2nd Cosmic-ray Antideuteron Workshop
University of California – Los Angeles

Production cross sections for anti-p and anti-d with COMPASS++/AMBER

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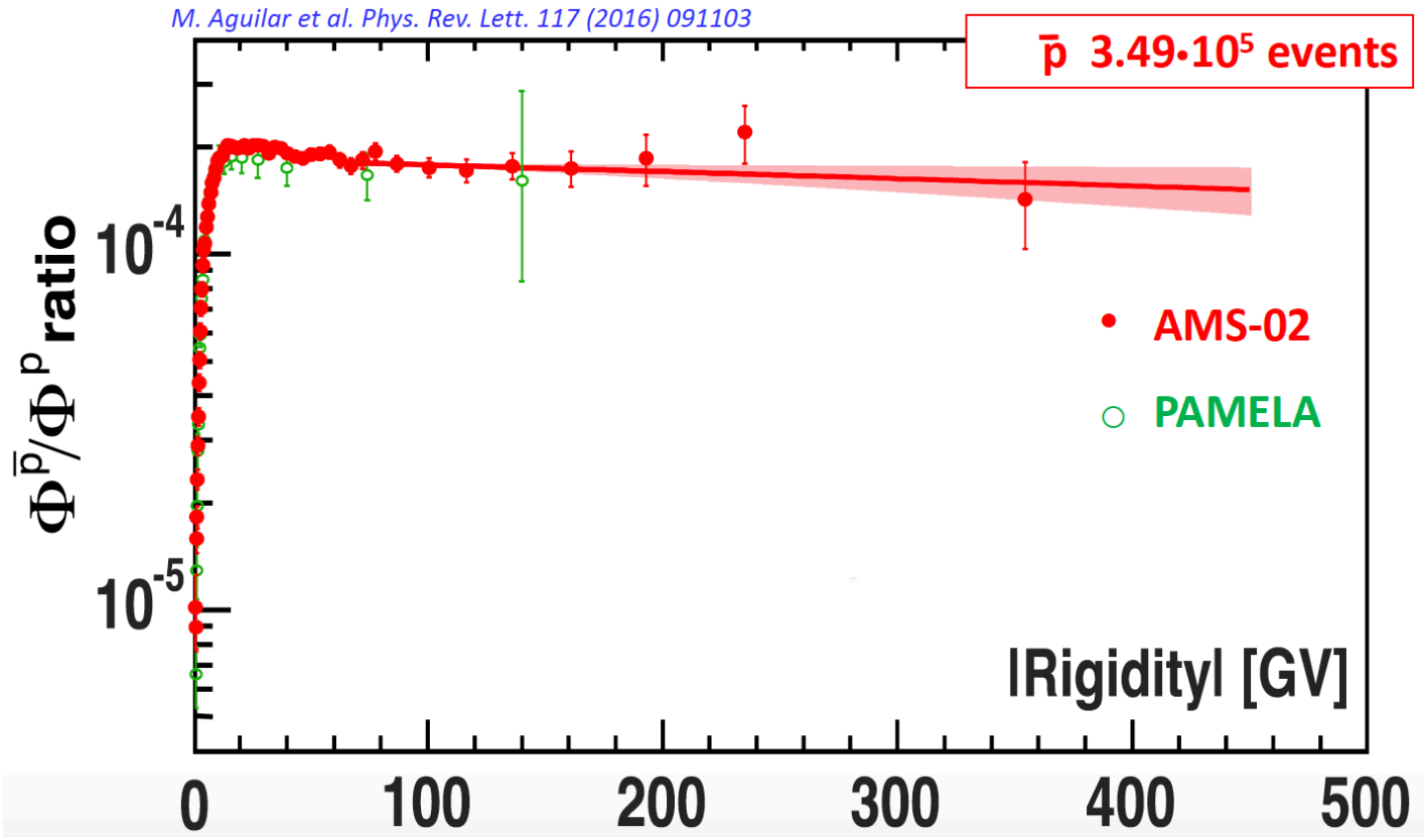
We left here two days ago!

AMS Measurement of anti-p/p ratio



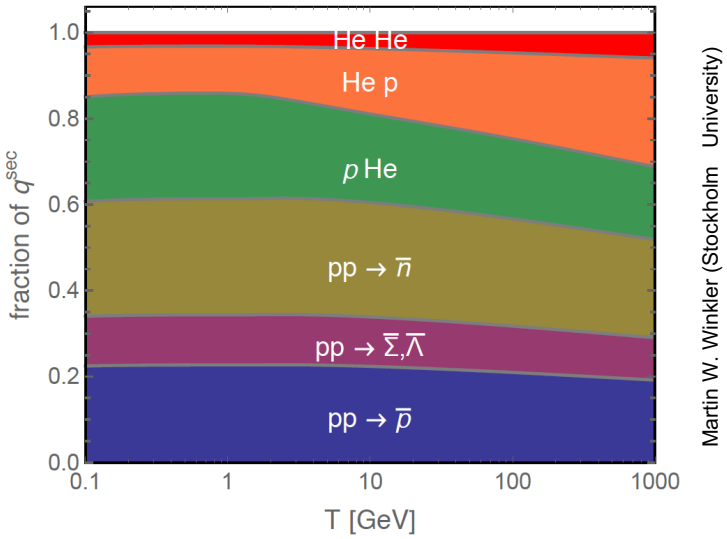
Two major uncertainties limit the prediction of the anti-p flux from CR interaction with ISM

- production cross sections p-p -> pbar +X p-He-> pbar + X
- CR propagation in the galaxy

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 and 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.
- NA61 published p-p to anti-p at 20, 31, 40, 80, and 158 GeV/c
- we want to investigate the possibility to perform a measurement with the SPS protons between 50 and 280 GeV/c on fixed LH2 and LHe targets, and a magnetic spectrometer

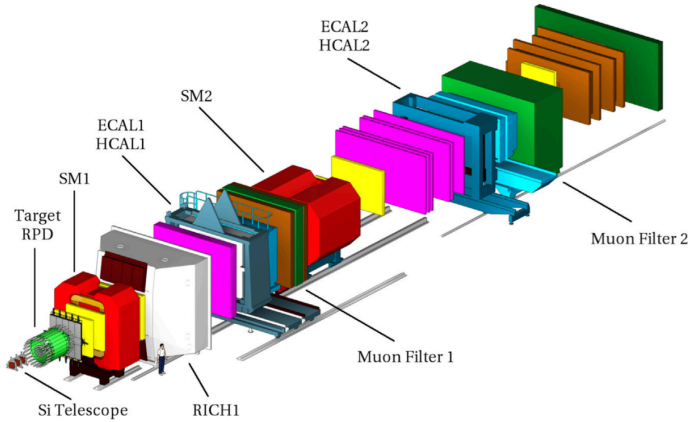
Fraction origin of anti-p from CR interaction with ISM

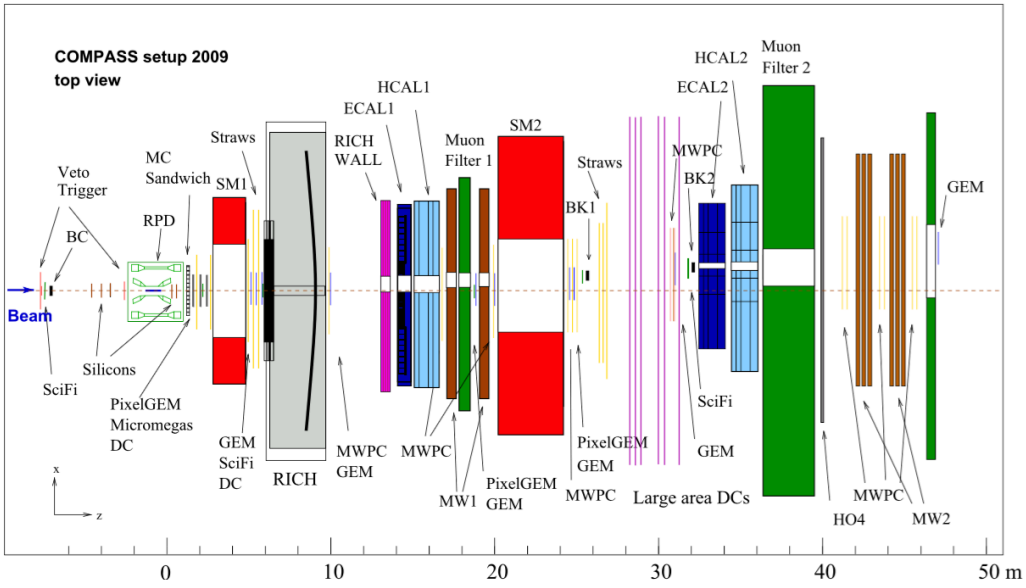


LHCb-CONF-2017-002
Measurement performed at 7 TeV p-He -> pbar + X

NA61 p+p data beam momenta of 20, 31, 40, 80, and 158 GeV/c
Eur. Phys. J. C 77, 671 (2017)

COMPASS @ CERN





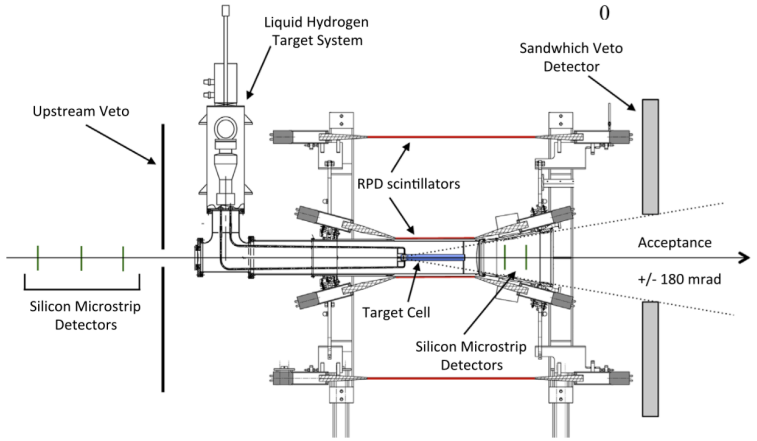


Fig. 4. Side view of the target region with the liquid hydrogen target system.

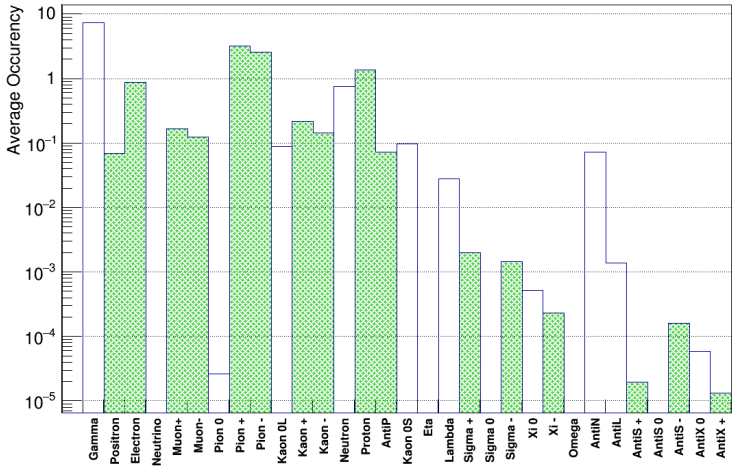
Acceptance:
+/- 180 mrad
+/- 10 deg
$2.4 < \eta < 8$

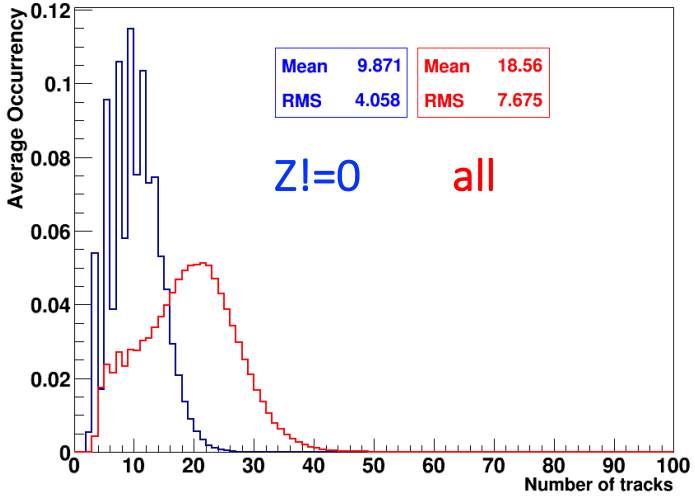
Fist Step

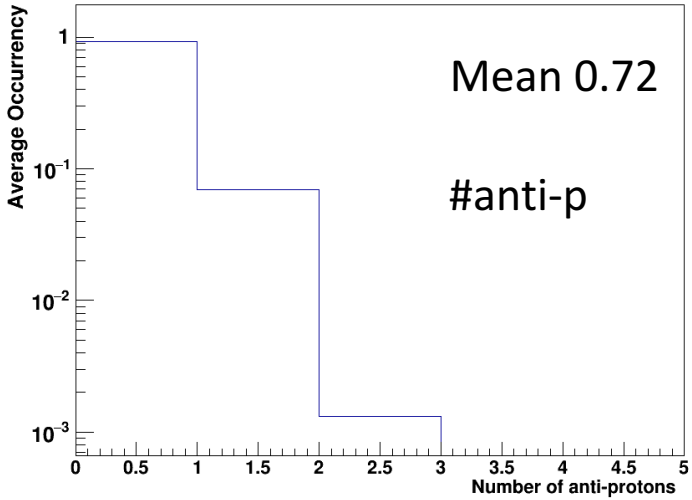
Use FLUKA to simulate p-p and p-He interactions with a beam of 190 GeV/c momentum.

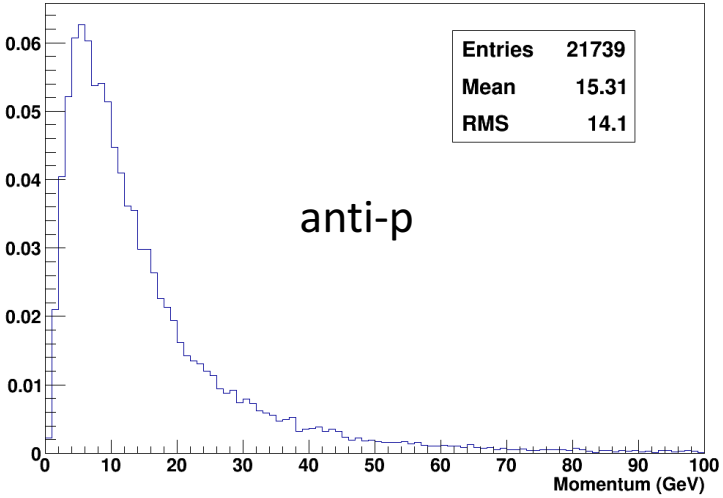
p-LH2 event features @ 190 GeV/c

3.05 10^5 interacting events



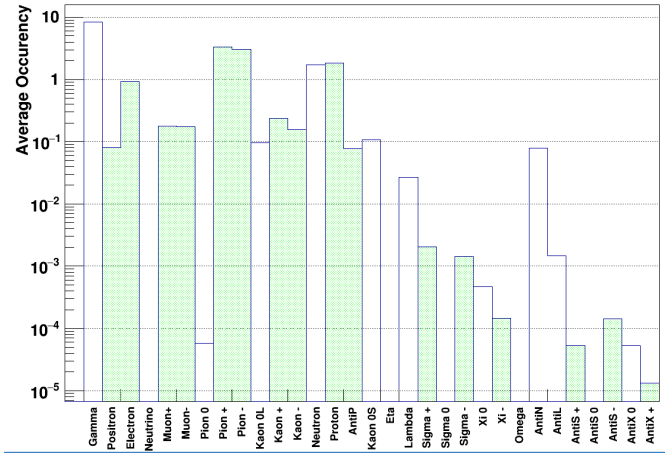


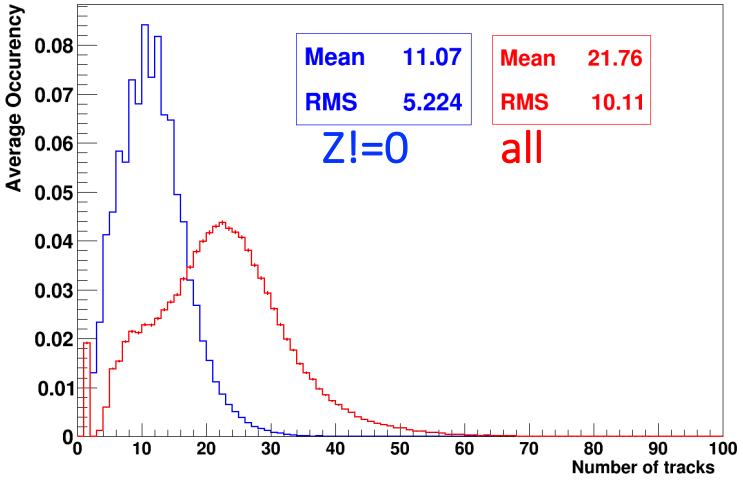


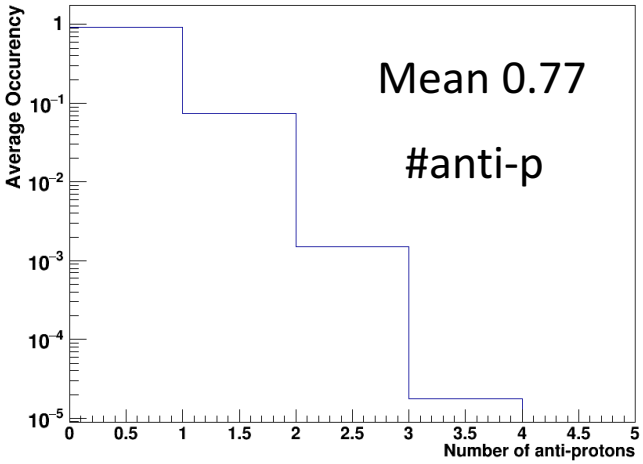


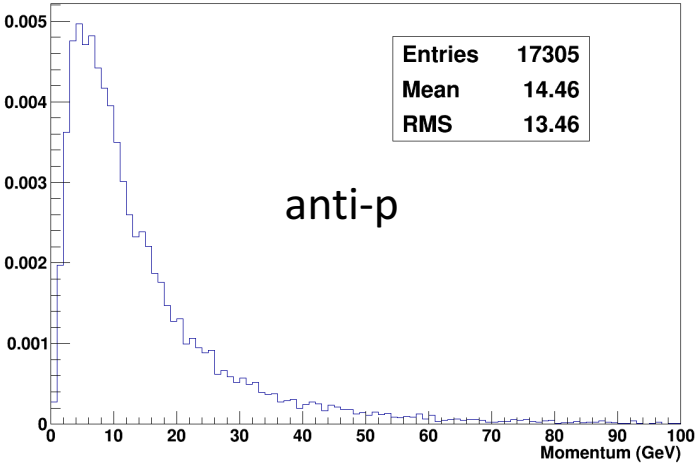
p-LHe event features @ 190 GeV/c

2.25 10^5 interacting events







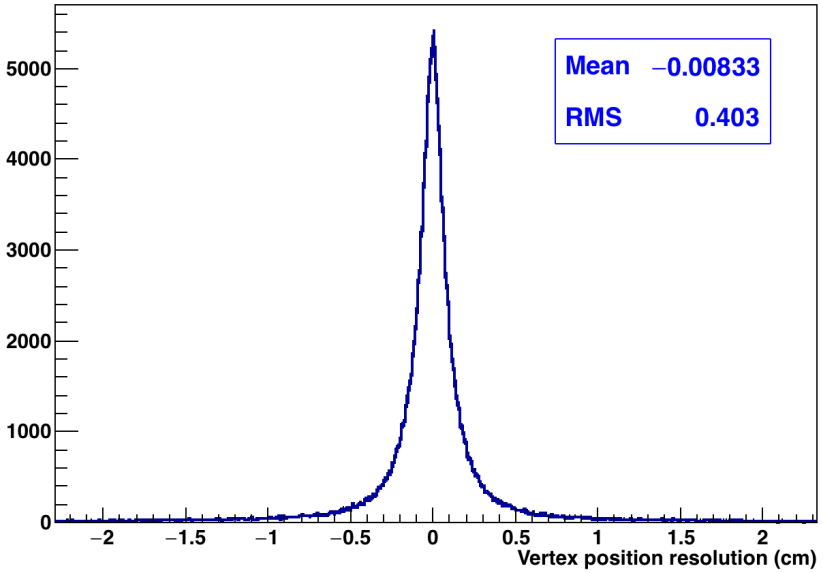


Second step

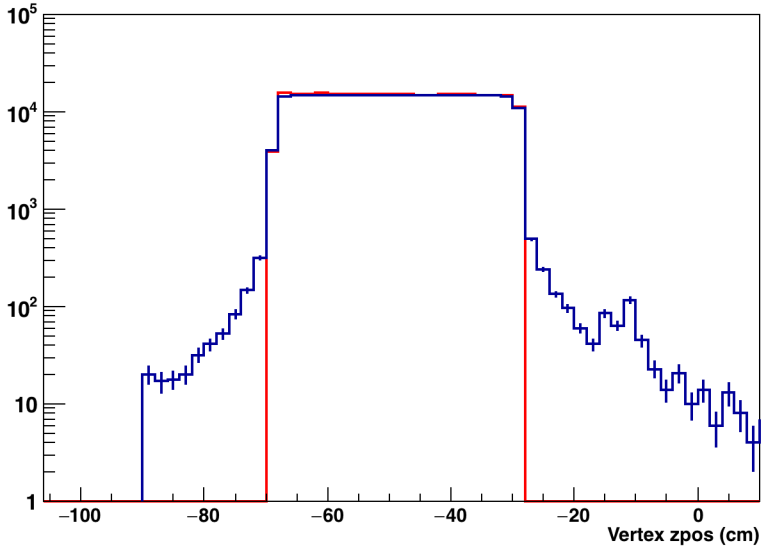
- **Use FLUKA generated interaction as input for the official COMPASS Geant 4 simulation (TGEANT)**
- **Pass the produced files through the official COMPASS reconstruction software**

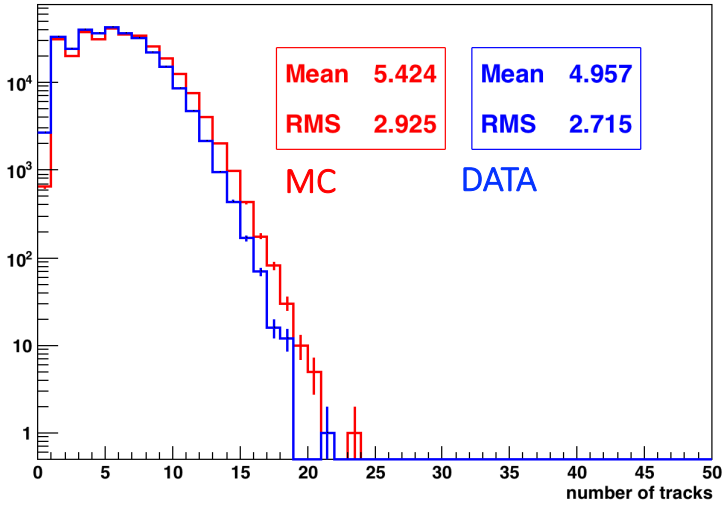
COMPASS simulation (p-p 190GeV)

Vertex resolution

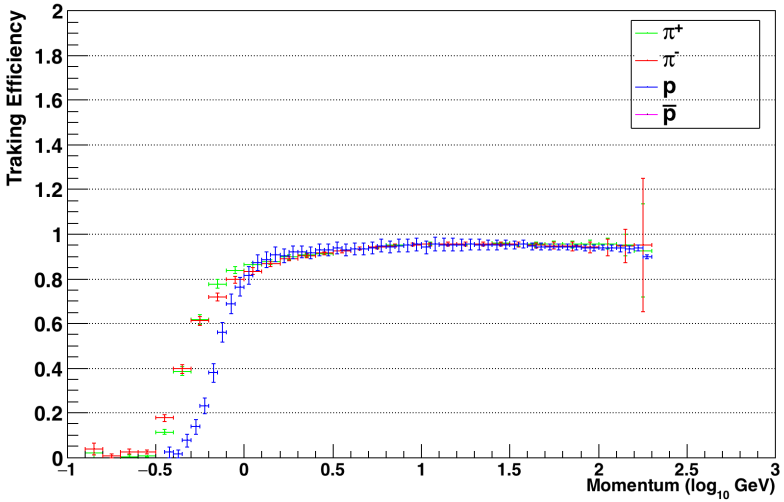


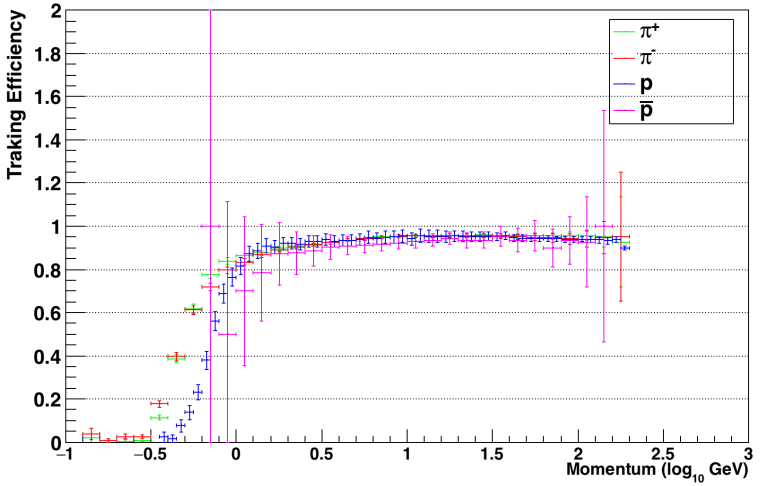
Vertex position

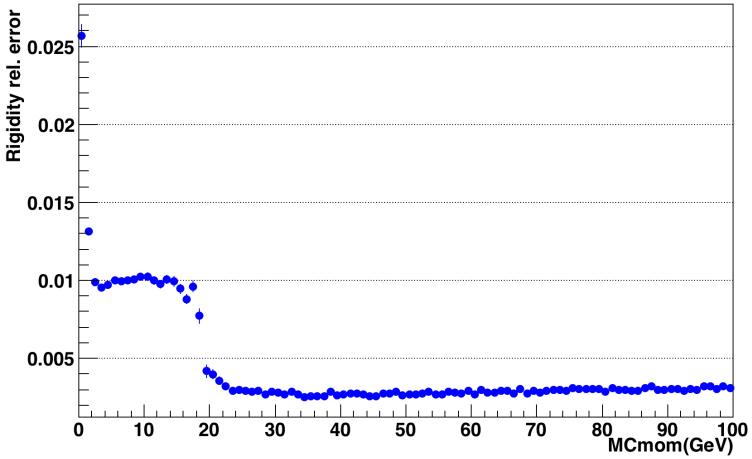




COMPASS Rec accuracy





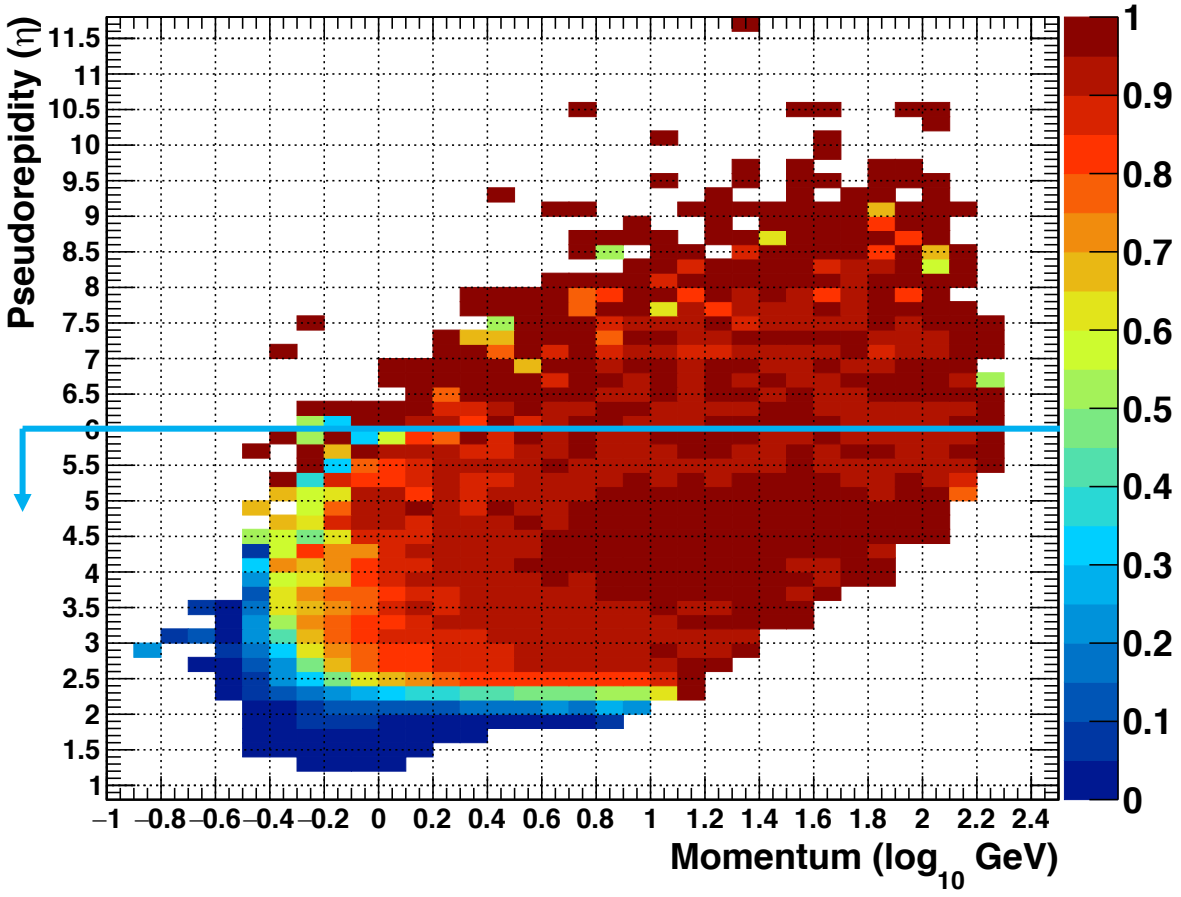


COMPASS simulation (p-p 190GeV)

Antiproton tracking efficiency

Pseudo-rapidity vs $\log_{10}$(momentum)

RICH Acc



Third step

Estimate RICH particle identification performance from p-p data already collected at 190 GeV

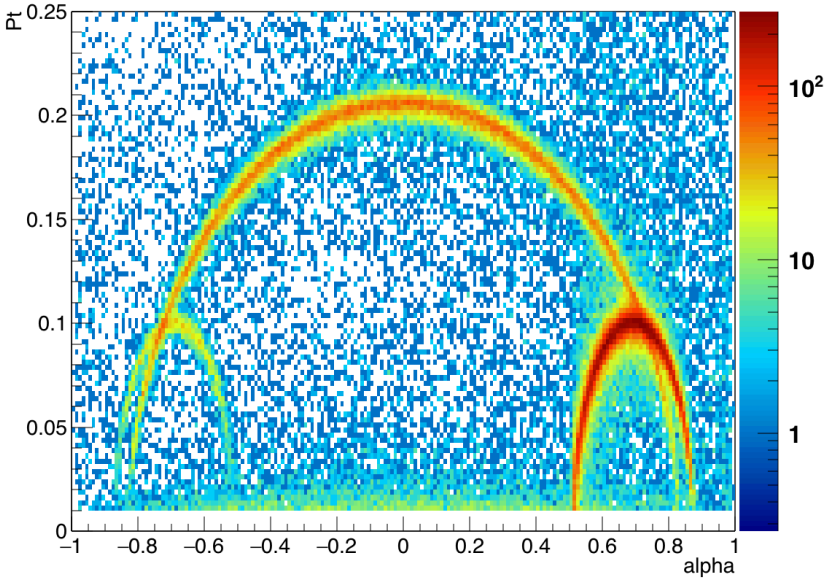
Select pure samples of p, pbar, π+ and π-

DATA SET collected in 2009 (p-LH2)

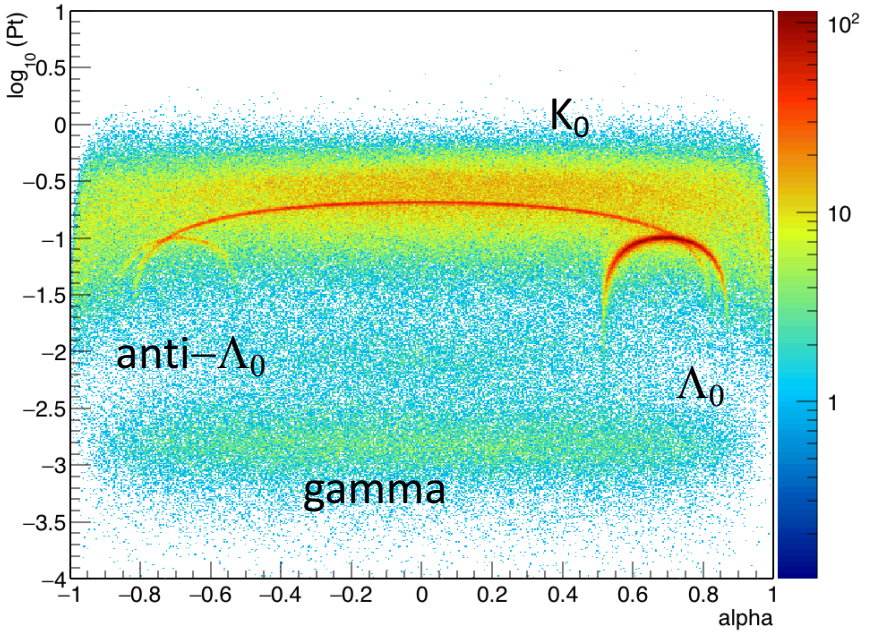
Select a sample of V0

- two tracks forming a vertex
- p=p1+p2 points to the primary vertex

After clean up (min dist, prim ang)

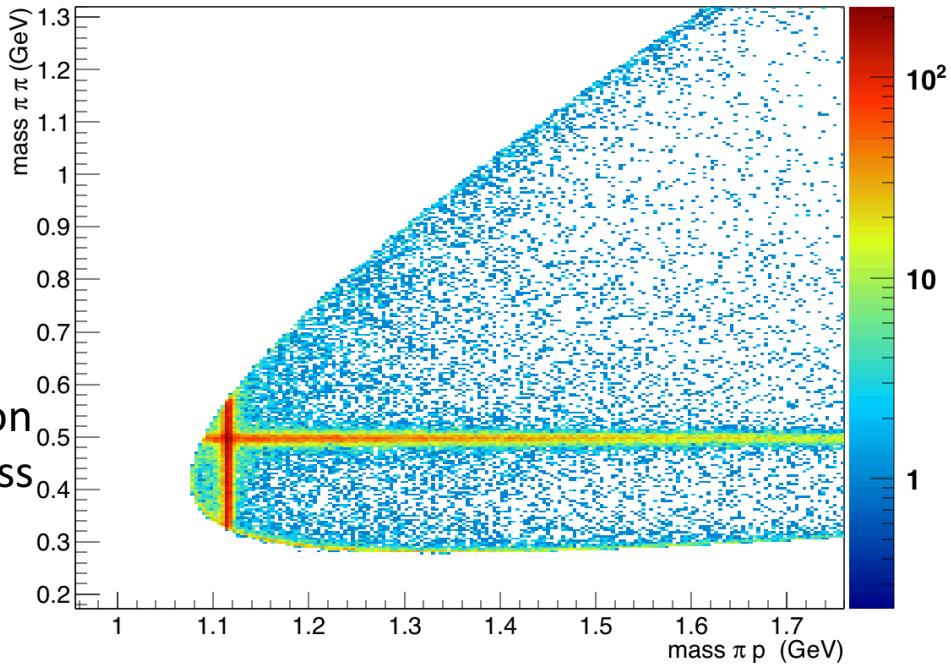


Armenteros plot



alpha = pl1-pl2/(pl1+pl2)

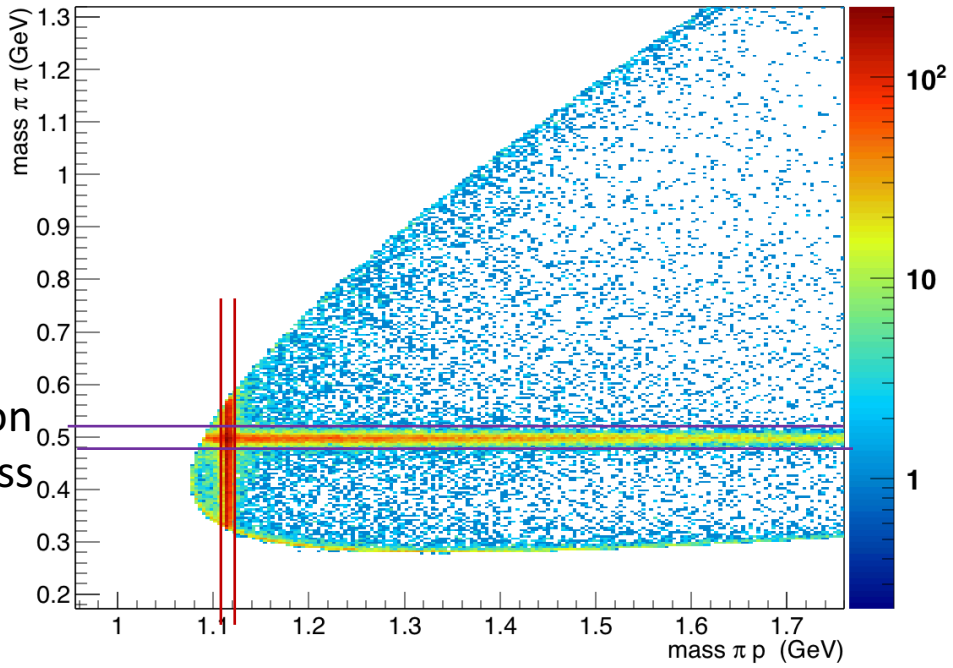
Mass selection



Kaon mass

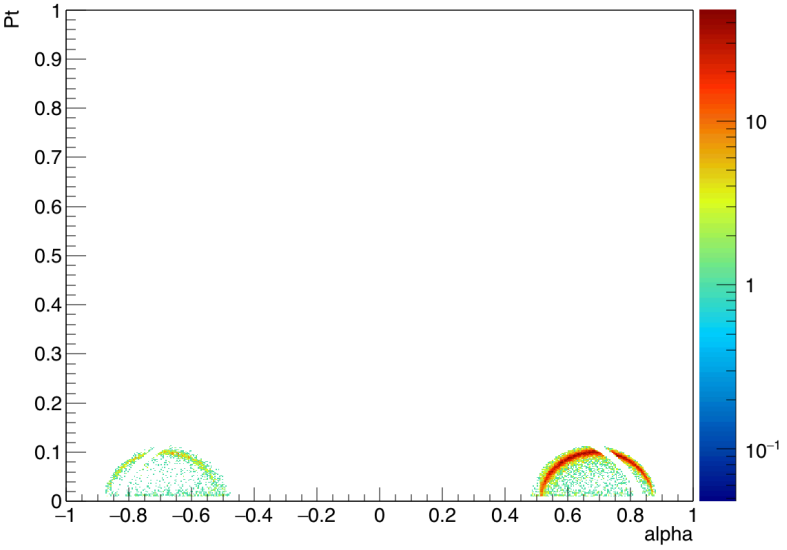
Lambda Mass

Mass selection

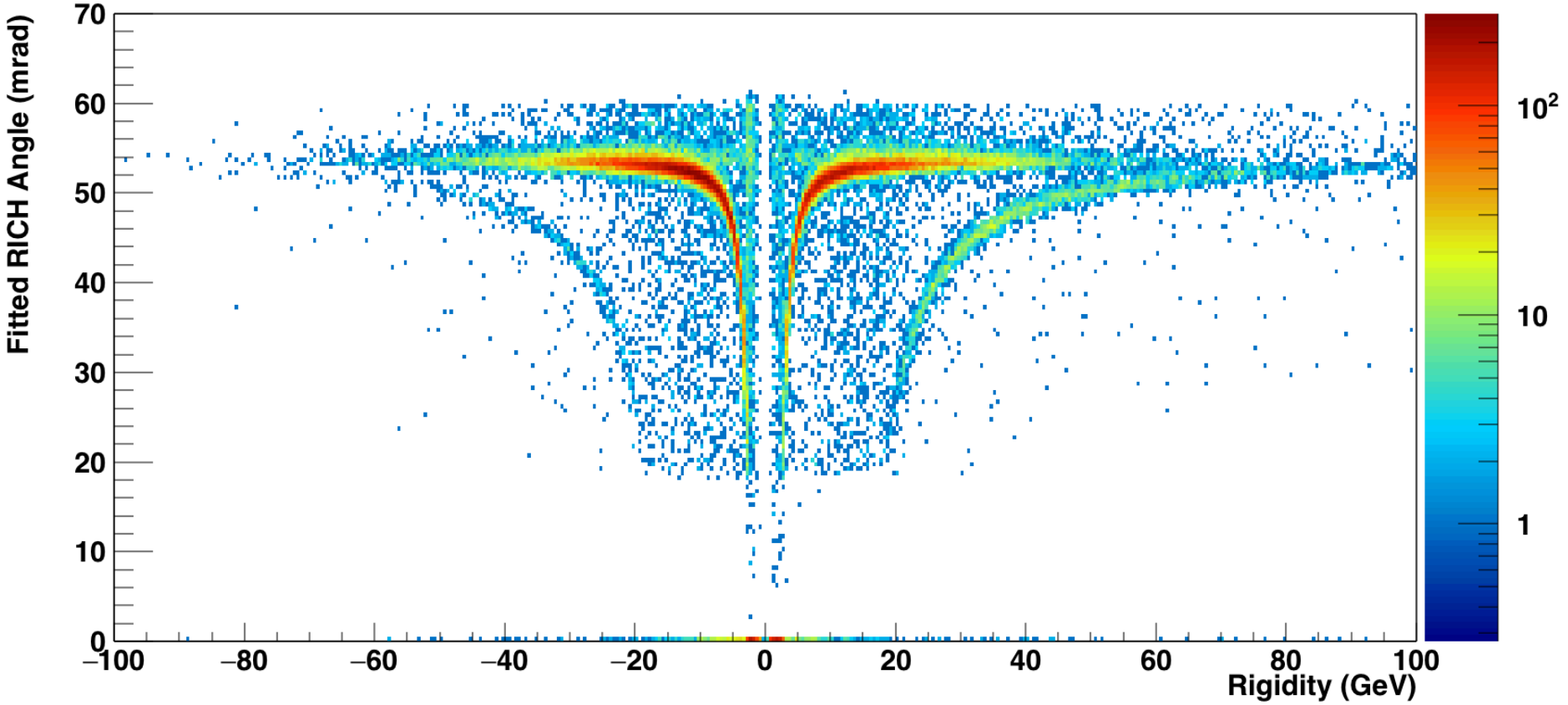


Kaon mass

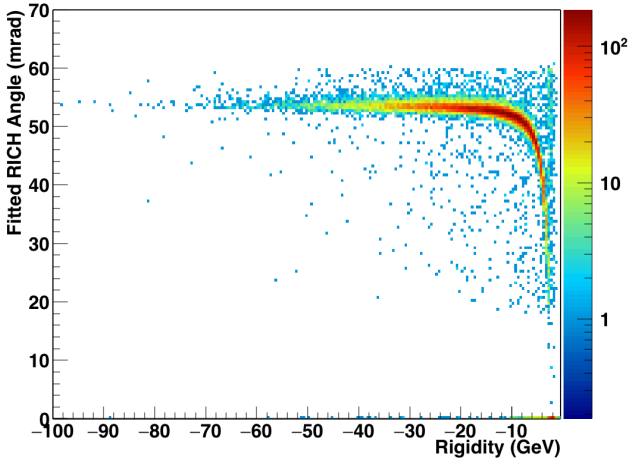
Lambda Mass



Selected Tracks from K_0 and Λ_0

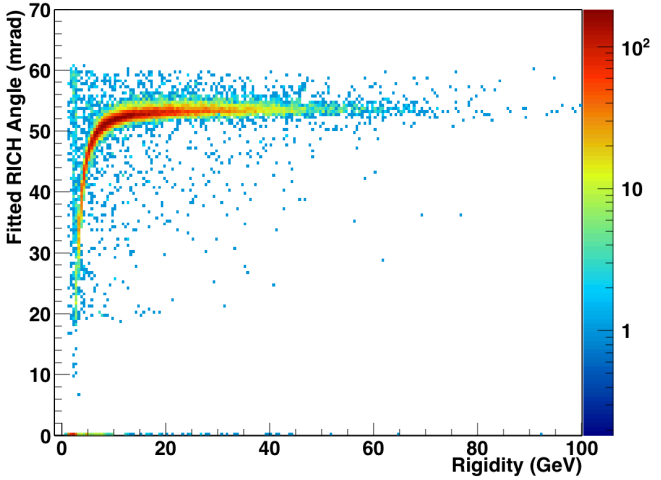


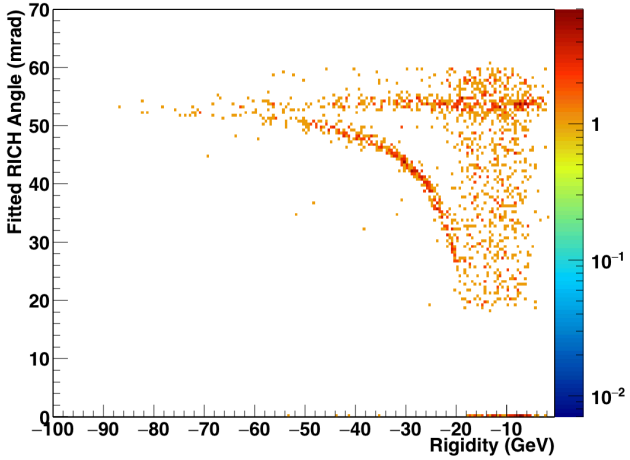
Individual “pure” samples



pi-

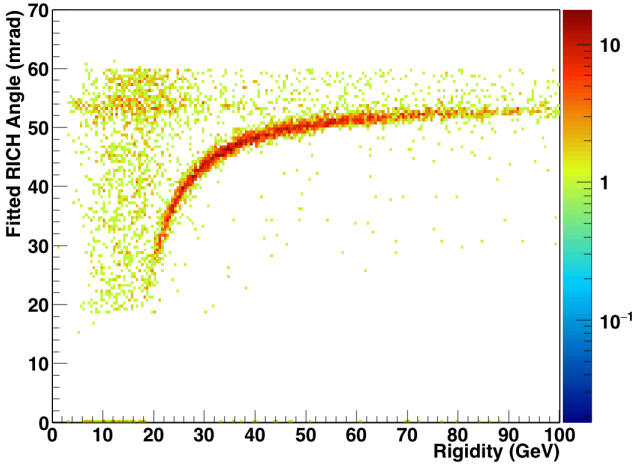
pi+



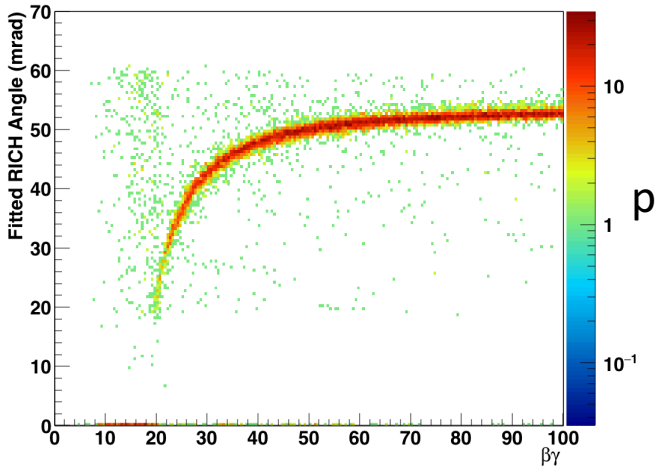


pbar

p

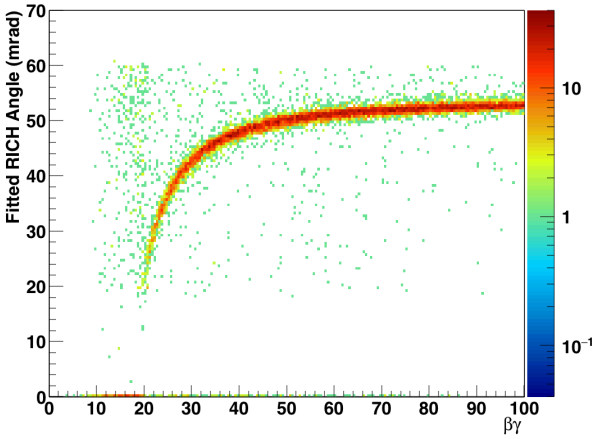


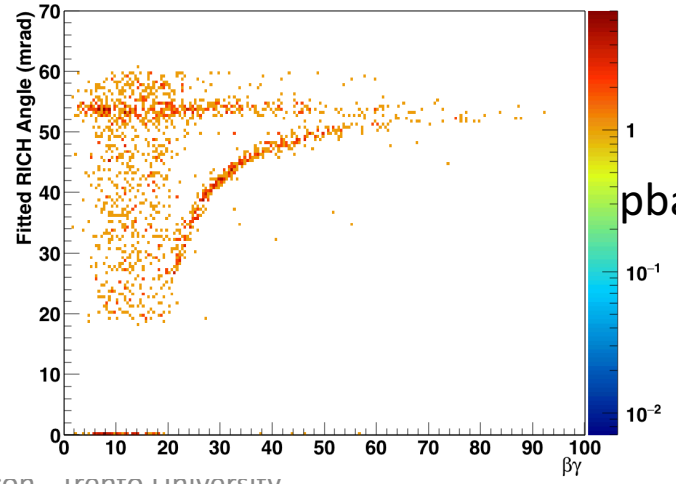
RICH angle vs βγ



pi-

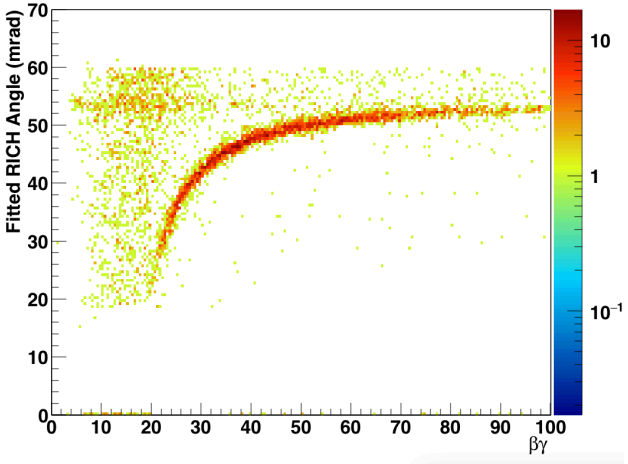
pi+





pbar

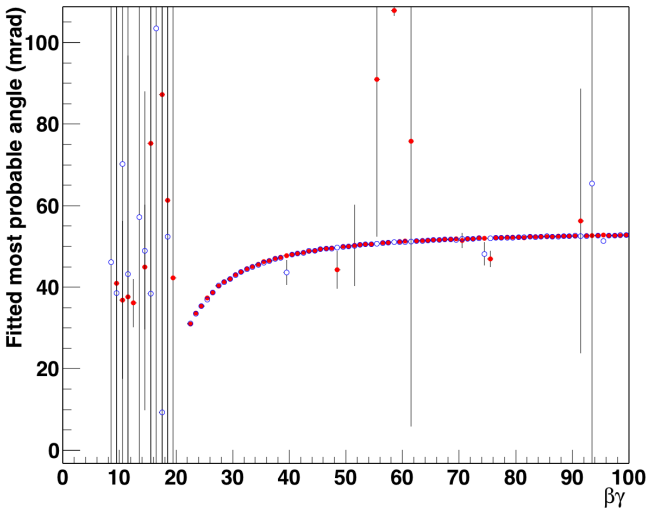
p



Gaussian Fit of the RICH angle

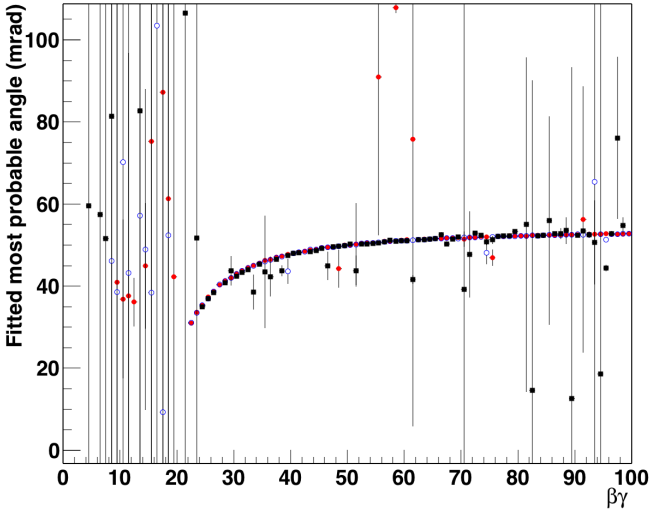
MPV

pi+
pi-

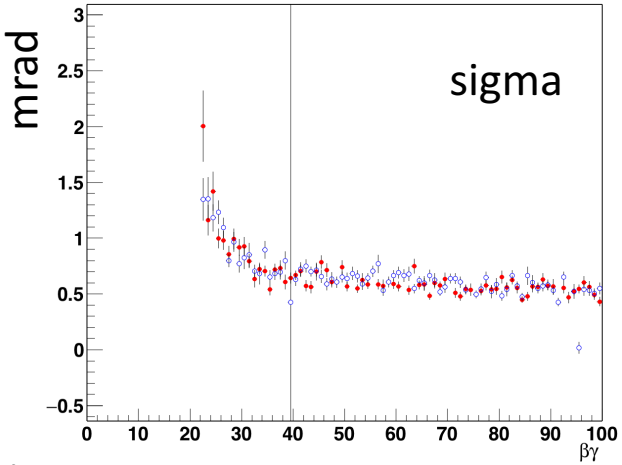


MPV

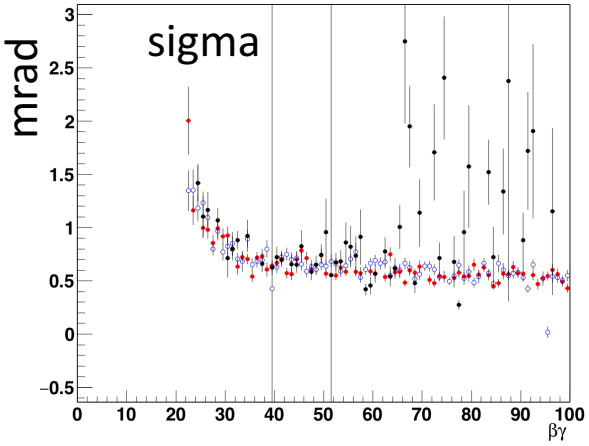
pi+
pi-
p



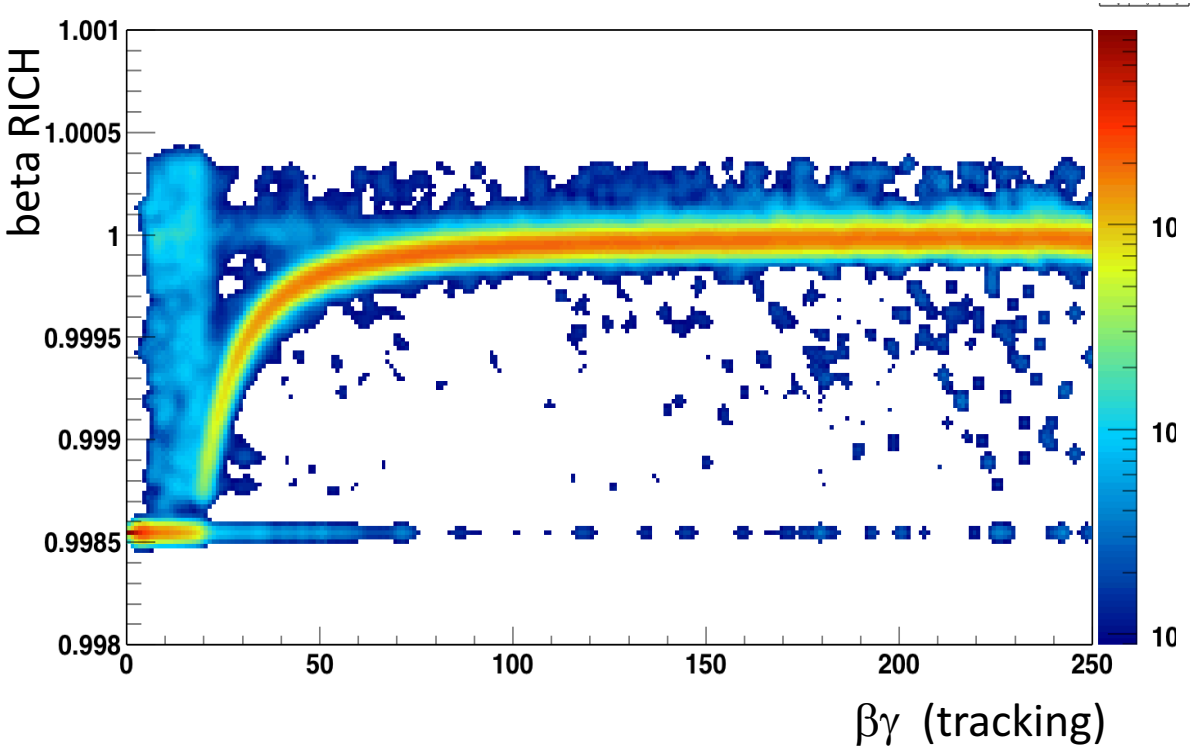
pi+
pi-

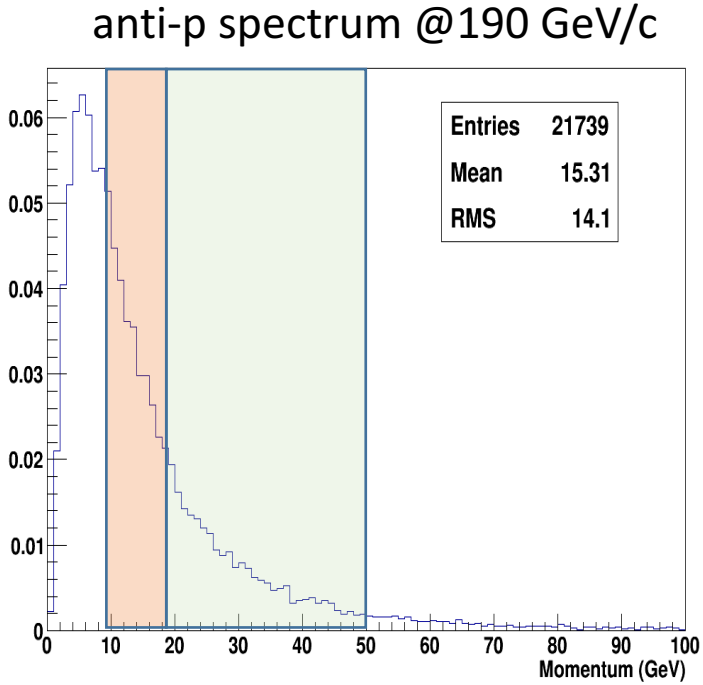


pi+
pi-
p



Universal RICH response function





anti-p and p are identified above threshold (~18 GeV/c) with an efficiency >95% up to ~60 (GeV/c)

From the Kaon threshold (~9 GeV/c) to the p threshold, p and anti-p are identified using RICH in veto mode.

Fourth step

Combine the elements to obtain a cross section measurement

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

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

- Several possible pitfalls and sources of systematic errors!

Compass Trigger system

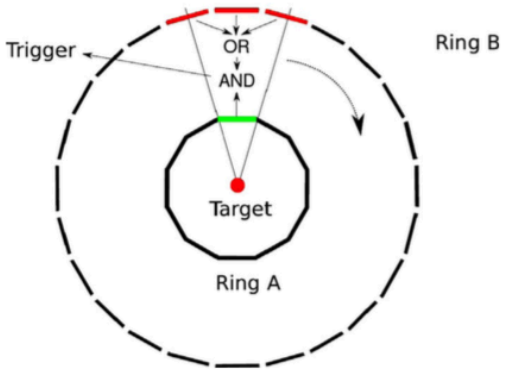


Fig. 54. Allowed combinations for target pointing in the RPD part of the proton trigger.

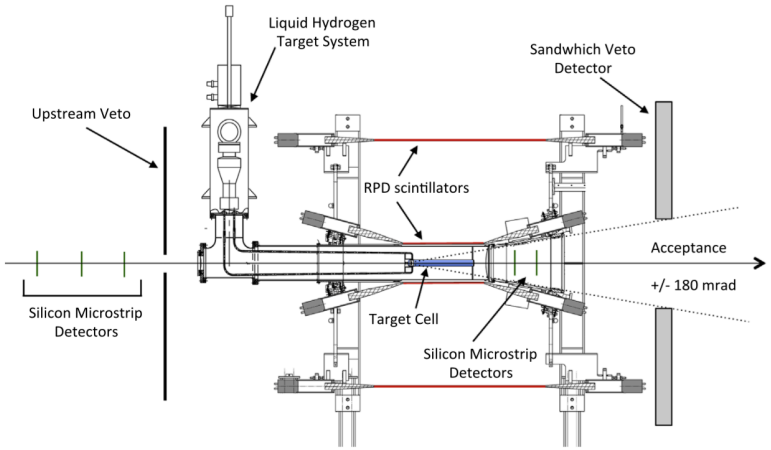


Fig. 4. Side view of the target region with the liquid hydrogen target system.

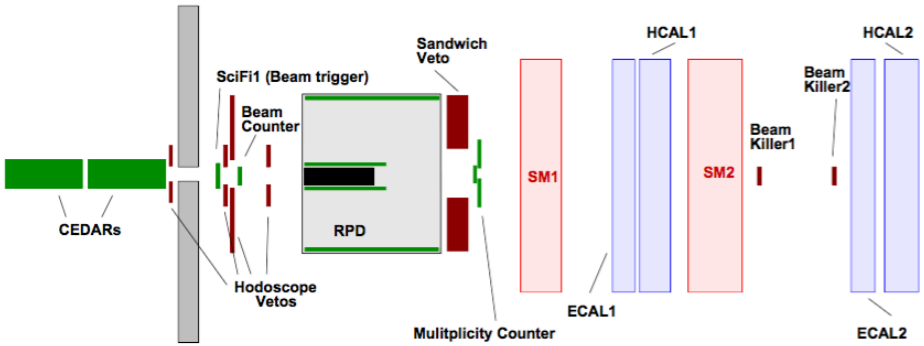


Fig. 51. Arrangement of trigger elements in the spectrometer (schematic side view, not to scale).

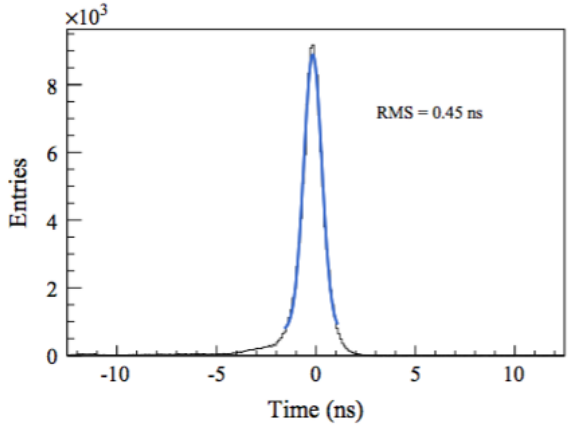
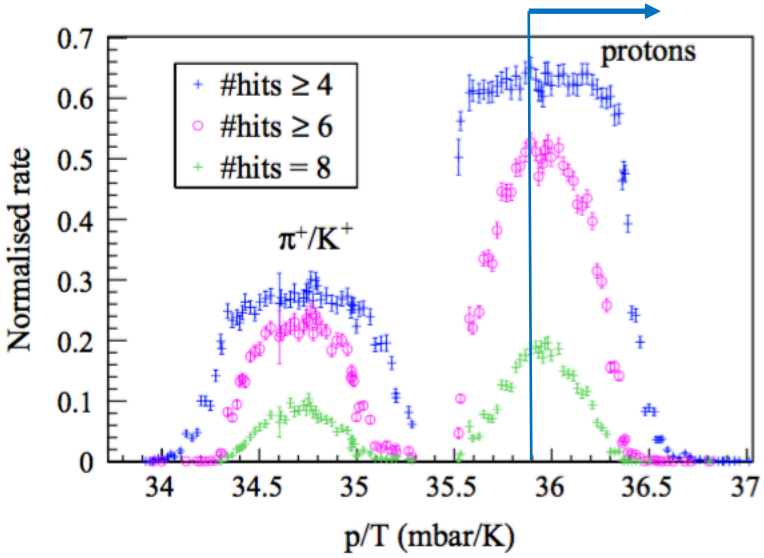


Fig. 53. Time residual of the beam trigger.

Rate statistics and pileup

- Typical beam intensity is 5 10^7 p for a 9.8s spill
- We expect ~ 5.4 % of the protons to interact with the 40cm LH2 target → ~ 270k interaction/s
- Compass standard trigger DT0 is $BT \,\&\, \overline{BK} \,\&\, \overline{Sandwich\ Veto} \,\&\, RPD$
- This reduce the trigger rate to 33 kHz which can be handled by the COMPASS DAQ
- For the future measurements we will ask to reduce the beam intensity to 5 10^6 and plan to use the trigger
  $BT \,\&\, \overline{BK} \,\&\, \overline{Sandwich\ Veto}$
- This will provide an expected rate of 25 kHz

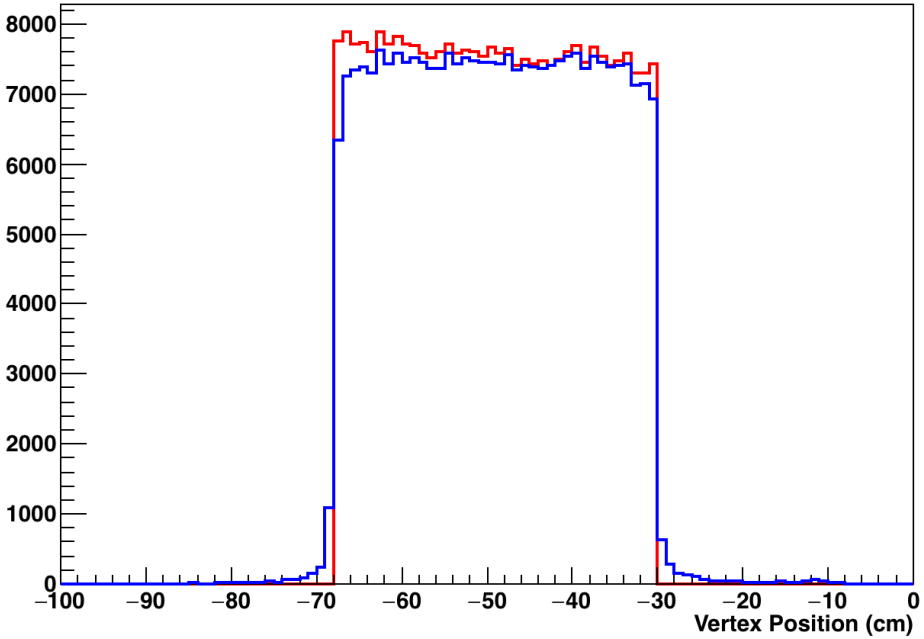
Upstream Threshold Cherenkov counter



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 within 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%

Summary of the expected errors

Systematic

	efficiency	est sys error
Track Recon	95%	~1%
Rich Efficiency	~ 99%	~0.5 %
RICH PID	99 to 75 %	0.1 to 4%
Trigger		1%
Vertex error	98%	0.5%
Beam Purity	99.9%	0.5%
TOTAL		4 to 6 %

Considering 2 targets (LHe and LH2, each 50 cm long),
The estimated acceptance and efficiency from the full COMPASS MC.
20 bins in momentum from [10, 50] GeV/c and 20 bin in Pt
75% beam purity at 5E5 p/s beam intensity
We expect to reach 1.7(1.0) % statistical error in most of the 400 differential cross section bins with 4(12) hours of beam time for each energy point.

Toward an actual measurement

The program for measuring p-p and p-He -> pbar (and dbar) + X has been included in the COMPASS 2020 LoI presented to CERN

The new program has been named COMPASS++_AMBER.

The program would start after the LHC long shutdown in 2021.
Preliminary measurements are expected to be performed in 2021 and 2022.

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

January 5, 2019

The LoI received a positive evaluation and the collaboration has been requested to prepare a proposal within the summer

Letter of Intent:

A New QCD facility at the M2 beam line of the CERN SPS

COMPASS++*/AMBER†

Projects to convert a spare LH2 target to LHe will also starts over the summer.

Summary

- CR antimatter data sensitivity to exotic sources is degraded by the poor knowledge of the pbar (and dbar) production cross sections
- We have shown that a measurement of p-p->pbar + X and p-He-> pbar + X (and dbar), can be performed at CERN with the COMPASS++/AMBER spectrometer at momenta ranging from 50 GeV/c to 280 GeV/c
- A letter of intent that includes a program for these measurements has been submitted and received a positive evaluation
- A full proposal is being now worked
- First data taking is supposed to happen in 2021

Particle range at 50 GeV/c momentum

MC_PID	Name	range	Mass	Charge	Lifetime		Energy	Beta	gamma
		m	GeV/c2		s		GeV		
20	SIGMA 0	9.31E-10	1.19E+00	0	7.40E-20		5.00E+01	1.00E+00	42
28	ANTISIGMA 0	9.31E-10	1.19E+00	0	7.40E-20		5.00E+01	1.00E+00	42
17	ETA	1.50E-08	5.48E-01	0	5.49E-19		5.00E+01	1.00E+00	91
7	PION 0	9.33E-06	1.35E-01	0	8.40E-17		5.00E+01	1.00E+00	370
24	OMEGA -	7.38E-01	1.67E+00	-1	8.22E-11		5.00E+01	9.99E-01	30
32	ANTIOMEGA +	7.38E-01	1.67E+00	1	8.22E-11		5.00E+01	9.99E-01	30
27	ANTISIGMA -	1.01E+00	1.19E+00	-1	7.99E-11		5.00E+01	1.00E+00	42
19	SIGMA +	1.01E+00	1.19E+00	1	7.99E-11		5.00E+01	1.00E+00	42
21	SIGMA -	1.85E+00	1.20E+00	-1	1.48E-10		5.00E+01	1.00E+00	42
29	ANTISIGMA +	1.85E+00	1.20E+00	1	1.48E-10		5.00E+01	1.00E+00	42
23	XI -	1.86E+00	1.32E+00	-1	1.64E-10		5.00E+01	1.00E+00	38
31	ANTIXI +	1.86E+00	1.32E+00	1	1.64E-10		5.00E+01	1.00E+00	38
16	KAON 0 SHORT	2.69E+00	4.98E-01	0	8.93E-11		5.00E+01	1.00E+00	100
22	XI 0	3.31E+00	1.32E+00	0	2.90E-10		5.00E+01	1.00E+00	38
30	ANTIXI 0	3.31E+00	1.32E+00	0	2.90E-10		5.00E+01	1.00E+00	38
18	LAMBDA	3.54E+00	1.12E+00	0	2.63E-10		5.00E+01	1.00E+00	45
26	ANTILAMBDA	3.54E+00	1.12E+00	0	2.63E-10		5.00E+01	1.00E+00	45
12	KAON -	3.76E+02	4.94E-01	-1	1.24E-08		5.00E+01	1.00E+00	101
11	KAON +	3.76E+02	4.94E-01	1	1.24E-08		5.00E+01	1.00E+00	101
10	KAON 0 LONG	1.56E+03	4.98E-01	0	5.17E-08		5.00E+01	1.00E+00	100
9	PION -	2.80E+03	1.40E-01	-1	2.60E-08		5.00E+01	1.00E+00	358
8	PION +	2.80E+03	1.40E-01	1	2.60E-08		5.00E+01	1.00E+00	358
6	MUON -	3.12E+05	1.06E-01	-1	2.20E-06		5.00E+01	1.00E+00	473
5	MUON +	3.12E+05	1.06E-01	1	2.20E-06		5.00E+01	1.00E+00	473
13	NEUTRON	1.42E+13	9.40E-01	0	8.87E+02		5.00E+01	1.00E+00	53
25	ANTINEUTRON	1.42E+13	9.40E-01	0	8.87E+02		5.00E+01	1.00E+00	53
46	TRITON	5.35E+24	2.81E+00	1	1.00E+15		5.01E+01	9.98E-01	18
45	DEUTERON	8.00E+24	1.88E+00	1	1.00E+15		5.00E+01	9.99E-01	27
15	ANTIPROTON	1.60E+25	9.38E-01	-1	1.00E+15		5.00E+01	1.00E+00	53
14	PROTON	1.60E+25	9.38E-01	1	1.00E+15		5.00E+01	1.00E+00	53
3	ELECTRON	2.94E+28	5.11E-04	-1	1.00E+15		5.00E+01	1.00E+00	97847
2	POSITRON	2.94E+28	5.11E-04	1	1.00E+15		5.00E+01	1.00E+00	97847
49	HE3	5.35E+24	2.81E+00	2	1.00E+15		5.01E+01	9.98E-01	18
47	ALPHA	4.04E+24	3.73E+00	2	1.00E+15		5.01E+01	9.97E-01	13