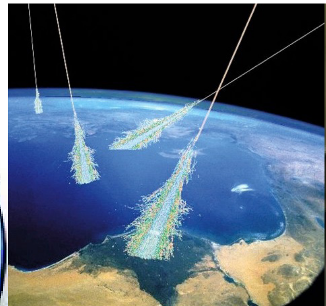
OPPORTUNITY TO CONTRIBUTE IN THE SEARCH OF DARK MATTER

Michela Chiosso, University of Torino and INFN
Paolo Zuccon, University of Trento and INFN

Mini Workshop for a QCD Facility at the SPS after 2021
CERN, 20 June 2018



INPUT TO DARK MATTER SEARCH: INTRODUCTION

The bulk of the measured flux consistent with a purely secondary origin in CR collisions onto interstellar medium gas (ISM) but additional primary components are not excluded, either of astrophysical origin or of exotic nature, such as dark matter annihilation or decay

More precise measurements of secondary components are needed

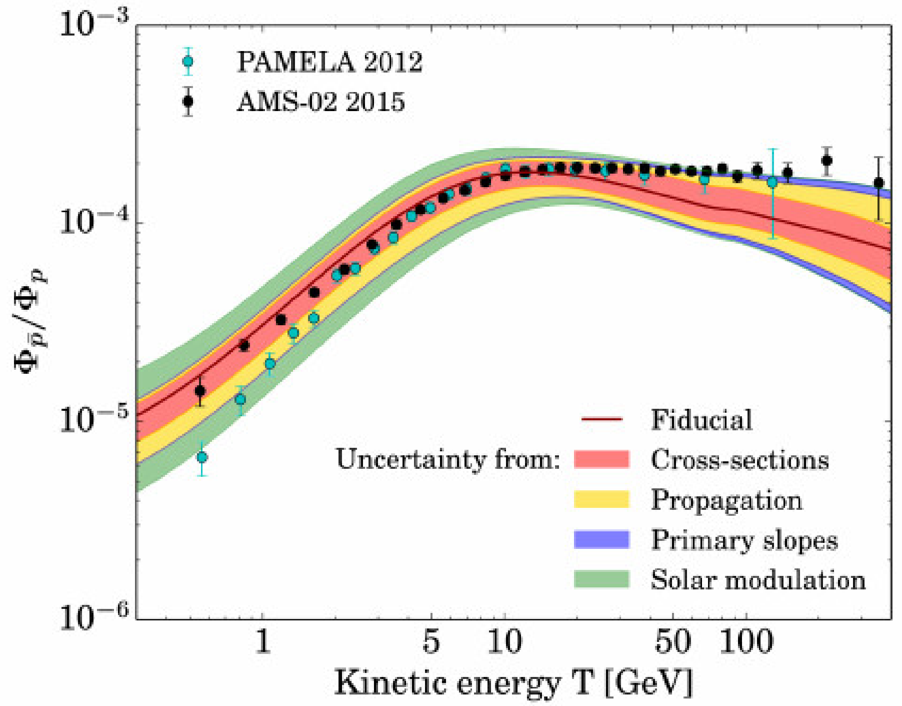
Secondary components mainly come from: p-p; p-He; He-p; He-He
Reactions involving helium represent a sizable fraction of the total yield, easily reaching 40% at low energies:
p p: 56%; p He: 24 %; He p: 12 %; He He: 6 %; p N (C, N, O) : 2%

- An accurate prediction of the expected pbar flux in cosmic rays in the rigidity range from few GeV to several hundreds of GeV, is interesting to understand cosmic ray an possibly search for signals of new physics

- The very first dataset on p-He collision was collected at the end of 2015 by the LHCb experiment at 7 TeV (arXiv:1705.05438) and at 4 TeV.

- We want to perform a measurement with the SPS protons at 20-280 GeV/c on fixed LH2 and LHe targets, and a magnetic spectrometer

INPUT TO DARK MATTER SEARCH: COSMIC RAYS ANTIPROTONS



- the Cosmic Ray generated antiproton (secondary) component is expected to decrease more rapidly than the primary proton spectrum

- however the predictions are affected by several uncertainties

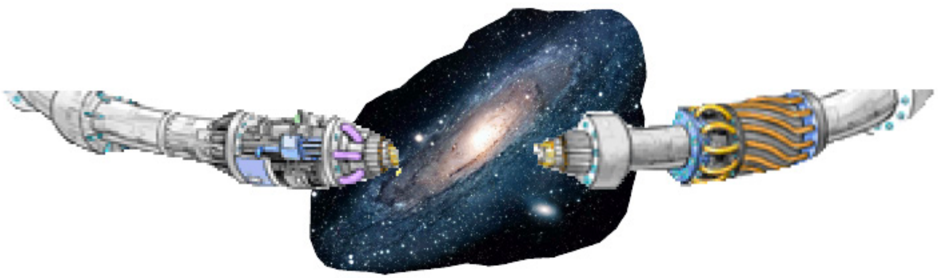
- we can identify three sources of uncertainty: the primary slopes, the propagation in the Galaxyand the antiproton production cross section

INPUT TO DARK MATTER SEARCH: COSMIC RAYS ANTIPROTONS

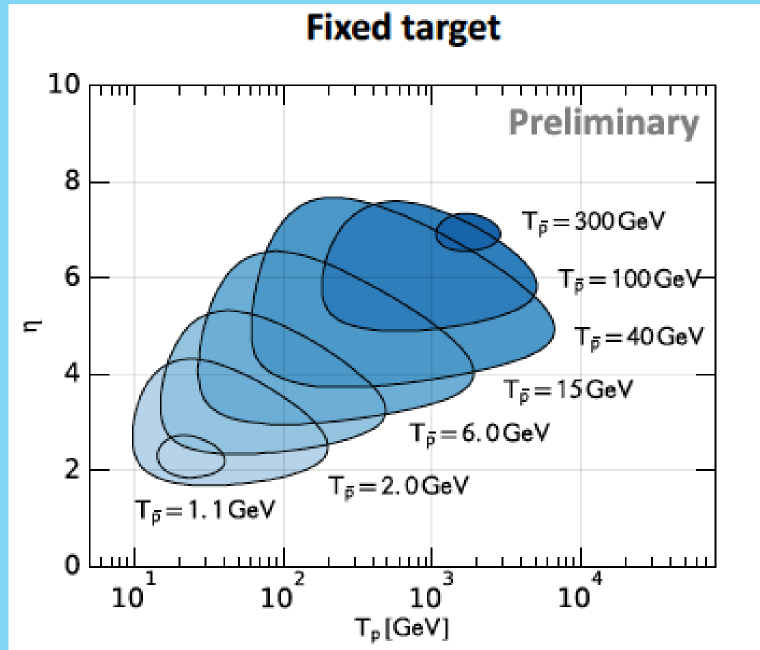
In order to cover all the AMS-02 pbar energy range
precise p+ p --> pbar+X and p+He --> pbar +X cross-section data are needed with:
proton beam kinetic energy Tp from 10 GeV to 6 TeV
a pseudorapidity η ranging from 2 to almost 8

The energy scale relevant for cosmic ray experiments is considerably below the energy scale of operating colliders:
AMS-02 is expected to detect antiprotons up to kinetic energies of several 100 GeV, which descend from primary cosmic rays with energies
$E \approx 10$ to 10000 GeV.

This corresponds to CM energies sqrt(s) $\approx$ 4-100 GeV

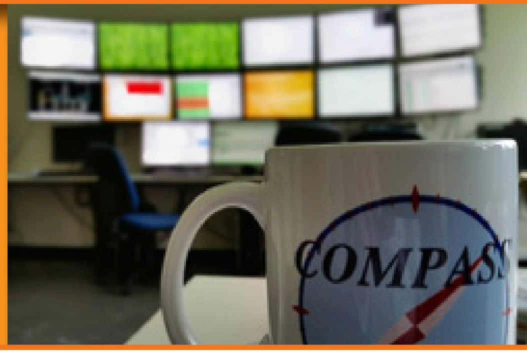


F. Donato, M. Korsmeier, M. Di Mauro
Phys.Rev. D96 (2017) no.4, 043007



AMS-02 pbar flux accuracy is matched if the cross section is measured at the 3% uncertainty inside the contours and at the 30% level outside

EXPERIMENTAL REQUIREMENTS: A COMPASS-LIKE SPECTROMETER



Most important features

1. Hadron beams
momentum range 20-280 GeV
intensities up to 10^8 particles per second

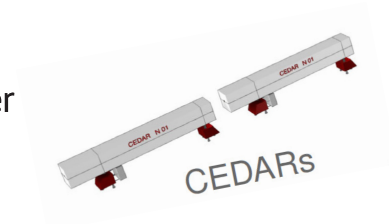
2. liquid hydrogen (helium) target

3. Advanced tracking

4. powerful PID systems
(RICH, Calorimeters, Muon Walls)

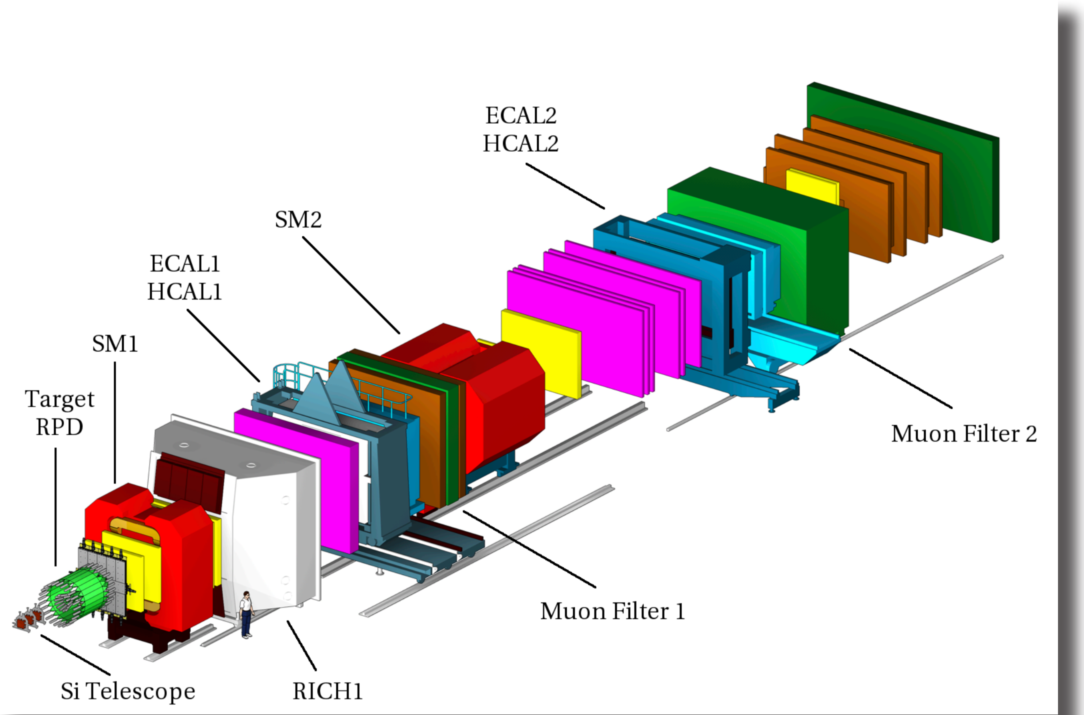
5. new DAQ

A high momentum resolution for charged particles provided by a two-stage magnetic spectrometer



Accessible final states

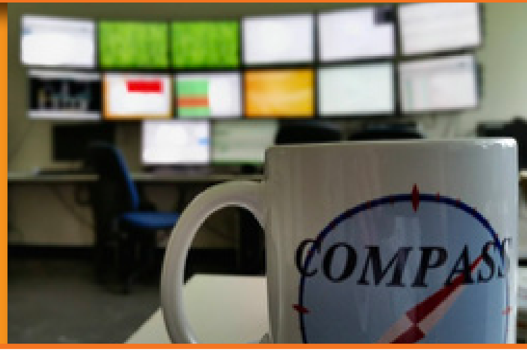
π, k, p, pbar, gammas



2009 data

190 GeV/c proton beam
40 cm long Liquid H2 target

EXPERIMENTAL REQUIREMENTS:
THE M2 HADRON BEAM LINE



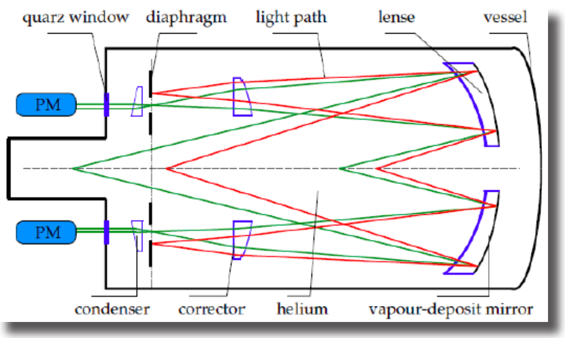
Momentum (GeV/c)	Positive beams π^+	K^+	p	Negative beams π^-	K^-	$\bar{p}$
100	0.618	0.015	0.367	0.958	0.018	0.024
160	0.360	0.017	0.623	0.966	0.023	0.011
190	0.240	0.014	0.746	0.968	0.024	0.008
200	0.205	0.012	0.783	0.969	0.024	0.007

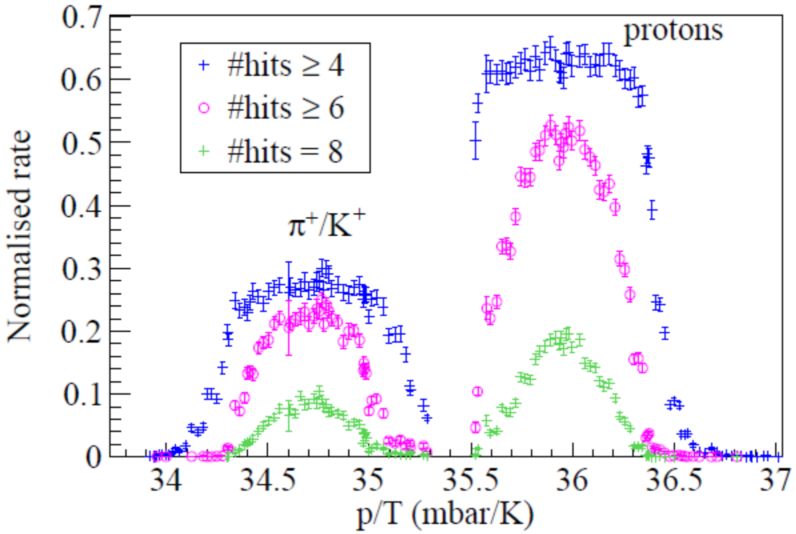
Most important features

Maximum beam momentum (high-energy mode) 280 GeV/c

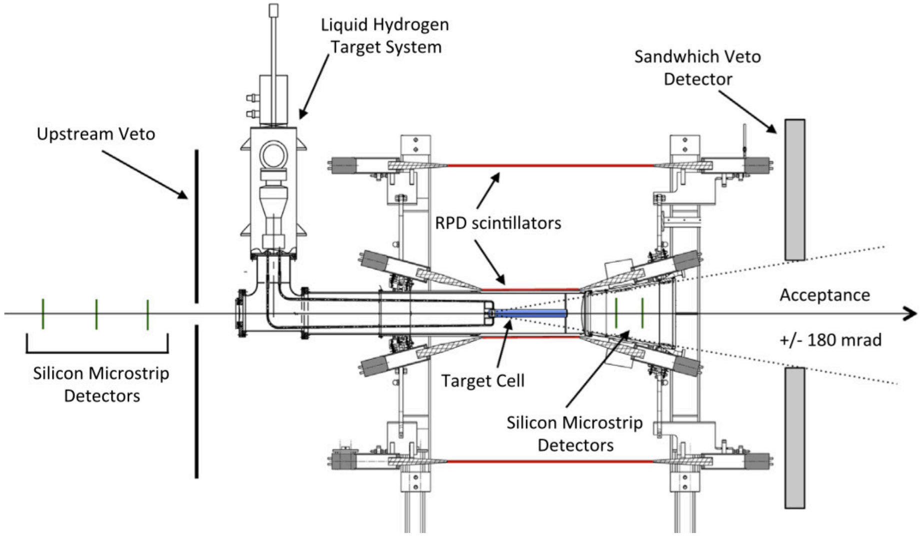
Two CEDARs designed to provide fast beam particle identification at high rates for particle momenta up to 300 GeV/c

a particle identification efficiency of almost 90% for protons is estimated using a multiplicity of 4 with a high purity of larger than 95% for the chosen working point of the CEDAR





EXPERIMENTAL REQUIREMENTS: A COMPASS-LIKE SPECTROMETER

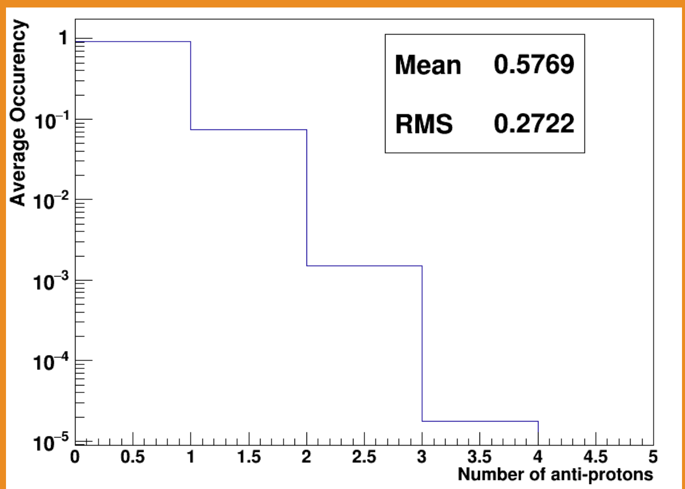


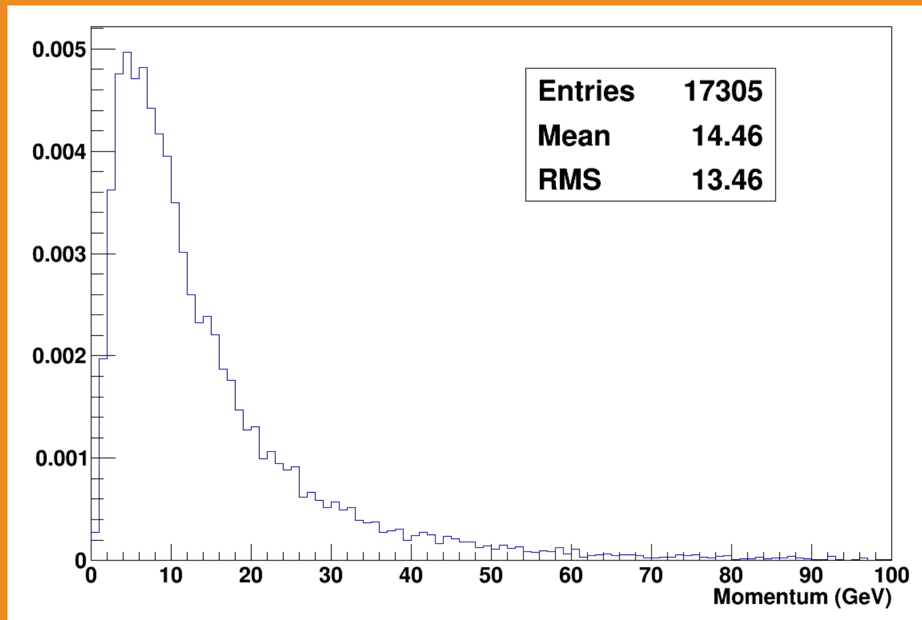
Acceptance:
+/- 180 mrad
+/- 10 deg
>2.4 η

	p+p	p+He
Beam Mom	190 GeV/c	190 GeV/c
Mult ($Z \neq 0$)	7.7	10.1
$\bar{p}$ ev frac	7.1%	7.7%
$\bar{p}$ $\langle p \rangle$(GeV/c)	15.3	14.5

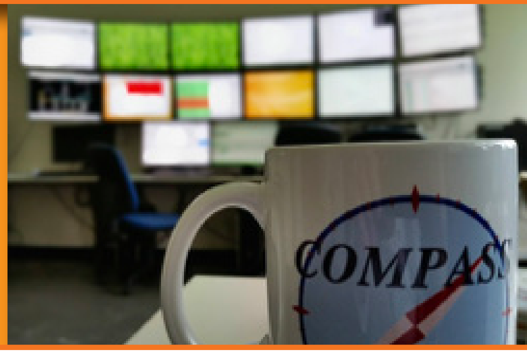
p-LHe event features @ 190 GeV/c

pbar

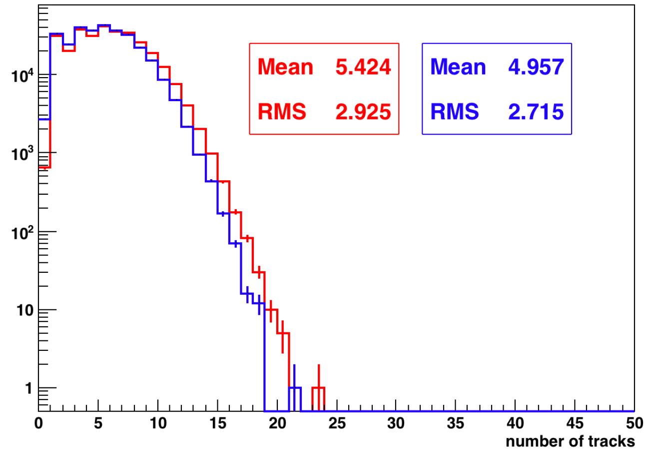




EXPERIMENTAL REQUIREMENTS:
A COMPASS-LIKE SPECTROMETER



Number of tracks (θ <10 deg)

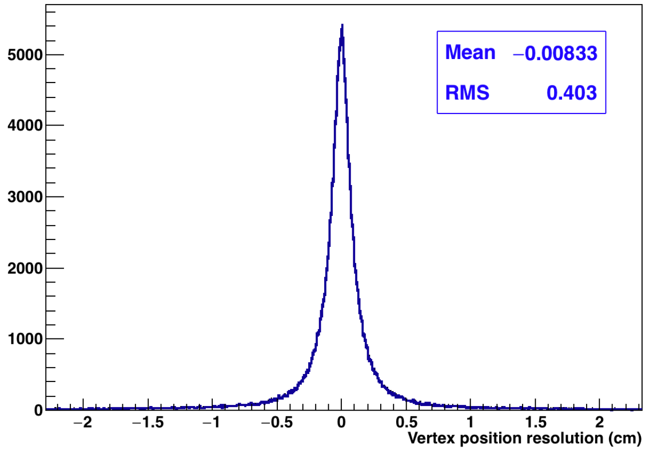


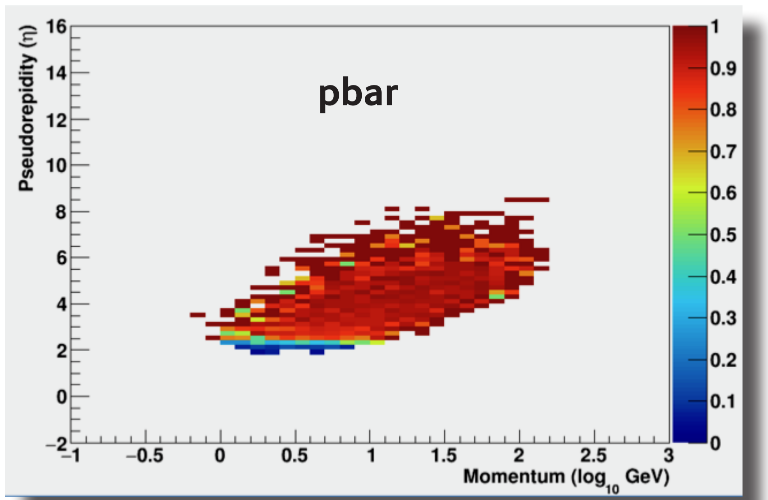
momentum resolution:
using the LAS (typically p < 20 GeV/c): $\sigma p/p$ 1%,
using the SAS: $\sigma p/p$ 0.3%.

Angular resolution: typical value of 0.8%
< 3% in the pseudo rapidity range $2.4 < \eta < 8$

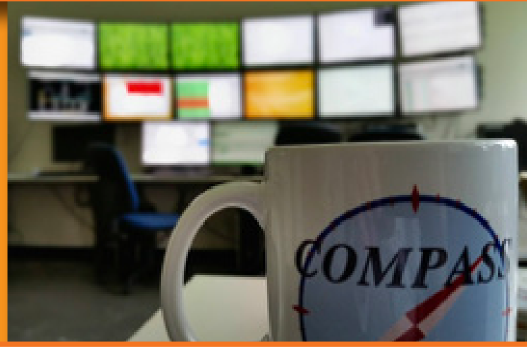
Track association in vertexes is very efficient. Within the spectrometer acceptance (η > 2:4; p >1 GeV/c) the ratio of the primary vertex reconstructed track multiplicity to the MC multiplicity is 0.98+/-0.05

the vertex resolution along the beam axis better than 4 mm



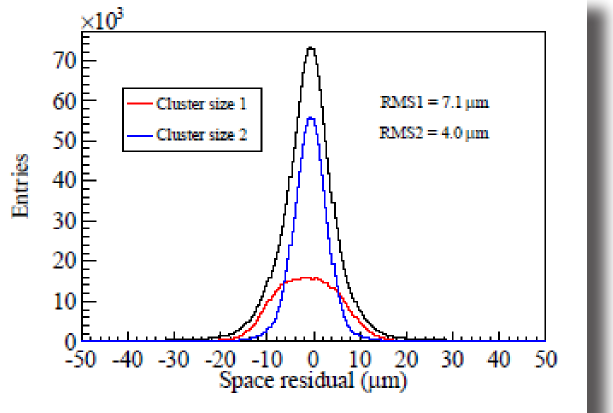


EXPERIMENTAL REQUIREMENTS: PRECISE VERTEX RECONSTRUCTION



Precise tracking immediately upstream and downstream of the target is performed by silicon microstrip detectors:
three stations upstream of the target, which are used as a beam telescope, and
two stations downstream of the target, which are used for vertex reconstruction

The spatial resolution of the cold silicon detectors is in the range 4–6 µm for clusters when two strips are hit. When only one strip is hit, the resolution is in the range 7–11 µm.

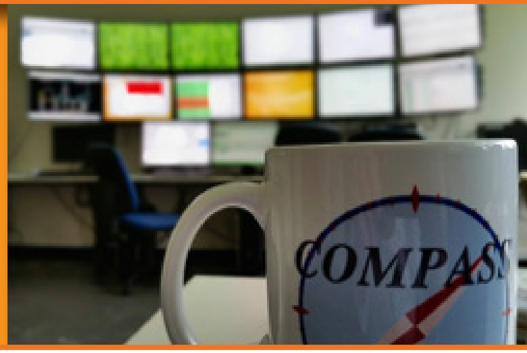


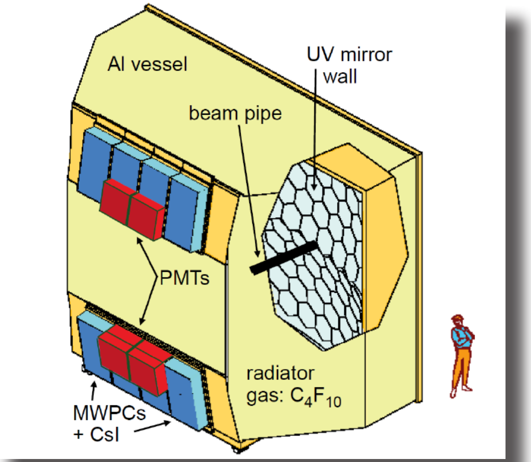
high resolution of the primary vertex position and tracking to reject pbar from hyperons decay (Λ, Σ)

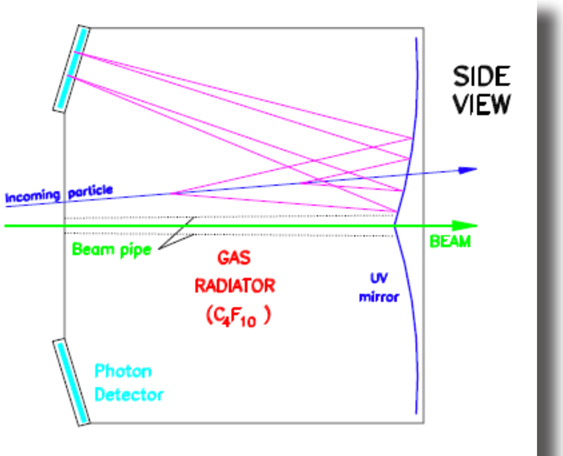
For the tracking in the beam region: pixelised Gas Electron Multiplier (GEM) detectors with a minimised material budget along the beam

For the tracking at small angles: pixelised Micromegas trackers

EXPERIMENTAL REQUIREMENTS: THE RICH FOR PID

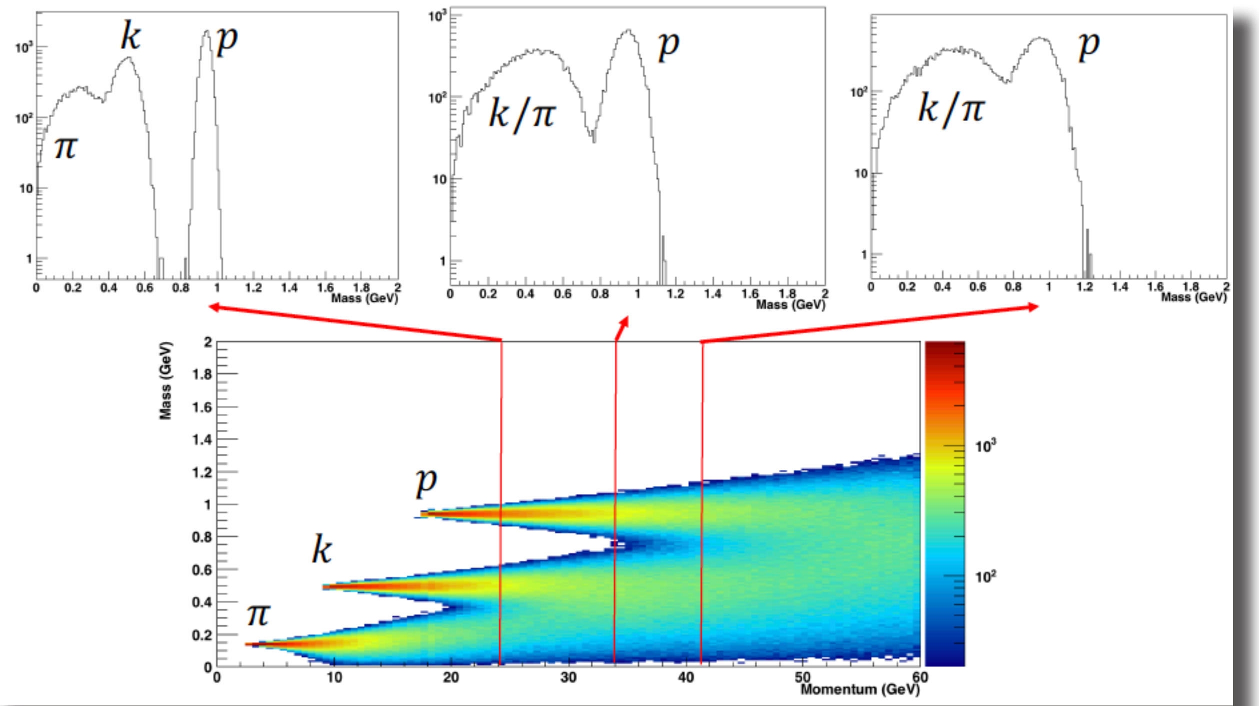






The RICH radiator is a buffer of C_4F_{10} gas with refraction index n = 1.0014

The corresponding momentum threshold depends on the particle mass: pmin = 2.6 GeV/c for kaons, pmin = 9.3 GeV/c for pions, **pmin = 17.7 GeV/c for protons**



EXPERIMENTAL REQUIREMENTS:
THE RICH FOR PID

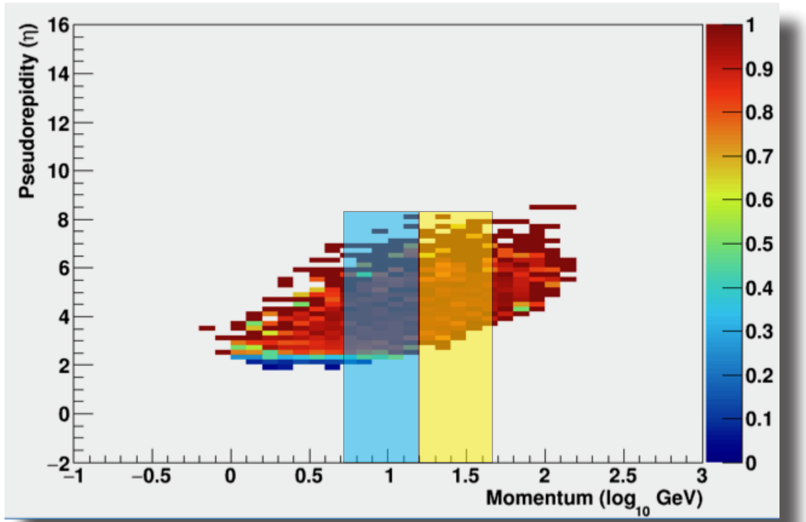
Two antiprotons momentum ranges:

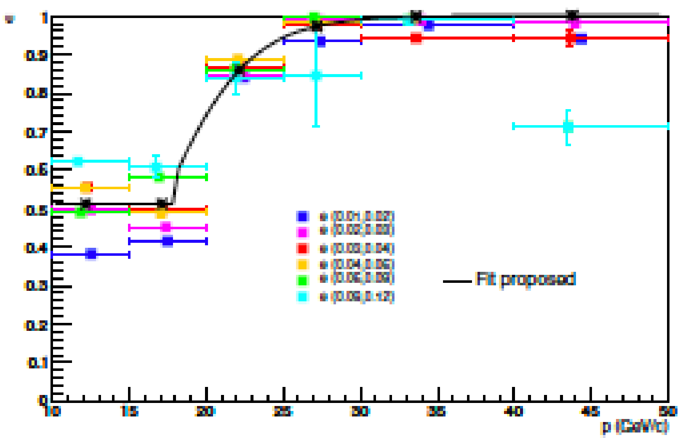
The first p[18;45]GeV/c where we can use the RICH to identify the antiprotons by their mass.

The second p[5;18]GeV/c where we use the absence of the RICH signal (veto mode)
to identify the particle as not π or K

OR

construction of a new “RICH0”





	$\bar{p}$		
Region	$FIT(\bar{p} \to \bar{p})$	$FIT(\bar{p} \to \pi^-)$	$FIT(\bar{p} \to K^-)$
10-15 GeV/c	0.5119 ± 0.0872	0.23 ± 0.0917	0.1832 ± 0.0331
15-20 GeV/c	0.5119 ± 0.0706	0.1792 ± 0.0652	0.1832 ± 0.0151
20-25 GeV/c	0.8377 ± 0.0799	0.0207 ± 0.0508	0.0790 ± 0.0177
25-30 GeV/c	0.9484 ± 0.0387	0.0057 ± 0.0248	0.0301 ± 0.0109
30-40 GeV/c	0.9722 ± 0.015	0.0011 ± 0.0147	0.0084 ± 0.011
40-50 GeV/c	0.9749 ± 0.0282	0.0001 ± 0.0312	0.0011 ± 0.0047

CROSS-SECTION MEASUREMENT

Strategy
– Count all the p-p (or p-He) interaction in the target (Ri)

– Identify events with one (or multiple) pbar vs reconstructed momentum and angle (Rs (p, θ))

– Calculate the double differential cross section as:

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

Proton beam intensity 5 *10^5 p/s

Different beam momenta: 20-280 GeV/c

40 cm long LHe (and LH2) target

Typical trigger rate: 25KHz

Expected ≈ 25 * 10^4 events per minute with 10sec SPS super cycle

double differential cross section with 20 bins in momentum and pseudorapidity --> we will reach a statistical error of 1% after a few hours of beam time

Different sources of systematic errors:
trigger efficiency, DAQ dead time, CEDAR purity
Reconstrruction efficiency, tracking efficiency, PID efficiency

Overall we expect to reach a systematic error of the order of 5%.

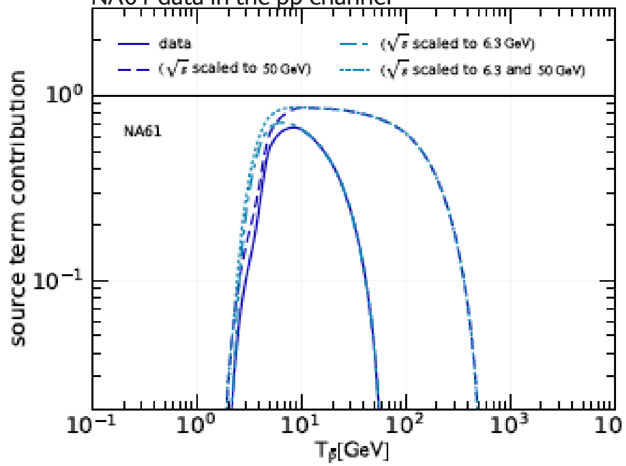
COMPETITION AND COMPLEMENTARITY

	Experiment	$\sqrt{s}$ [GeV]	
p-p	NA49	17.3	
p-p	NA61	7.7, 8.8, 12.3, 17.3	
p-He	LHCb	86.7, 114.7	$2 < \eta < 5$
p-He p-p	COMPASS++	6.3 - 23	$2.4 < \eta < 5$

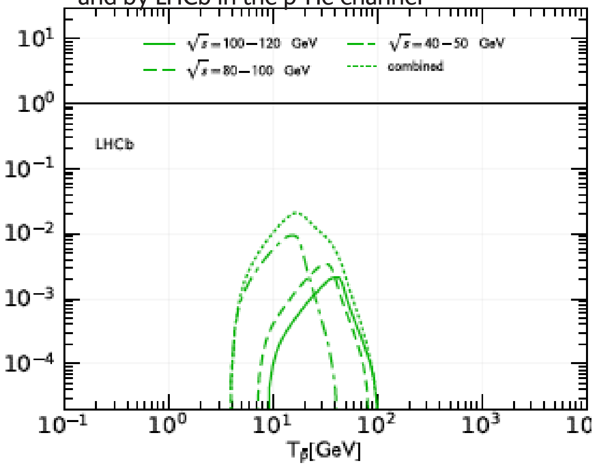
	pbar(18-45 GeV/c)	pbar (5-18 GeV/c)
p-p @ 0-280GeV/c	OK 2009 data @190GeV	RICH veto or RICH0
p-He @0-280GeV/c	new LHe target	RICH veto or RICH0

F. Donato, M. Korsmeier, M. Di Mauro
Phys.Rev. D97 (2018) no.10, 103019
Fraction of the antiproton source term originating from the kinematic parameter space of the cross section which currently is experimentally determined by:

NA61 data in the pp channel



and by LHCb in the p-He channel



The LHCb data are taken at very high energies of sqrt(s) = 110 GeV -> their antiproton production in the energy range interesting for CRs results in a very small contribution to the source term

Combined with the LHCb measurements at very high energy, the **COMPASS++ data** could fulfill the necessary kinematical coverage, finally contributing to significantly reduce the uncertainty the expected amount of secondary antiprotons produced by spallation of primary cosmic rays on the in terstellar medium

ARE YOU INTERESTED IN THIS PROGRAM?

CONTACT US!

PERSONS ALREADY INVOLVED

COMPASS collaboration members

AMS: Paolo Zuccon (University of Trento and INFN), Nicolò Masi (University of Bologna and INFN)

Theoretical Physicist: Fiorenza Donato (University of Torino and INFN)

	pbar(18-45 GeV/c)	pbar (5-18 GeV/c)
p-p @ 0-280GeV/c	OK 2009 data @190GeV	RICH veto or RICH0
p-He @0-280GeV/c	new LHe target	RICH veto or RICH0

analysis of 2009 COMPASS data with 190 GeV/c proton beam on 40 cm long Liquid H2 target is ongoing to complete the fisibility studies for the preparation of the proposal