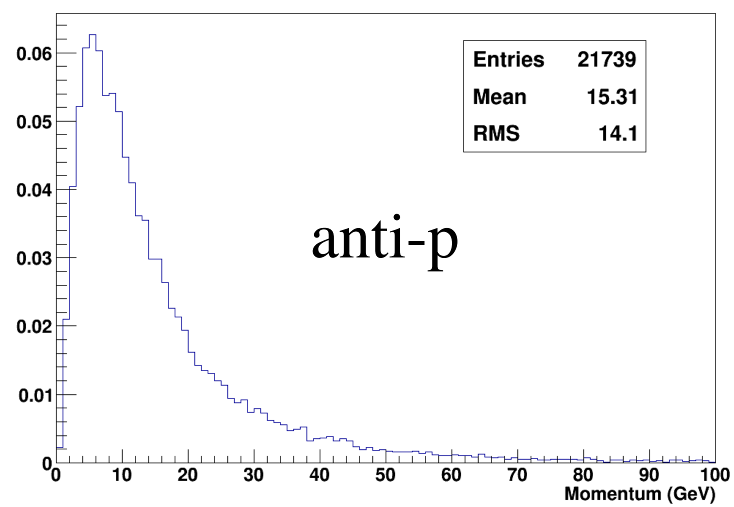
p-LH2 event features @ 190 GeV/c

3.05 10^5 interacting events



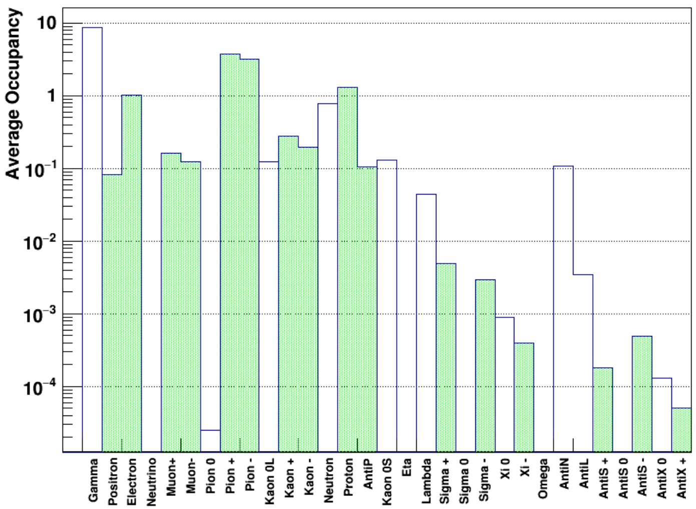


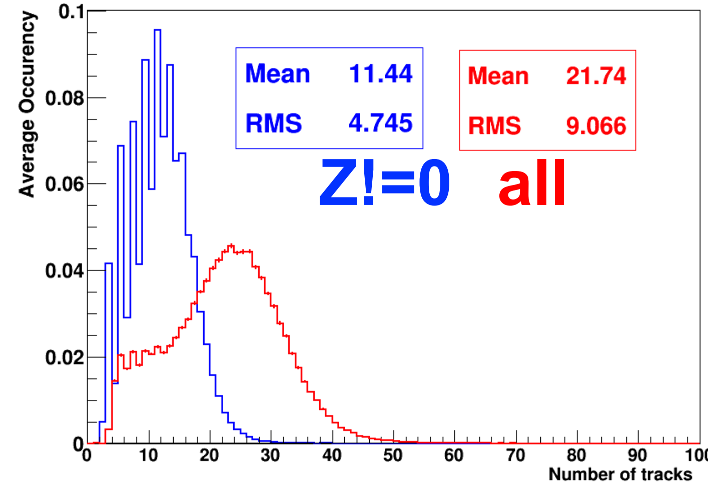


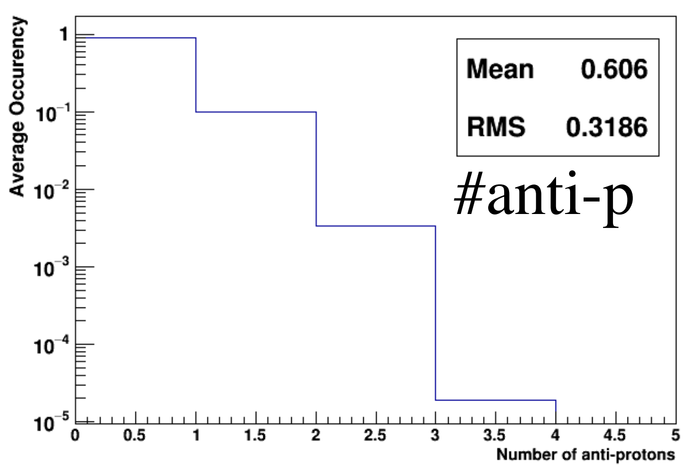


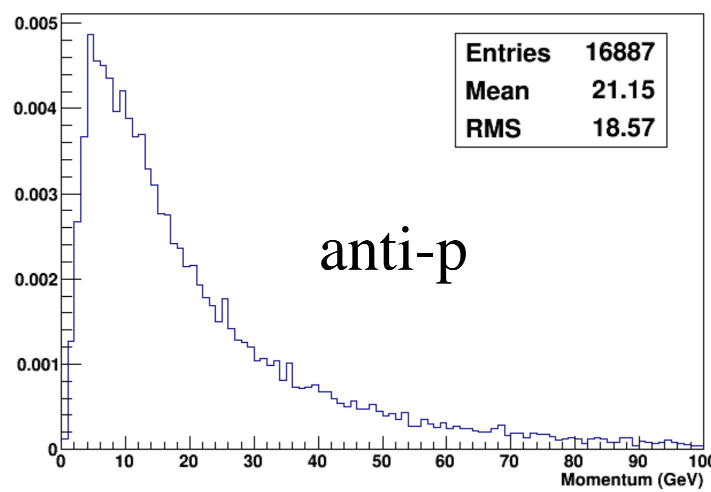
p-LH2 event features @ 400 GeV/c

1.06 10^5 interacting events



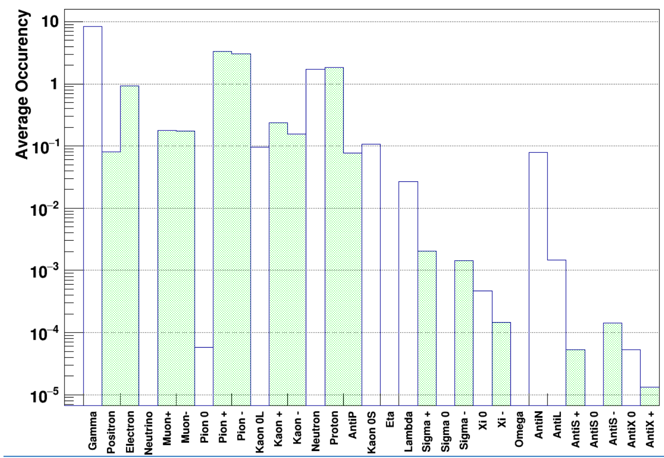


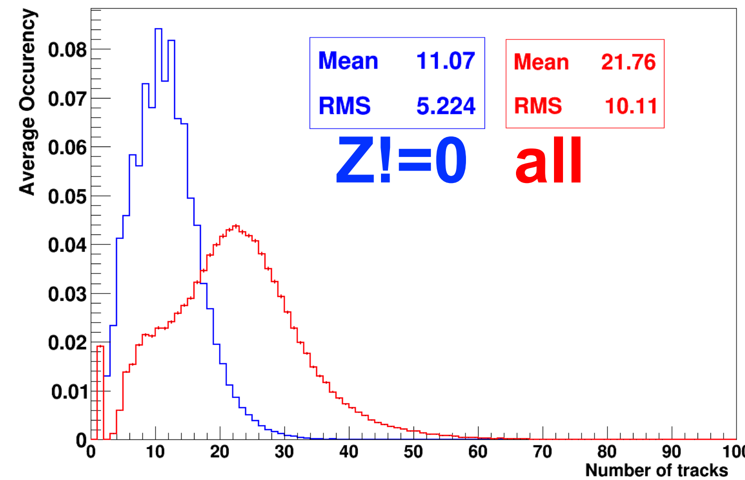


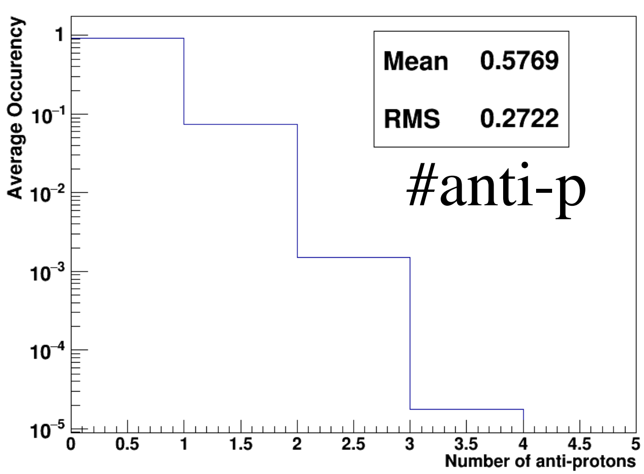


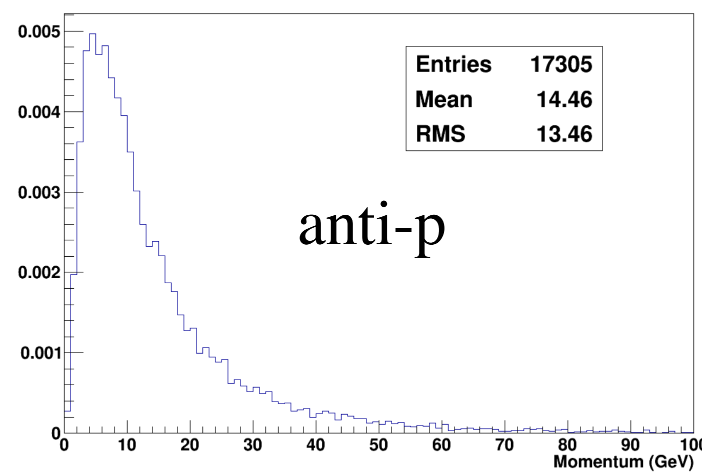
p-LHe event features @ 190 GeV/c

2.25 10^5 interacting events



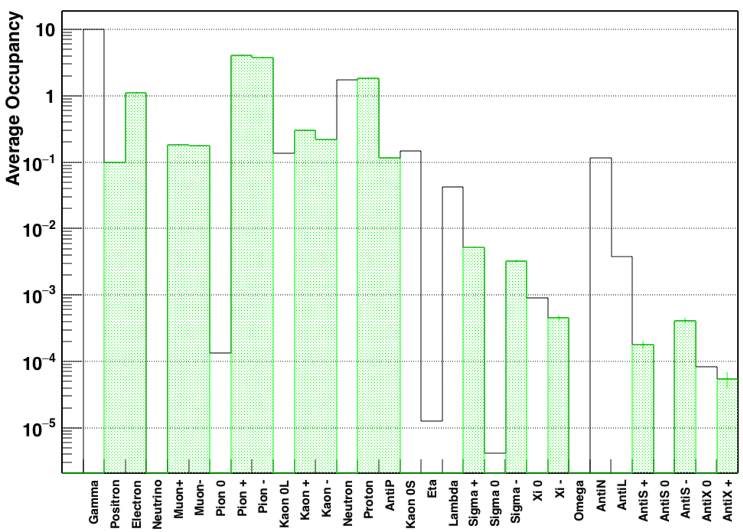


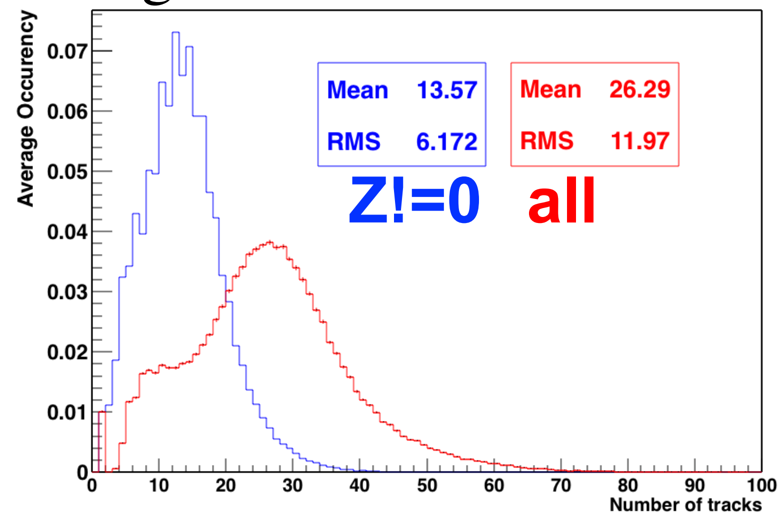


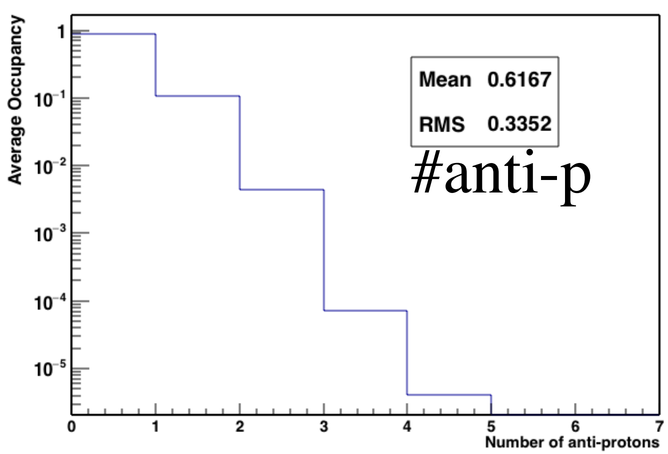


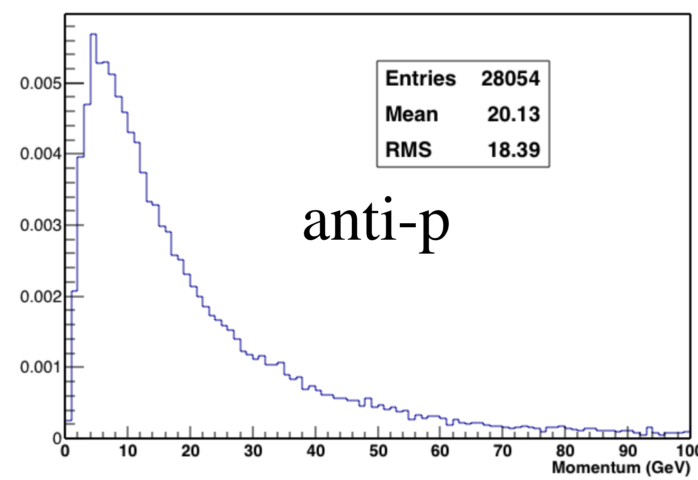
p-LHe event features @ 400 GeV/c

2.4 10^5 interacting events

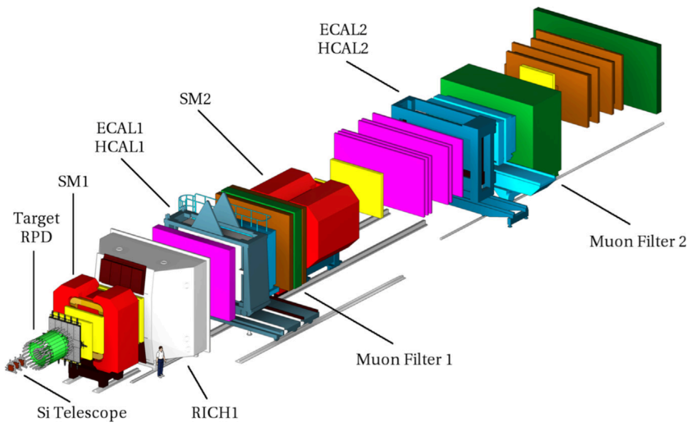


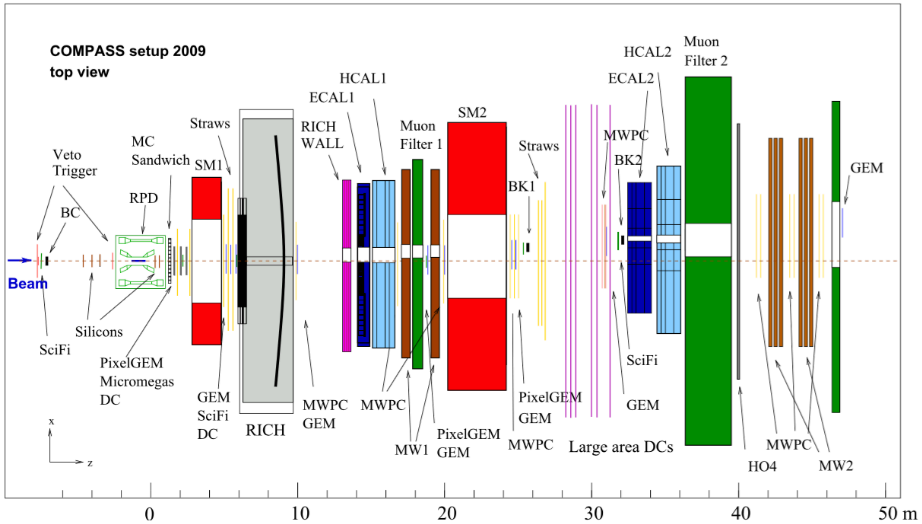






COMPASS @ CERN north area





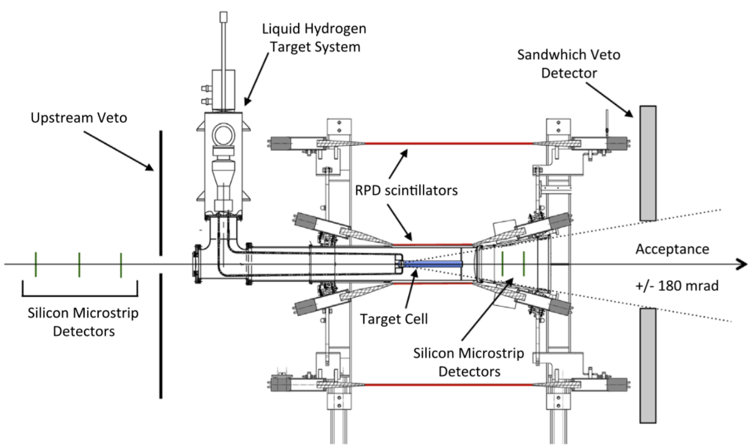


Fig. 4. Side view of the target region with the liquid hydrogen target system.

Acceptance:

+/- 180 mrad

+/- 10 deg

>2.4 η

COMPASS simulation

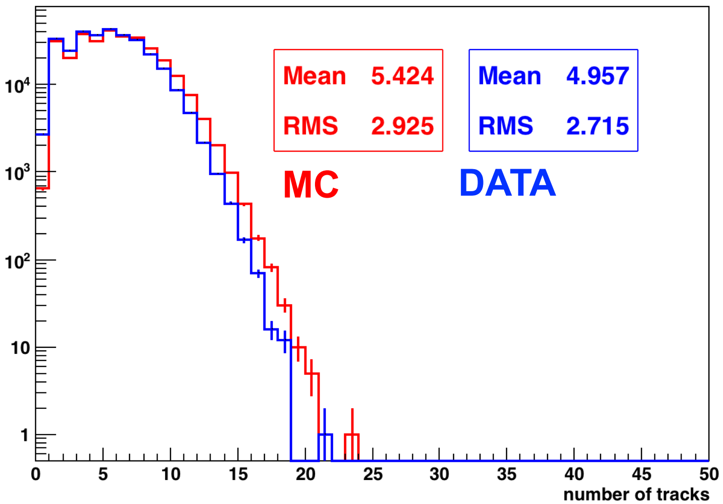
- I used the FLUKA generated interaction as input for the official COMPASS Geant 4 simulation (TGEANT)
- I then passed the produced files through the official COMPASS reconstruction software

Acknowledgements and disclaimer

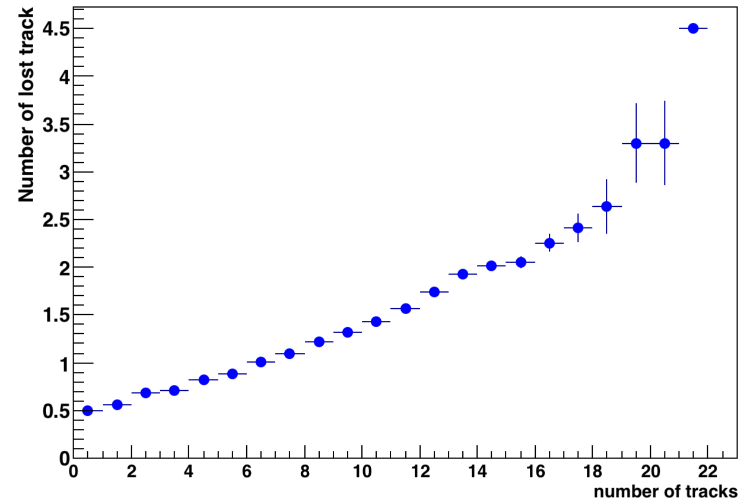
- I am not a member of COMPASS
- I thanks M. Chiosso, O. Denisov, for kindly allowing me of using COMPASS software and for the outstanding support
- I made my own minor modifications to the sw, so anything right is thanks to the COMPASS collaboration, all the mistakes are my own faults ☺

COMPASS simulation (p-p 190GeV)

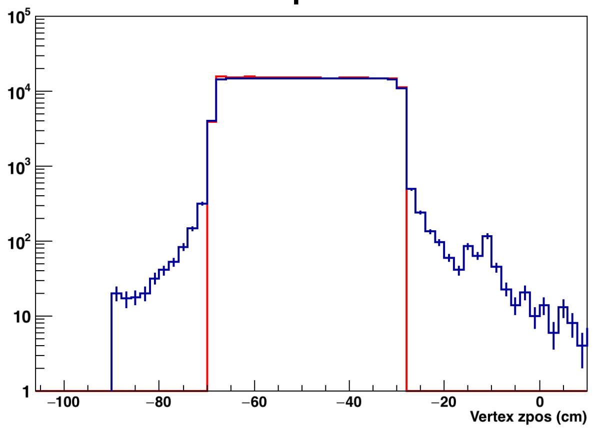
Number of tracks (θ <10 deg)



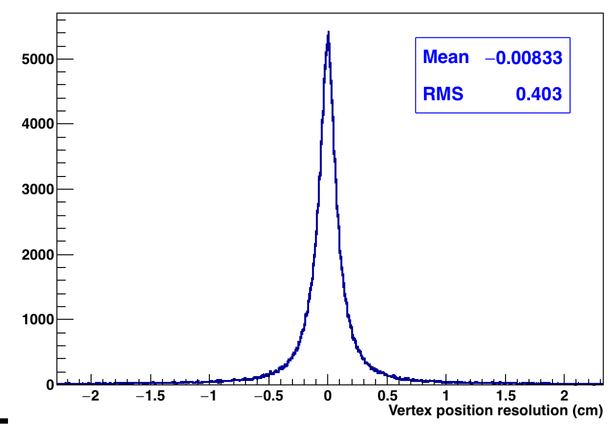
Number of lost tracks (θ <10 deg)



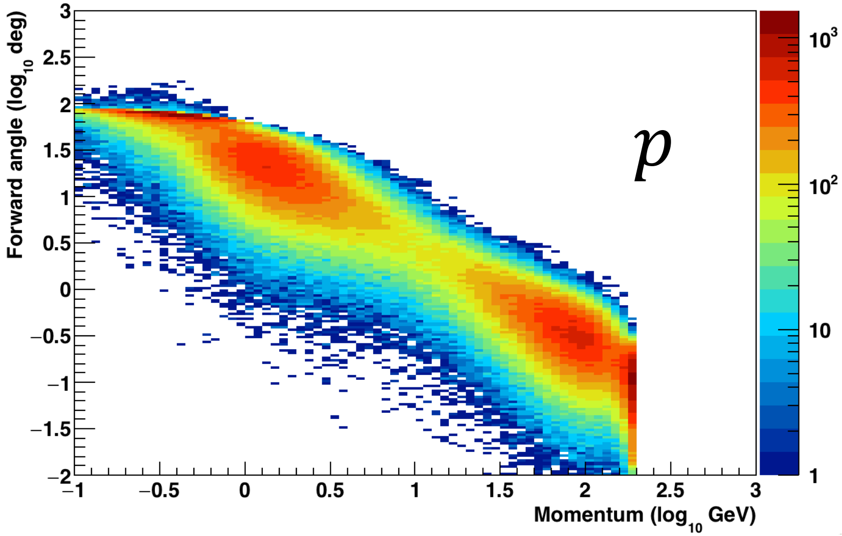
Vertex position

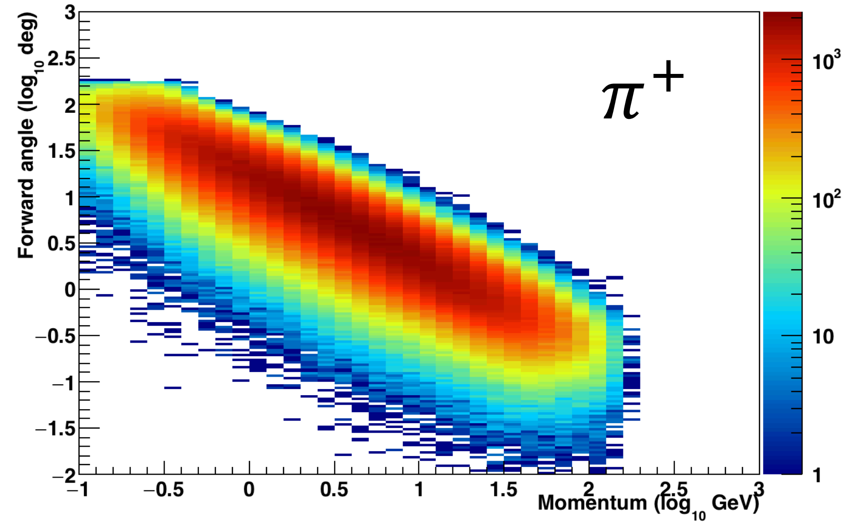


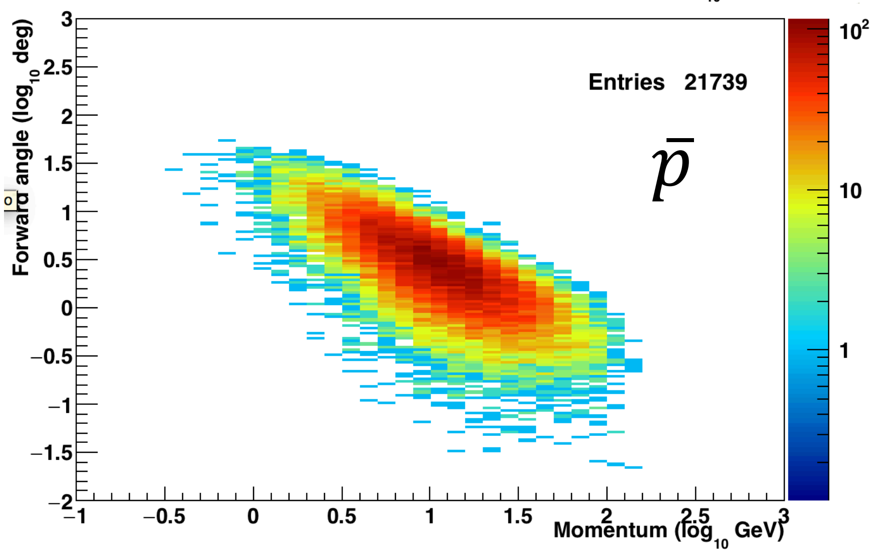
Vertex resolution

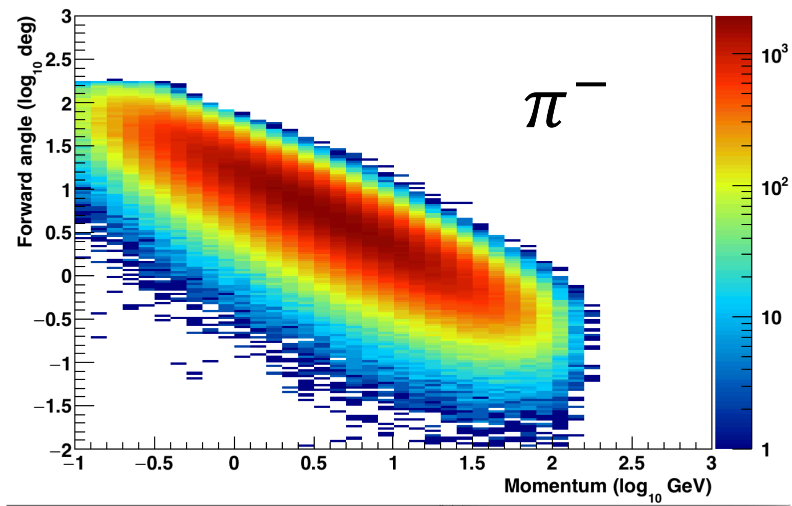


COMPASS simulation (p-p 190GeV)

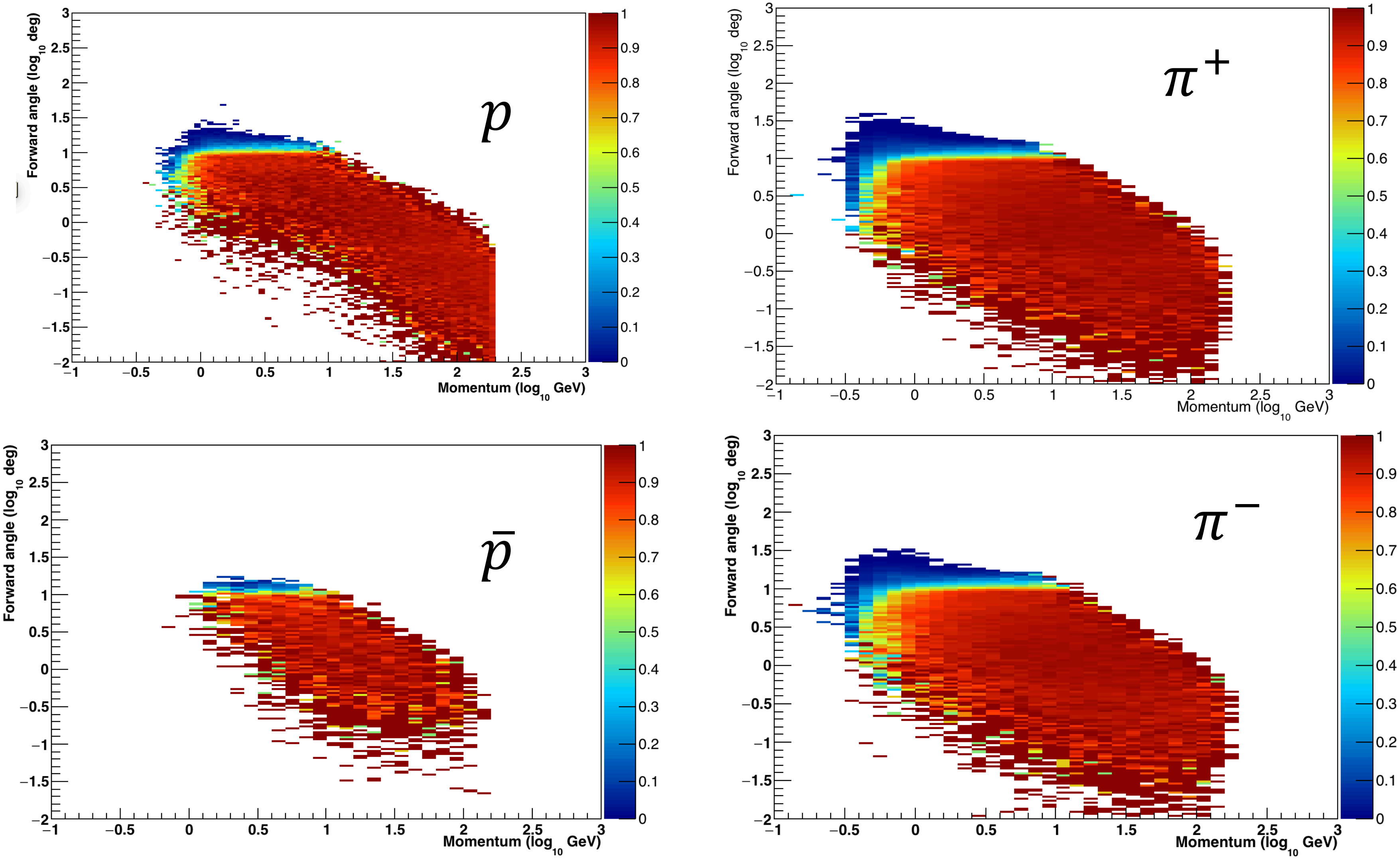








COMPASS Rec Efficiency (p-p 190GeV)



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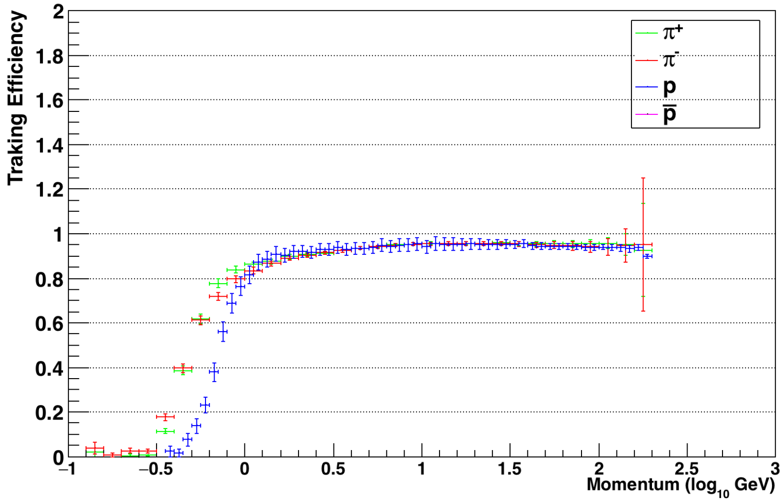
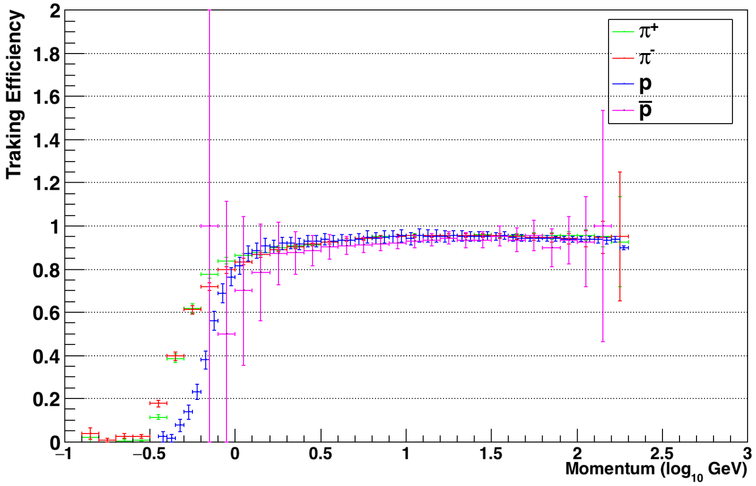
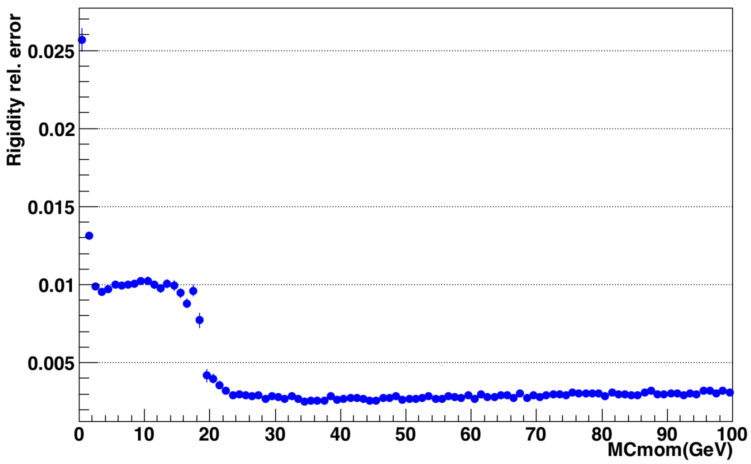
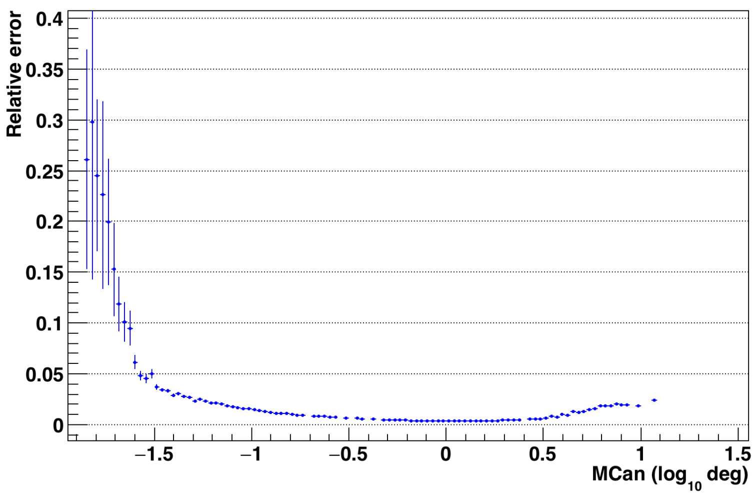
Compass Rec accuracy

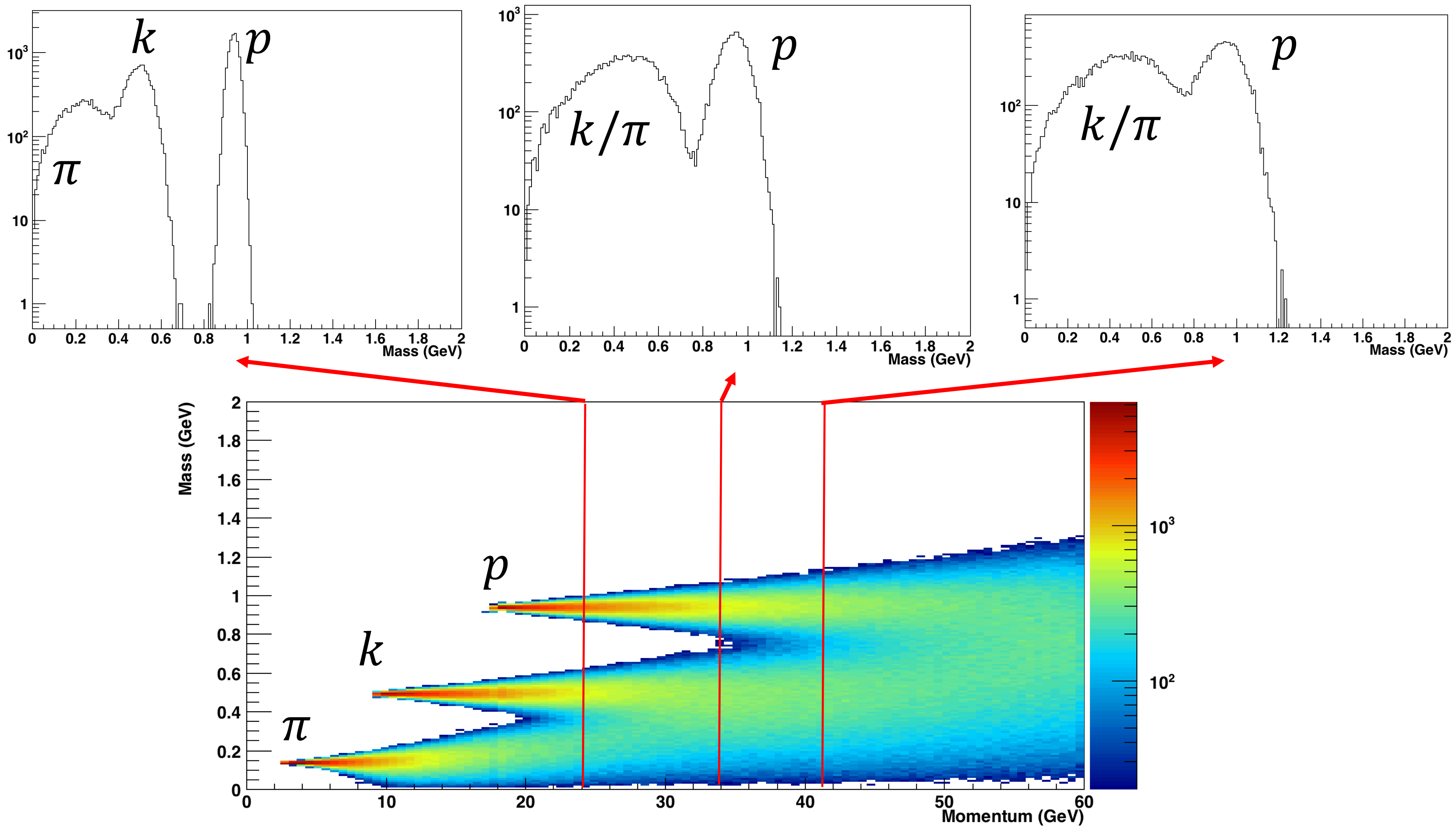






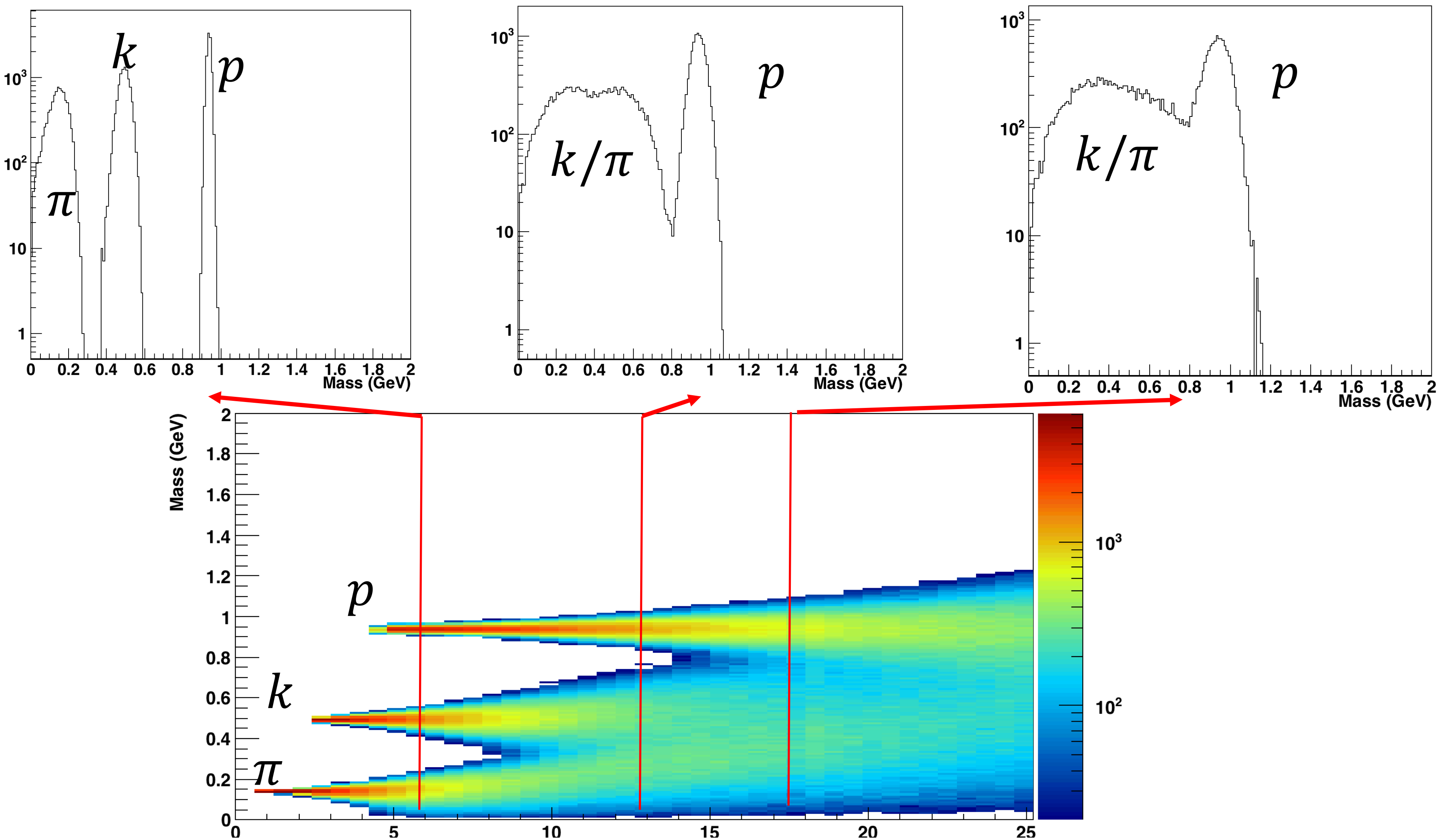


RICH1 performance ($\eta = 1.0014$)



Useful range for protons 17 to 45 GeV

(wished) RICH2 performance ($\eta = 1.02$)

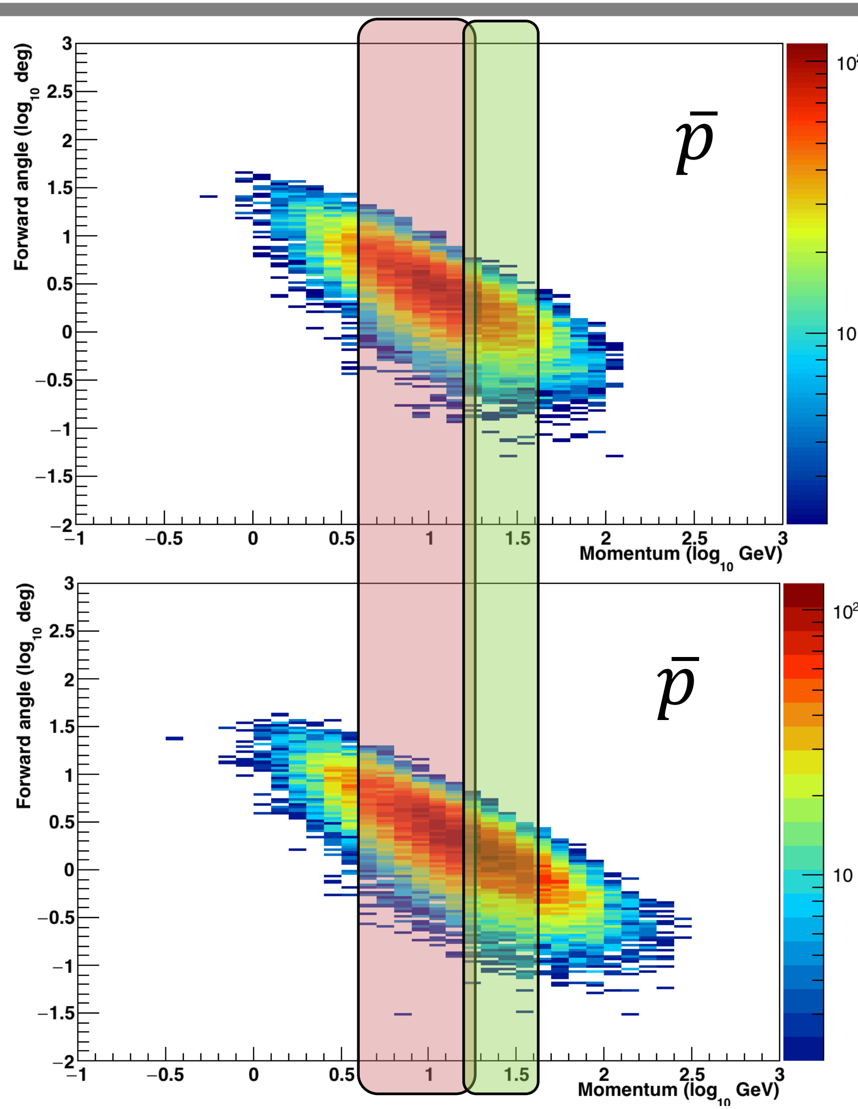


Useful range for protons 4 to 18 GeV

anti-p identification and measurement

p-p @ 190GeV

p-He @ 400GeV



RICH1

RICH2

Cross section measurement

- Strategy
  - Count all the p-p (or p-He) interaction in the target (R_i)
  - Identify events with one (or multiple) anti-p vs reconstructed momentum and angle ($R_s\ (p, \theta)$)
  - Calculate the double differential cross section as

$$\frac{d\sigma_{\overline{p}}}{dp\ d\theta} = \frac{R_s(p, \theta)}{R_i}$$

- Several possible pitfalls and sources of systematic errors!

Compass Trigger system

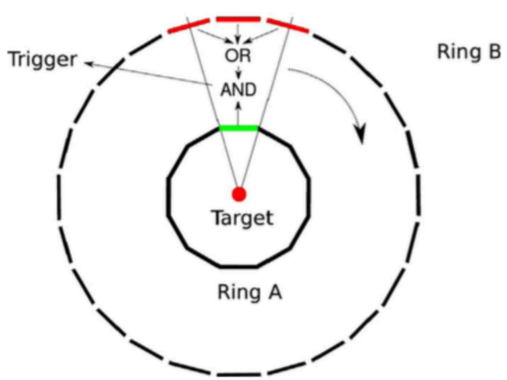


Fig. 54. Allowed combinations for target pointing in the RPD part of the proton trigger.

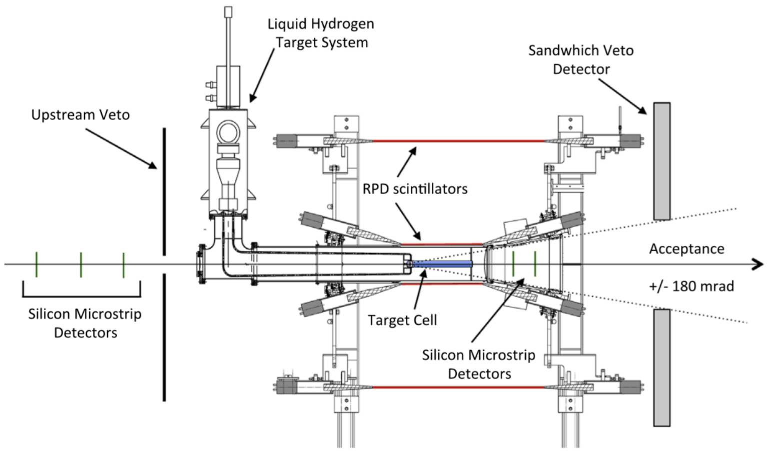


Fig. 4. Side view of the target region with the liquid hydrogen target system.

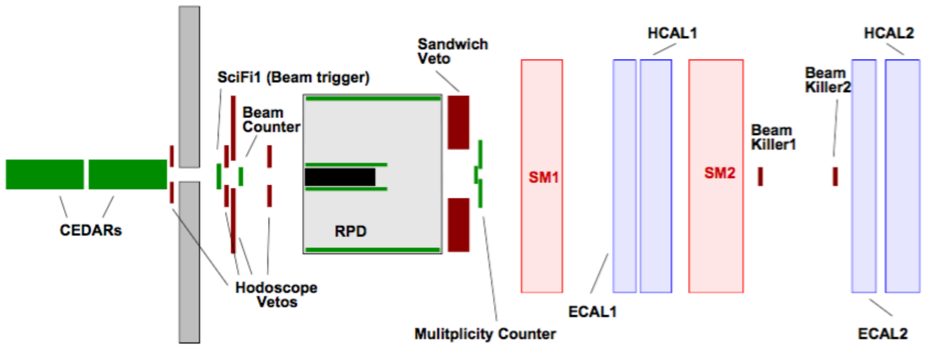


Fig. 51. Arrangement of trigger elements in the spectrometer (schematic side view, not to scale).

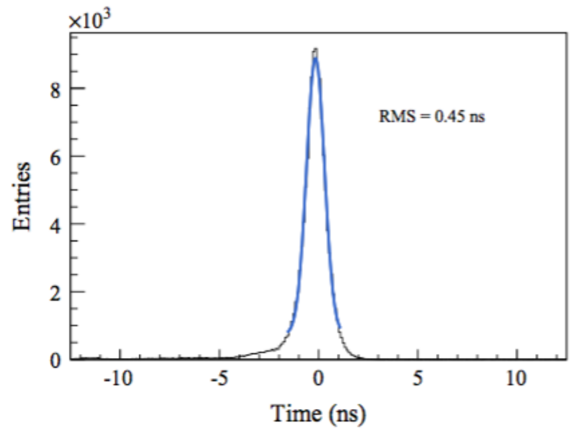
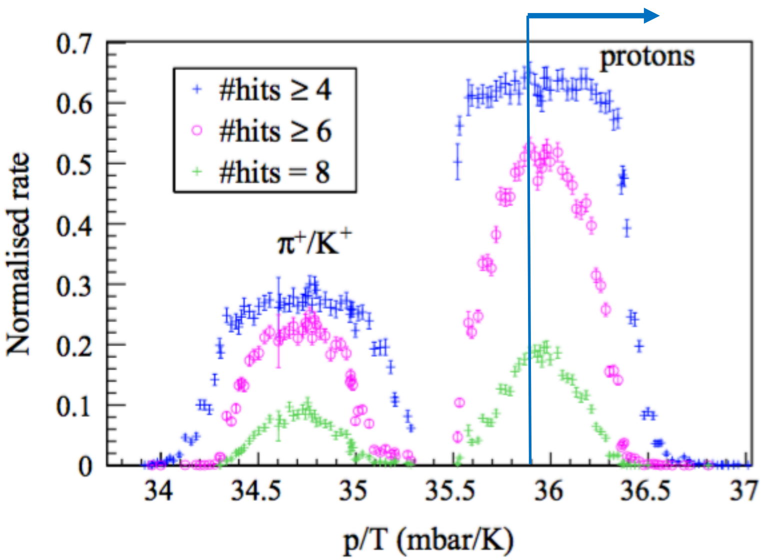


Fig. 53. Time residual of the beam trigger.

Rate statistics and pileup

- Typical beam intensity is 5 10^7 p/s for a 9.8s spill
- We expect ~ 1.2 % of the protons to interact with the 40cm LH2 target → ~ 4 10^5 interaction/s
- COMPASS trigger has a time resolution of 5 μs
- Vertex spatial resolution better than 4 mm
- Pile-up is under control and not a problem
- Statistical errors becomes negligible after few hour of data taking.

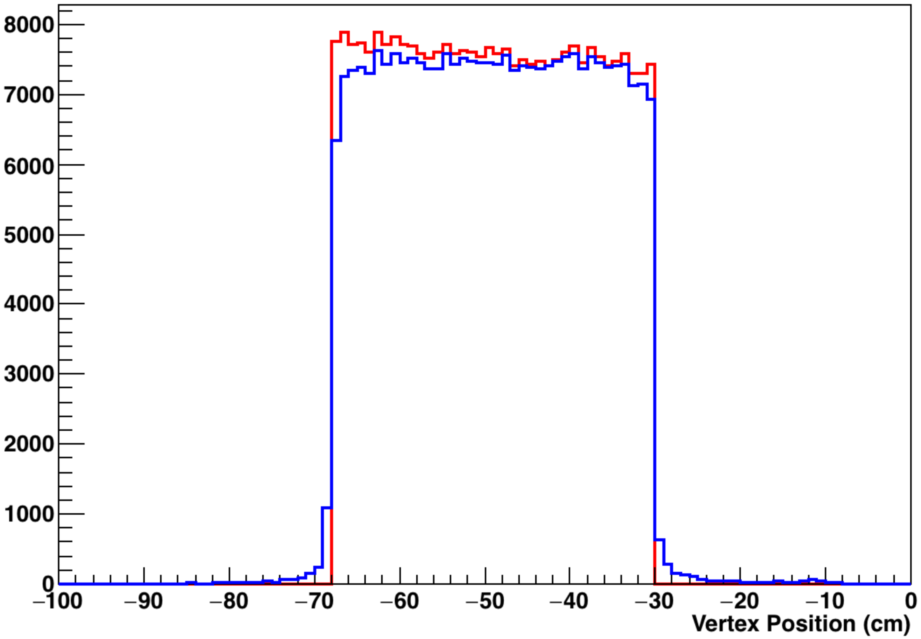
Upstream Threshold Cherenkov counter



Beam and Trigger error ~ 0.5%

Lost Interaction events

- Select a fiducial volume on the target [-68,-30] cm
- Look how many events have a reconstructed vertex withig the fiducial volume



MC events: 288312
No Vertex: 2753 (0.95%)
Vtx outside: 2856 (0.99%)

Thanks to the Recoil Detector no-vertex events can be cross-checked with data

Vertex error 0.5%

Reconstruction uncertainties

	efficiency	est sys error
Track Recon	95%	~1%
Rich Efficiency	~ 90%	~3 %
RICH PID	99 to 75 %	0.1 to 5 %
Vertex error	98%	0.5%
Beam Purity	99.9%	0.5%
TOTAL		5 to 10 %

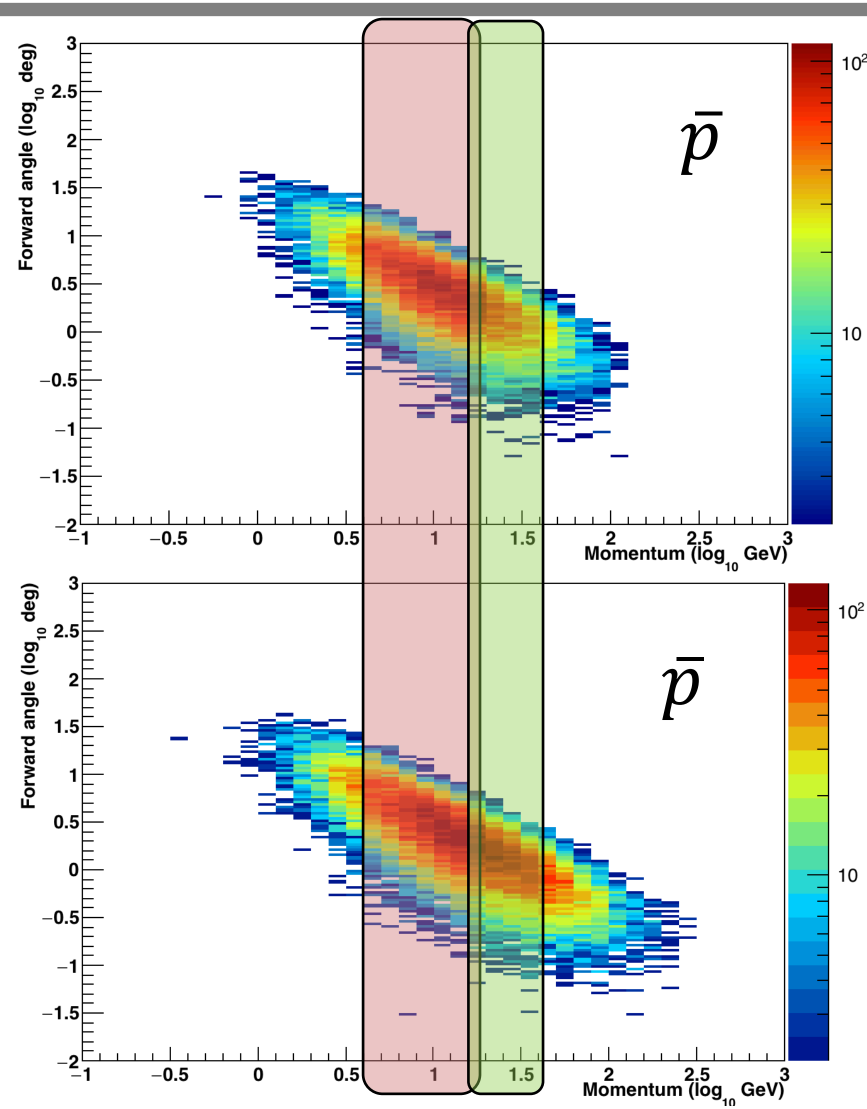
Status of a possible measurement

	anti-p (17-45 GeV)	anti-p (5-45 GeV)
p-p @ 190 GeV	**OK** analyze 2009 data	Need RICH2
p-He @ 190 GeV	refurbish target LH2 → LHe	+ RICH2
p-p @ 400 GeV	Upgrade beamline	+ RICH2
p-He @ 400 GeV	refurbish target LH2 → LHe Upgrade beamline	+ RICH2

Possible outcome of a measurement

p-p @ 190GeV

p-He @ 400GeV



RICH1

RICH2

Summary

- We studied the possibility to measure anti-p cross section from p-p and p-He with SPS beam and the COMPASS detector
- COMPASS seems to have a good performances to perform a measurement of the order of 4 to 10% depending on the anti-p momentum in the range (17 to 45 GeV) over an extended p_t range.
- With upgrades to the target, RICH and/or beamline more ambitious goals seem reachable.
- We are willing to analyze the 2009 to confirm this exercise and to possibly produce a measurement.