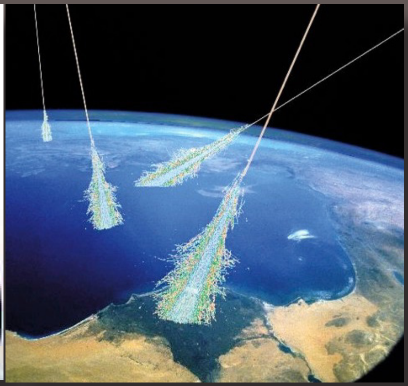
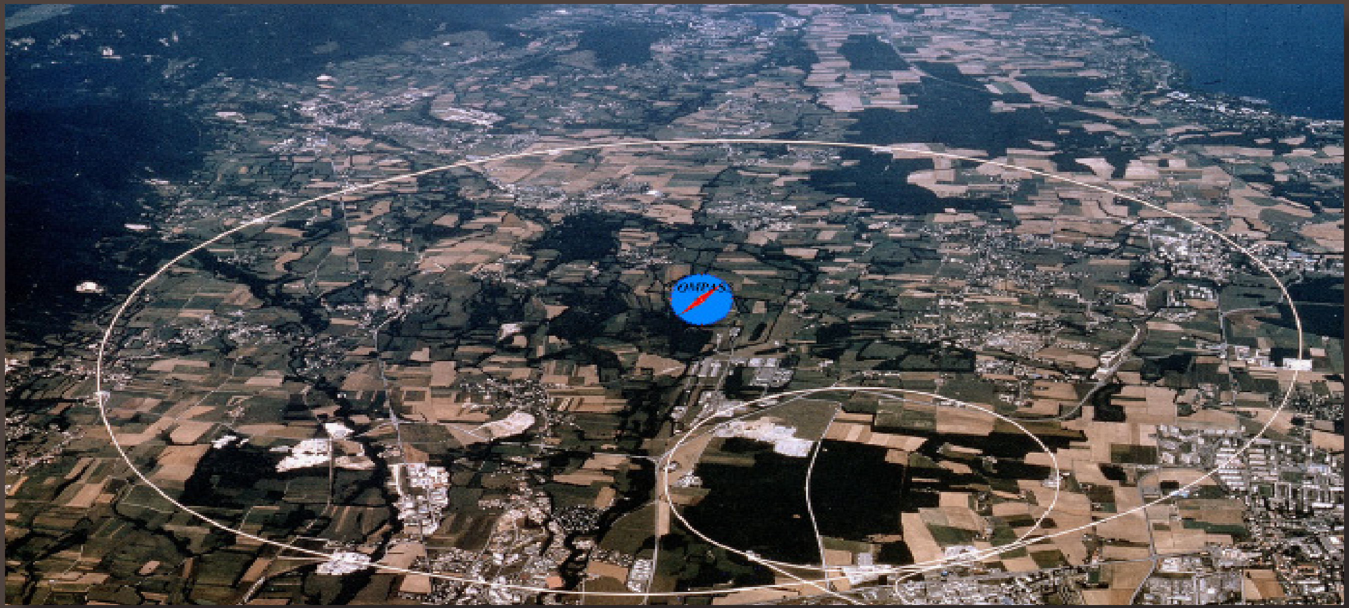
THE COMPASS DETECTOR POTENTIALS FOR COSMIC RAYS PHYSICS

Michela Chiosso
Compass Collaboration

XSCRC2017: Cross sections for Cosmic Rays @ CERN
29 - 31 March 2017

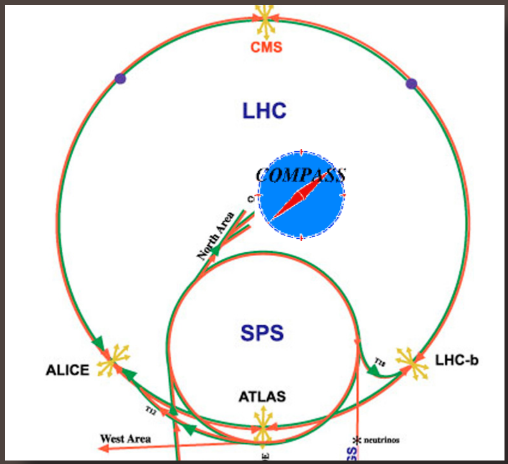


THE COMPASS FACILITY @ CERN

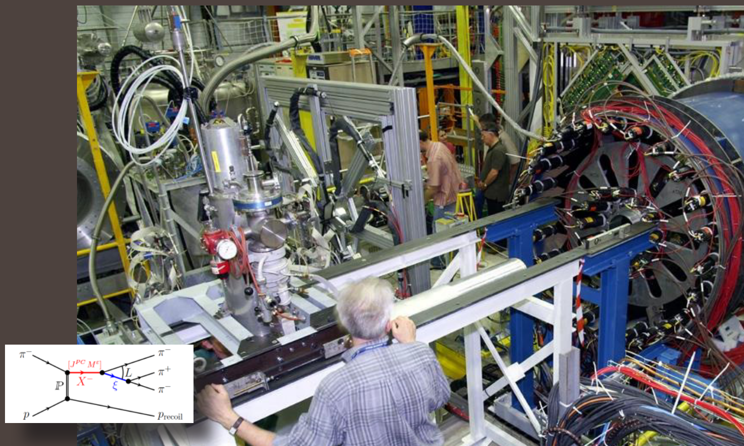


COMPASS Collaboration:
~240 physicists
(~60 PhD, ~25 Master & Diploma students)
12 countries + CERN, 24 institutions

COMPASS Spectrometer at SPS M2 beam line (CERN)
versatile and flexible apparatus

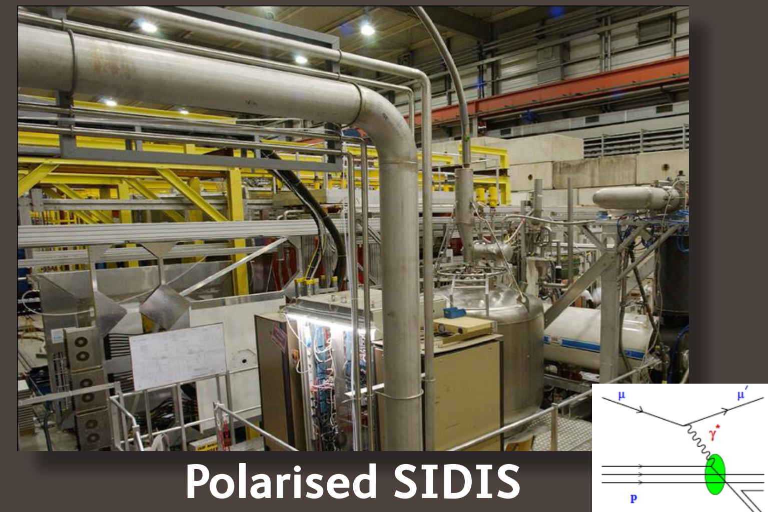


COMPASS FACILITY AT SPS M2 BEAM LINE



Hadron Spectroscopy & Polarisability

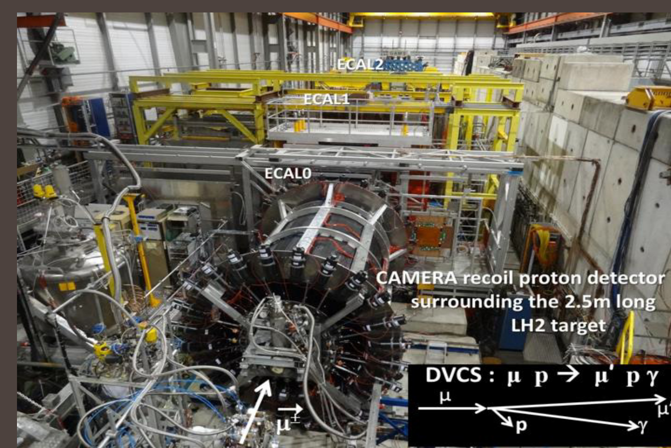
COMPASS I
2002-2011



Polarised SIDIS

Polarized Drell-Yan

COMPASS II
2012-2018



DVCS (GPDs) + unp. SIDIS

COMPASS WHAT NEXT?

COMPASS beyond 2020 Workshop

21 Mar 2016, 08:05 → 22 Mar 2016, 17:10 Europe/Zurich

222-R-001 (CERN)

Description The goal of the workshop is to explore hadron physics opportunities for fixed-target COMPASS-like experiments at CERN beyond 2020 (CERN Long Shutdown 2 2019-2020). The programme comprises

- Reviews of the various physics domains: TMDs, GPDs, FFs, spectroscopy, exotics, tests of ChPT, astrophysics

- Reviews of physics results expected in the next 10 years from major labs around the world

- Some critical long-term issues of the COMPASS spectrometer

- Discussions

https://indico.cern.ch/event/502879/

March 2017: IWHSS workshop in Cortona (Tuscany, Italy)

COMPASS WHAT NEXT?
Opportunity beyond 2020

COMPASS has joined the CERN “Physics Beyond Colliders” Working Group

Long-range plan focused on separated kaon and antiproton beams
- TMD parton distributions via Drell-Yan
- direct photon production
- Strange-meson excitation spectrum, K-γ-reactions
- ppbar beyond 5 GeV/c^2

mid-range plans
- pion DY
- semi-inclusive DIS, (polarised) DVCS, DVMP (muon beam!)
- hadron spectroscopy
- dark-matter search (e.g. pbar production c.s.)

Drafting of a new LoI in 2017

THE COMPASS FACILITY @ CERN

COmmon Muon and Proton Apparatus for Structure and Spectroscopy

Most important features

1. Muon, electron or hadron beams
momentum range 20-250 GeV
intensities up to 10^8 particles per second

2. Solid state polarised targets (NH3 or 6LiD)
as well as liquid hydrogen target and
nuclear targets

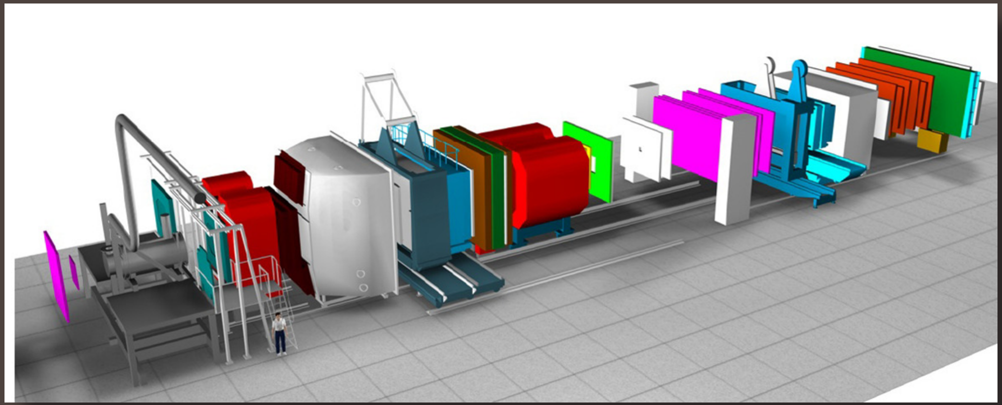
3. Advanced tracking (350 planes)

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

5. new DAQ

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

Accessible final states
p, k, p, pbar, gammas



2009 data

190 GeV/c proton beam
40 cm long Liquid H2 target
Trigger on recoil proton
measurements with nuclear targets:
a target holder can house up to 16 target disks

CAN COMPASS CONTRIBUTE TO…

Dark Matter searches related measurements:
p-He cross section measurements --> pbar production in ISM

High Energy Cosmic Rays composition related searches:
particle production in atmospheric showers

?

COSMIC RAYS ANTIPROTONS

Cosmic ray antiprotons are a remarkable diagnostic tool for astroparticle physics

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

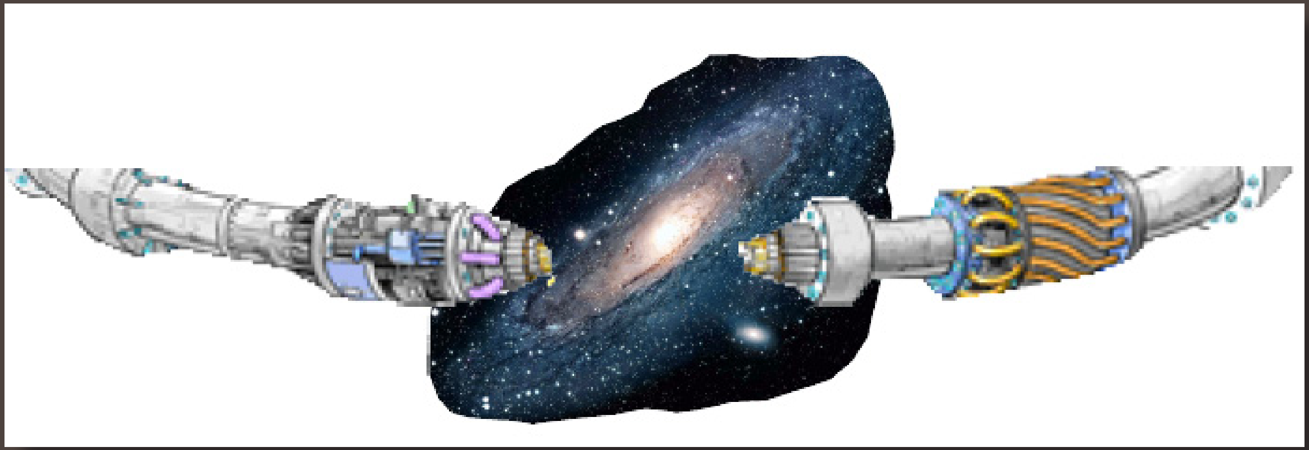
More precise measurements of secondary components are needed
Secondary components mainly come from:
p-p; p-He; He-p; He-He

Reactions involving helium represent a sizable fraction of the total yield
p p: 56%; p He: 24 %; He p: 12 %; He He: 6 %; p N (C, N, O) : 2%

COSMIC RAYS ANTIPROTONS

AMS-02 detects antiprotons between 1GeV and a few 100 GeV, which descend from primary cosmic rays with energies from 10 GeV to 10 TeV.

This corresponds to CM energies between about 4-100 GeV



COSMIC RAYS ANTIPROTONS

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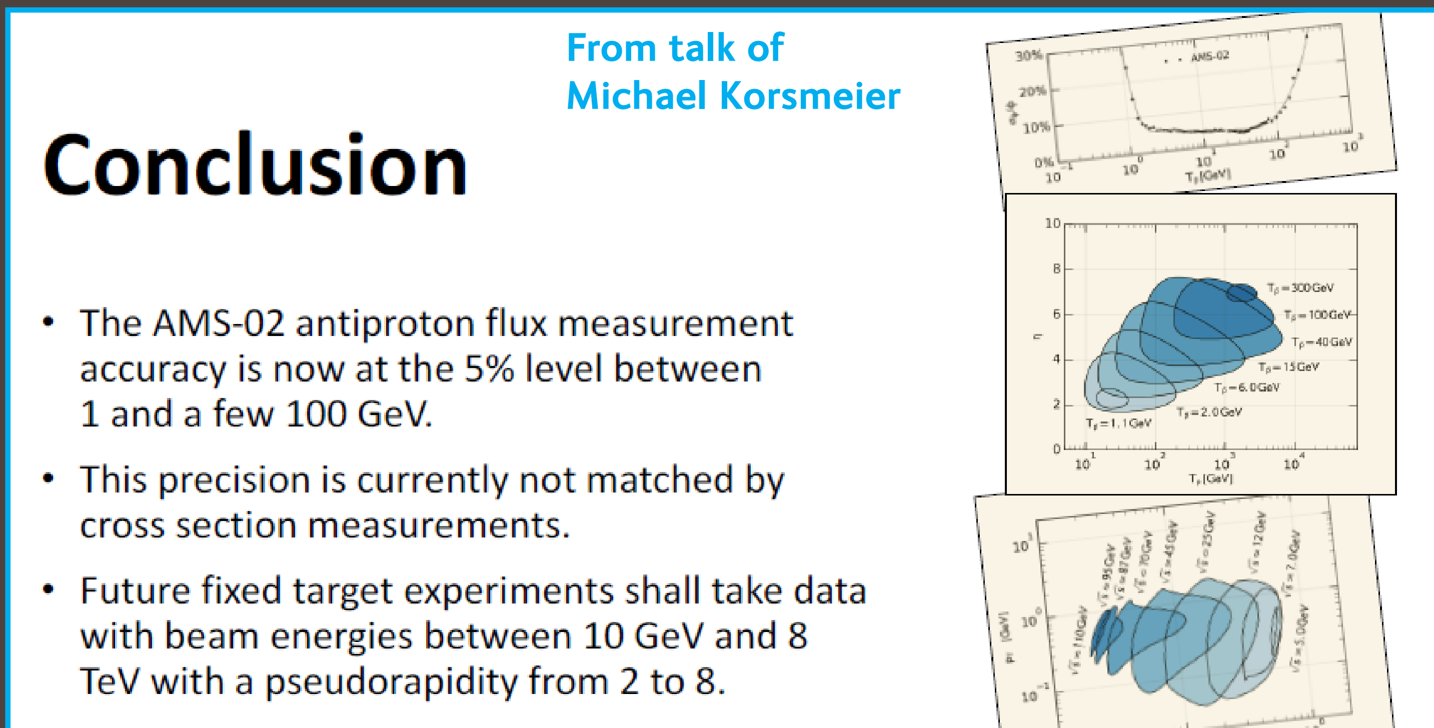


THESE EXPERIMENTS REQUIRE:

a state-of-the-art spectrometer with high acceptance and high resolution for charged and neutral particles in order to perform measurements of multi-particle final states over a wide kinematic range

Proton beam, variable energy in the range 10 GeV – 1 TeV

Liquid He target

micro vertex detection and precise tracking

Particles identification detectors: antiprotons, positrons, gammas in the final state

Data needed also on:

p+p and p+He $\rightarrow e^+ + X$ at $E_e < 50$ GeV

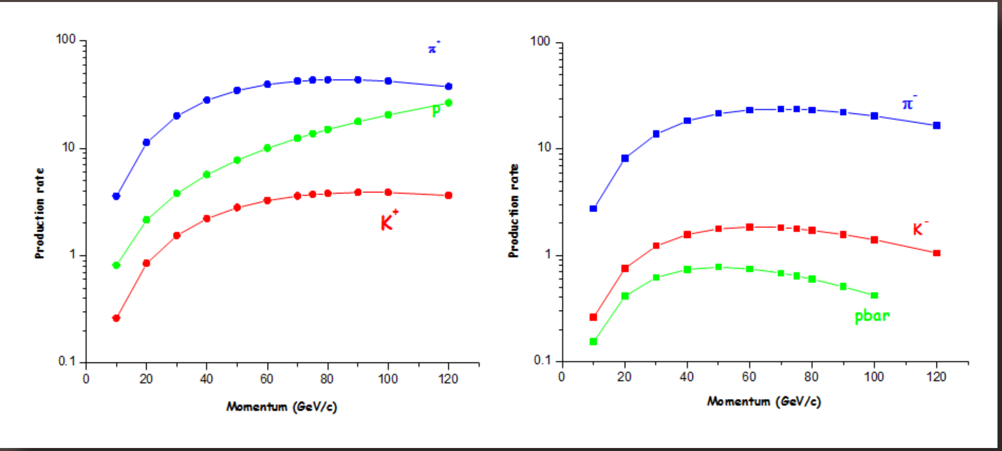
p+He $\rightarrow \pi^0 \rightarrow \gamma\gamma$ at E_γ from 500 MeV up to 500 GeV

The goal: absolute cross-section measurement at 3% level

COMPASS FACILITY AT CERN:
THE M2 BEAM LINE SECONDARY BEAMS

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

Advantages of the COMPASS setup: possibility to study reactions with different projectiles in high-intensity beams with up to 10^7 part./s and to reconstruct final states containing both neutral and charged particles

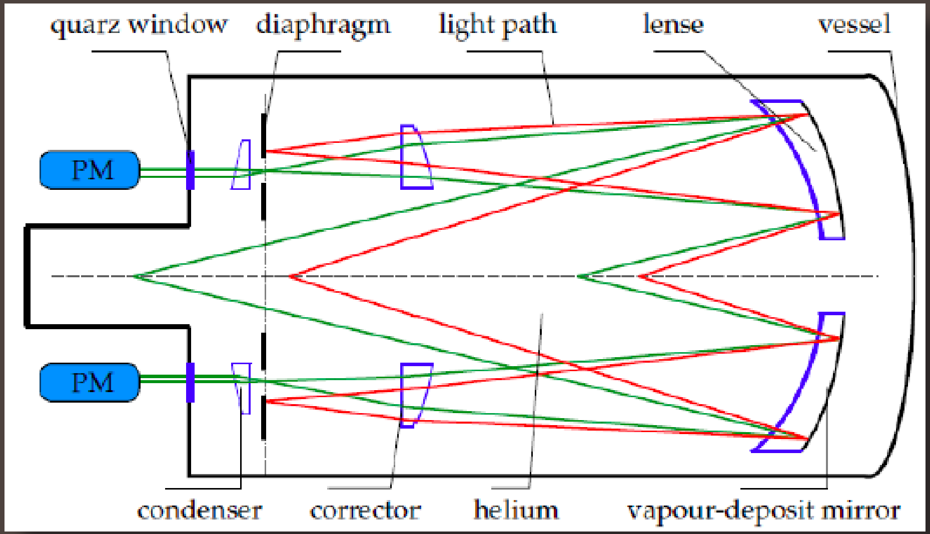


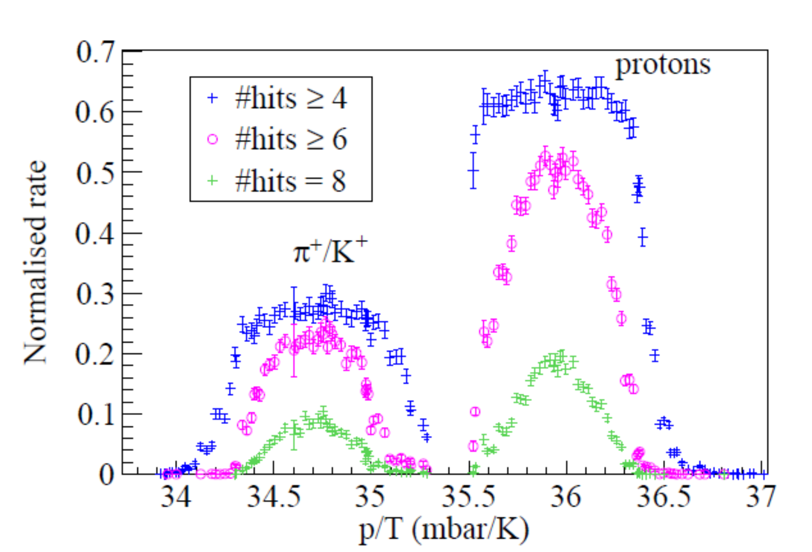
PROTON TAGGING WITH CEDARS

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

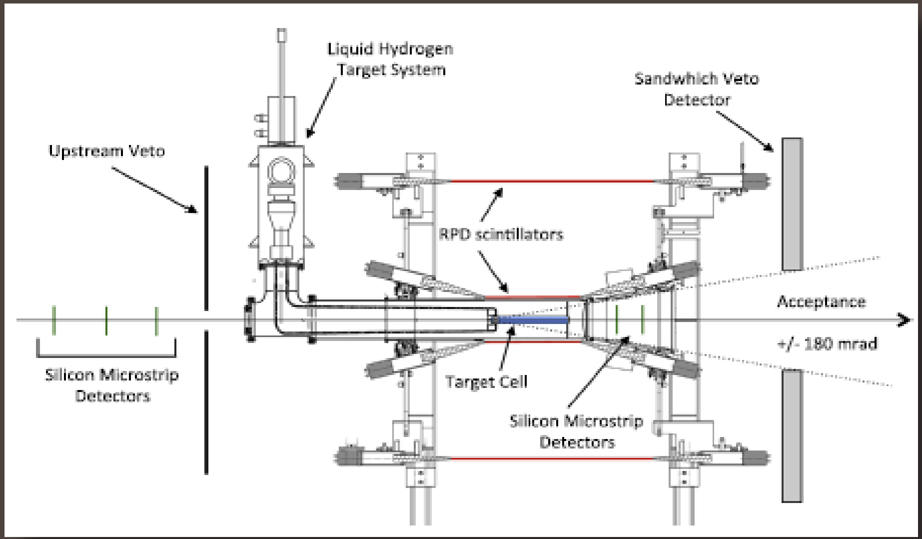
a particle identification efficiency of almost 90% for protons is estimated using a multiplicity of 4 with a high purity of larger than 95% for the chosen working point of the CEDAR

Nominal Beam intensity: of 5 x 10^6 s^{-1} (2009)
75% p at 190 GeV/c
With 90% efficiency of the CEDARs proton tagging
we can expect up to ≈ 3.4 x 10^6 p s^{-1}

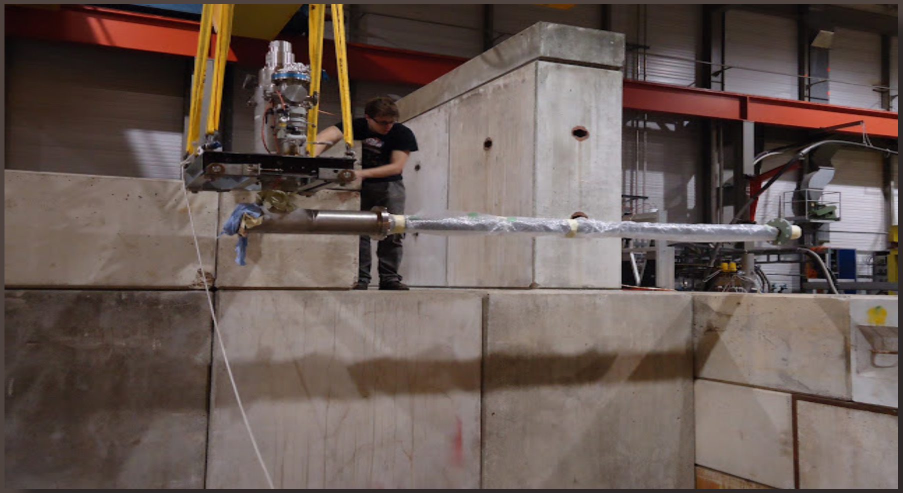




COMPASS LIQUID H2 TARGETS



Small 40 cm long liquid H2 target

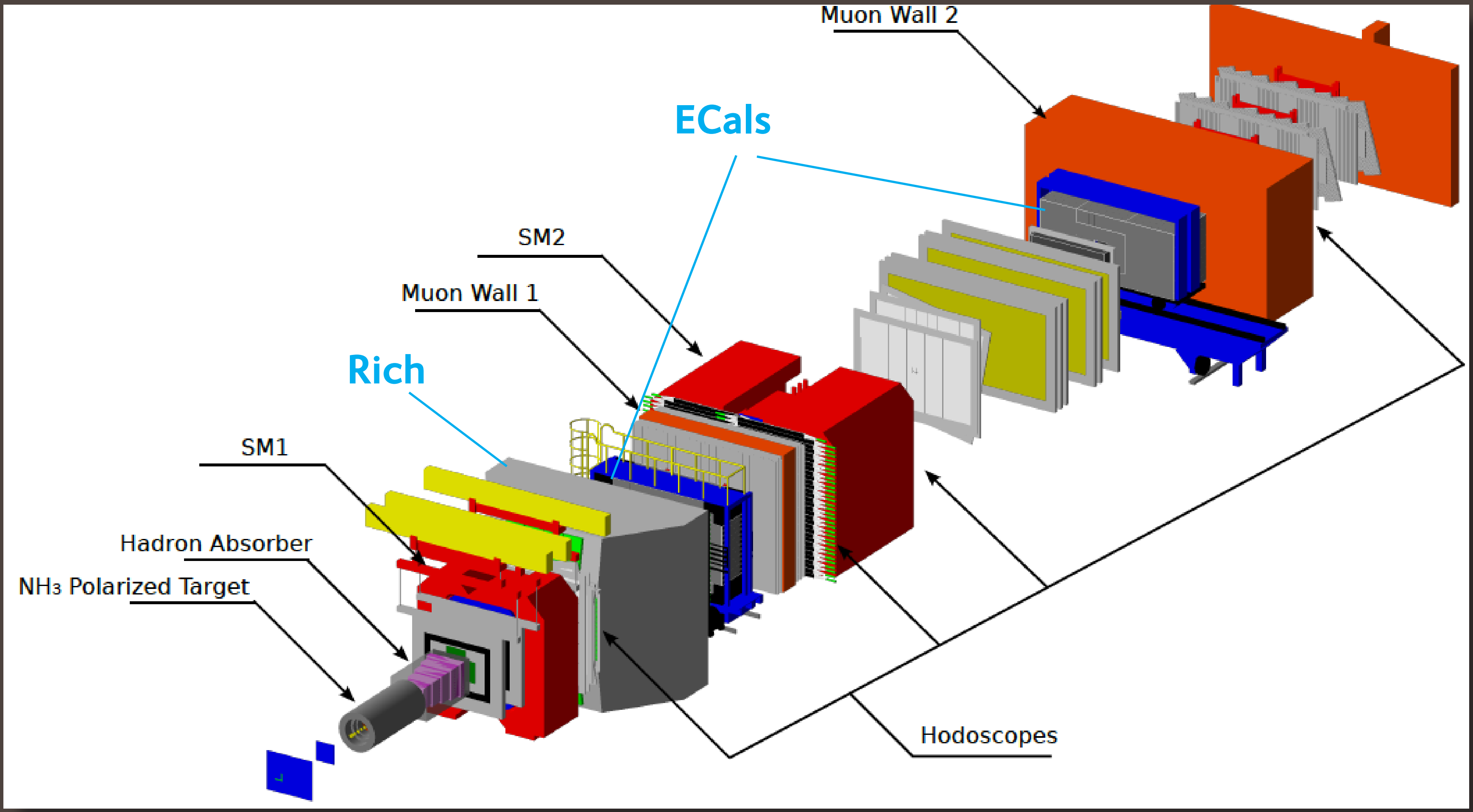


Large 2.5 m long liquid H2 target

Liquid He target will be based on the existing liquid LH2 target

PARTICLE IDENTIFICATION @ COMPASS

Antiprotons, gamma, positrons, pions

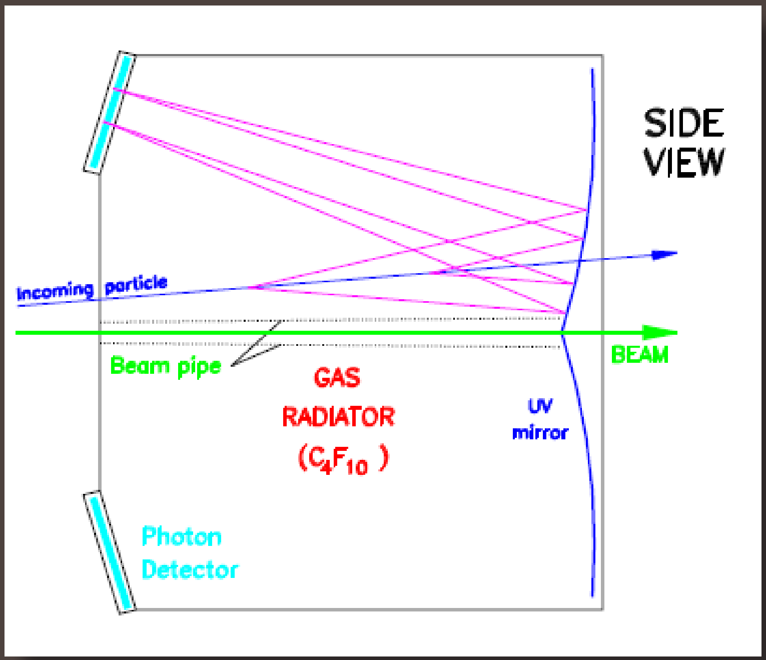


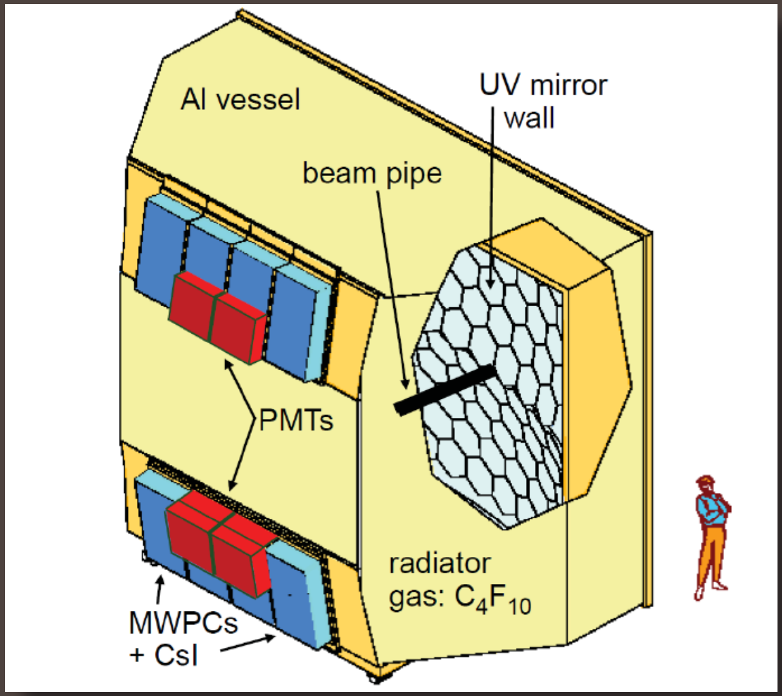
ANTIPROTON IDENTIFICATION

The RICH Detector

3m long vessel filled with C4F10 gas as a radiator

The refractive index of the radiator material (n 1.0015) corresponds to Cherenkov thresholds of about 2.5, 9, and 17GeV/c for pions, kaons, and protons, respectively.

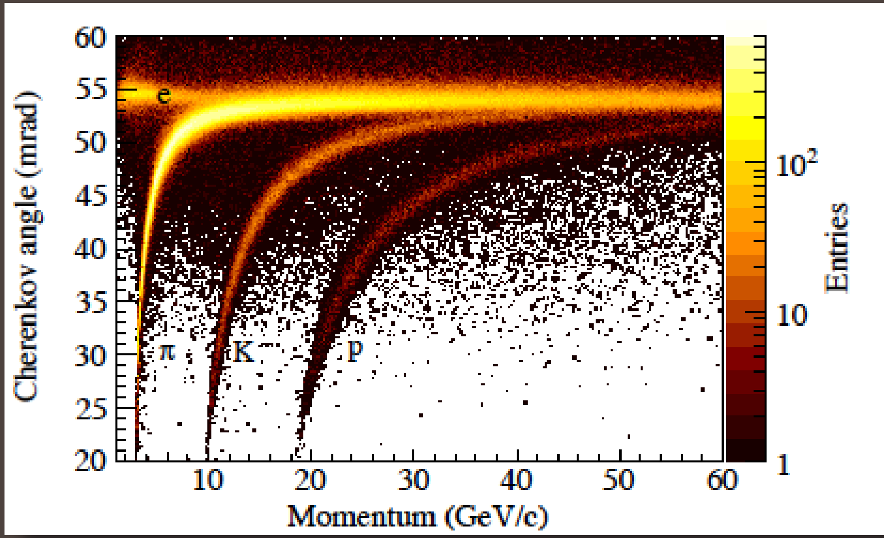


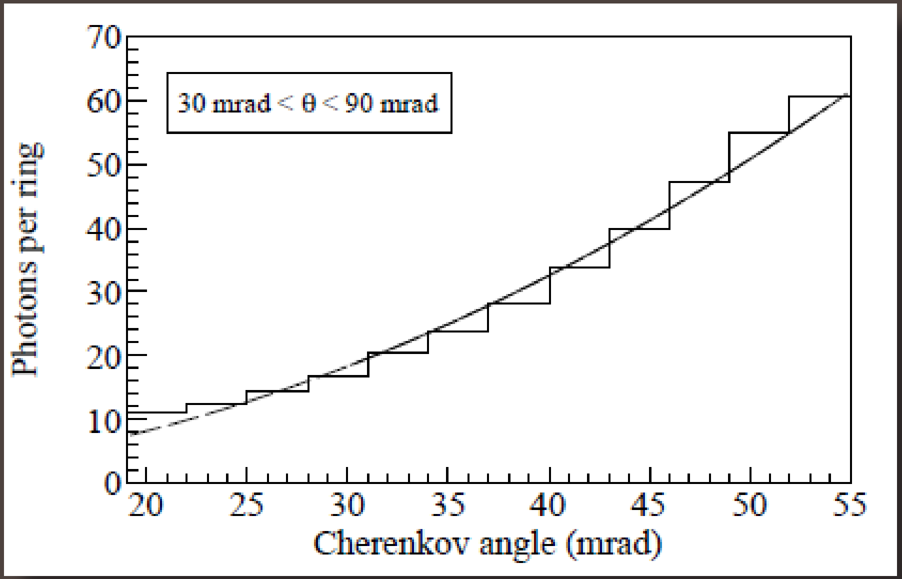


ANTIPROTON IDENTIFICATION

The RICH Detector

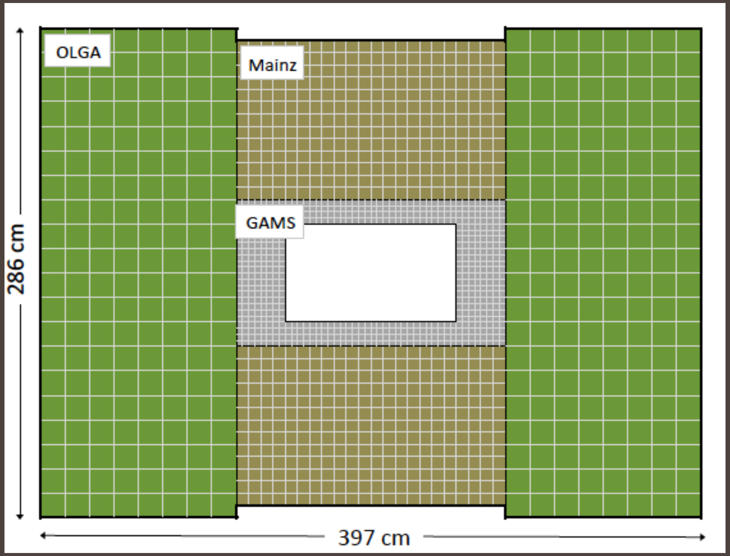
pion-kaon separation at 95% confidence level for momenta up to 45 GeV/c.
Average number of photons per ring at saturation, i.e. for $\beta=1$ is 56 in the central and 14 in the peripheral region
The uncertainties in the reconstructed angle of the individual Cherenkov photons is 2 mrad in the central region and 2.5 mrad in the periphery
The uncertainties in the determination of the mean Cherenkov angle (ring angle) are 0.3 mrad and 1.6mrad, respectively

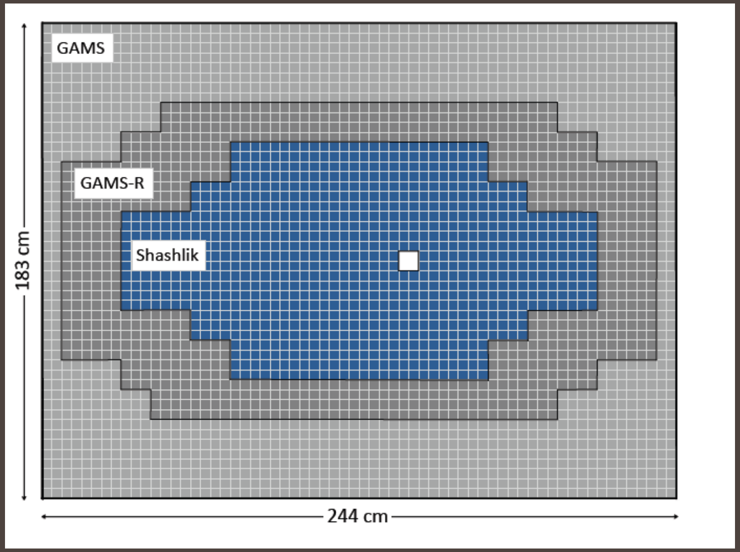




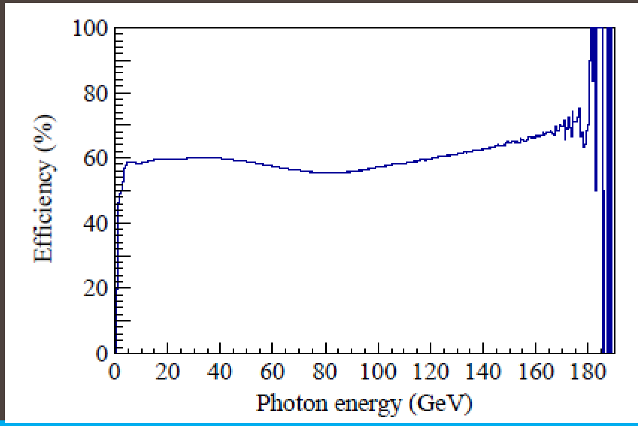
ELECTROMAGNETIC CALORIMETRY

ECAL1: the dynamic range is set to detect energies of up tp 60 GeV in GAMS cells, 30 GeV in MAINZ cells and 20 GeV in OLGA cells
ECAL2: the dynamic range of the central cells is set to a maximum energy of 150 GeV and to 60 GeV for the outermost two rows and lines for diffractive data taking





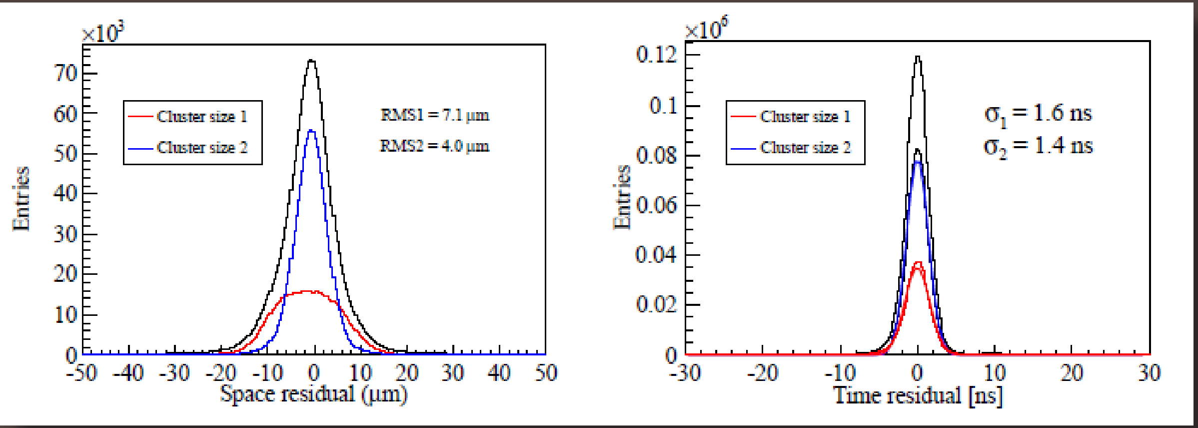
γ, $e^{+/-}$, π^0 separation capability in the final state



PRECISE VERTEX RECONSTRUCTION AND TRACKING

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.

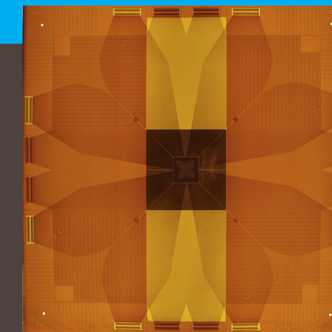


high resolution of the primary vertex position and tracking to reject pbar from hyperons decay (Λ, Σ)

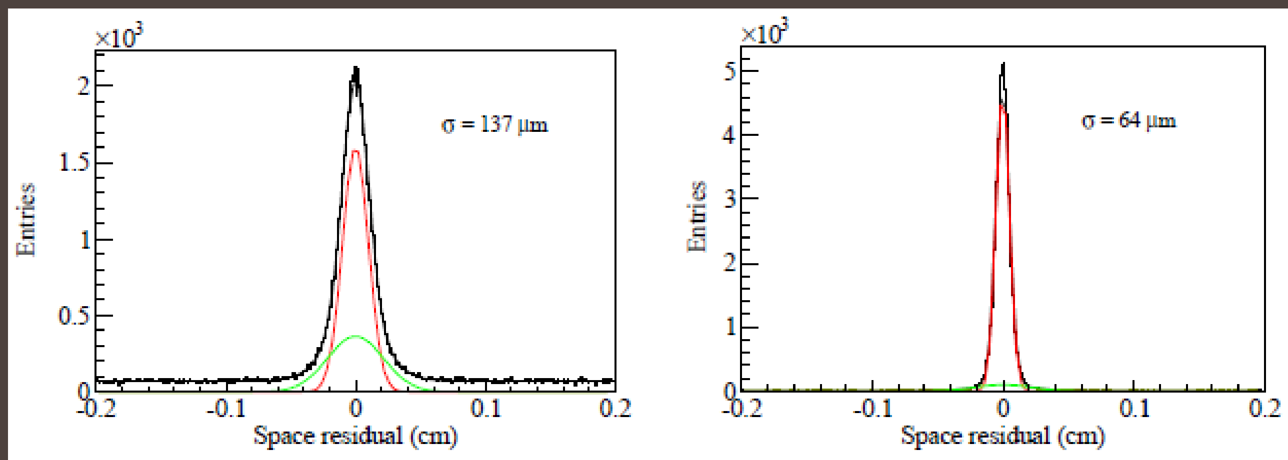
For the tracking in the beam region: pixelised Gas Electron Multiplier (GEM) detectors with a minimised material budget along the beam

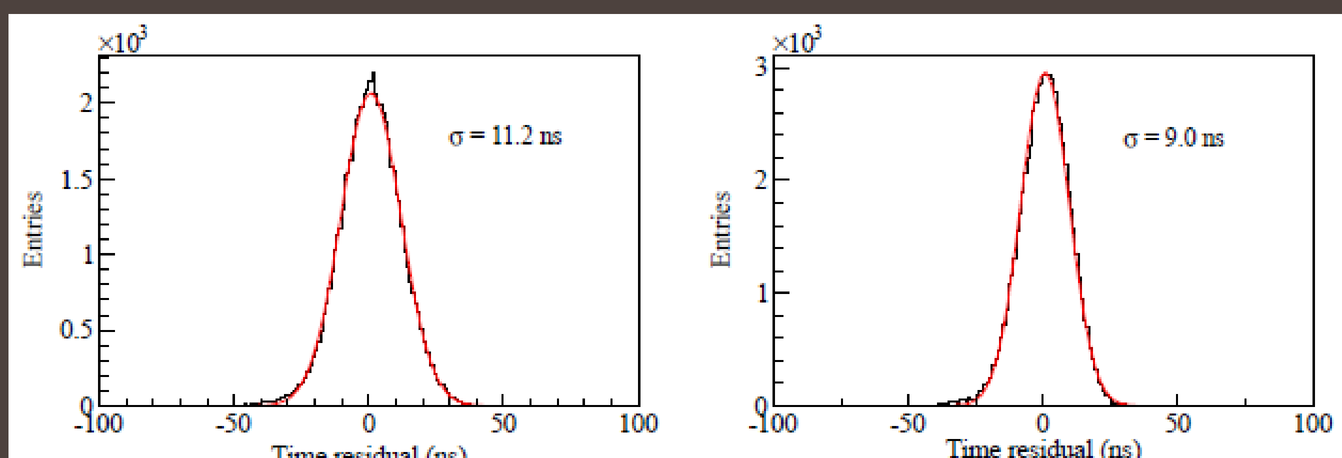
For the tracking at small angles: pixelised Micromegas trackers

PRECISE TRACKING



Pixel-GEMs detectors with pixel readout in the central region for precise tracking in the beam region, able to cope with the high particle fluxes in the beam centre, and to separate individual hits close to the beam





DATA SET C0LLECTED IN 2009

p + p -> pbar + X + p

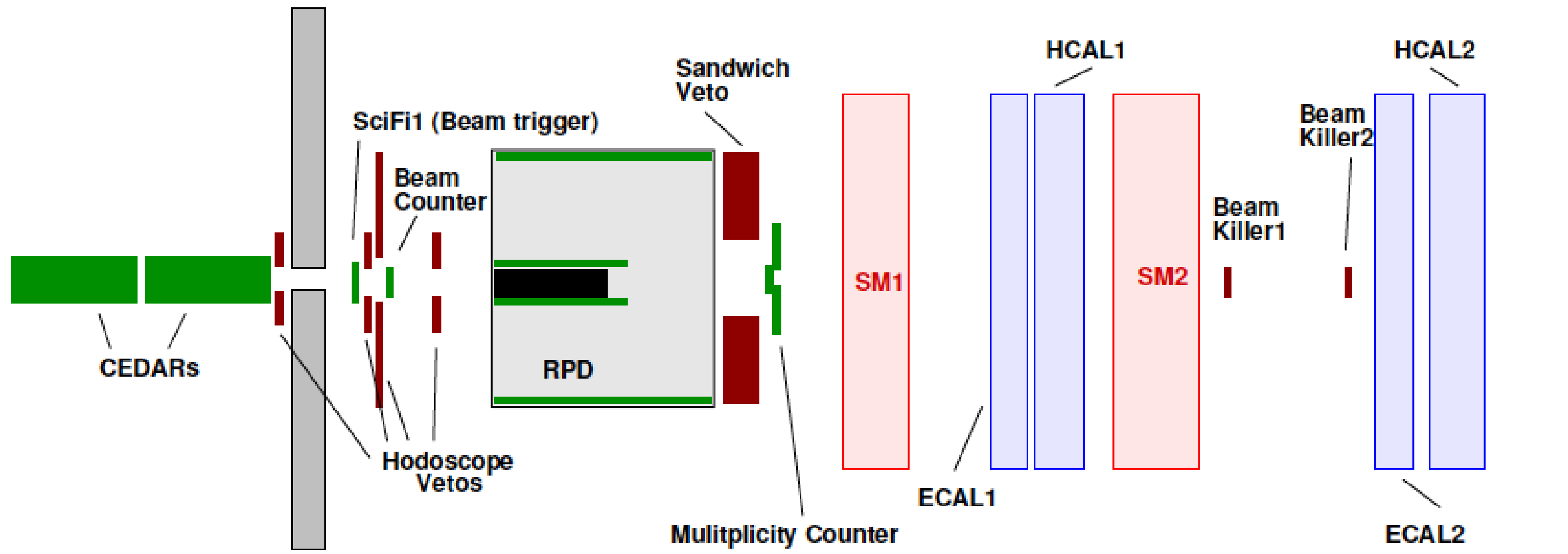


Fig. 51: Arrangement of trigger elements in the spectrometer (schematic side view, not to scale).

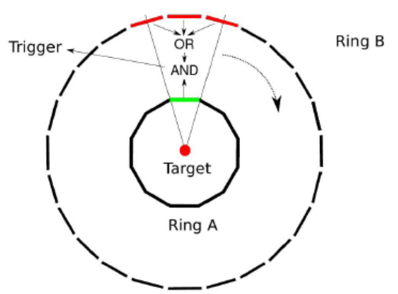
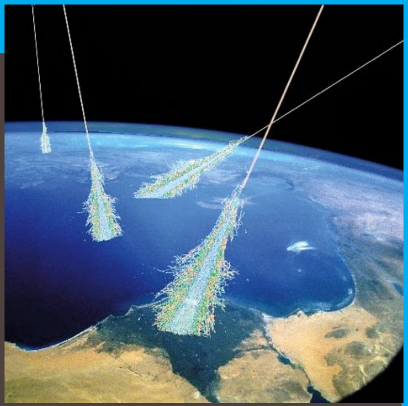


Fig. 54: Allowed combinations for target pointing in the RPD part of the proton trigger.

Physics trigger	**Logical composition**
Diffractive trigger DT0	BT $\wedge$ proton trigger $\bar{\wedge}$ veto

COSMIC RAYS STUDIES



Elemental composition at high energy is still unknown → essential to:
solve finally the puzzle of high energy cosmic rays sources

understand the transition from galactic to extra-galactic cosmic rays
understand change in the power-law of the cosmic rays fluxes, like the “knee”, at 3×10^6 GeV

Cosmic rays measurements above 10^5 GeV are based on detection at ground of secondary particle showers (EAS) which they produce in the Earth Atmosphere

The uncertainty of the extrapolation of the hadronic production cross section in extensive air shower is a major problem for the interpretation of existing cosmic ray data for example in terms of the primary mass composition

Relevant measurements for cosmic rays physics: pion-carbon and proton carbon from 50 GeV beam energy up to a few hundreds of GeV

Uncertainty of hadron interaction models

↓

Uncertainty in the interpretation of the observables

THE COMPASS DETECTOR POTENTIALS FOR COSMIC RAYS PHYSICS?

Feasibility studies

COMPASS:
Beam Intensity: 5x10^6 p/s
LH target: 40 cm long
Factor 1000 more events/day

NA49 (2001: 13 days of data taking)
p+p at 160 GeV/c: 1.100.000 events
→ 550.000 events on DST (special spill)
42.000 events/day
Beam Intensity: 1x10^4 p/s
LH target: 20.29 cm long

large data set of p+LH2 → ps+X taken in 2009
We have never tried neither to extract absolute cross-sections using this data sample nor to identify antiprotons in the final state

Concerning the possible future p+LHe4 → p/pbar + X measurements we have adequate beam line and spectrometer but feasibility studies are needed

THE COMPASS DETECTOR POTENTIALS FOR COSMIC RAYS PHYSICS?

COMPASS what's next

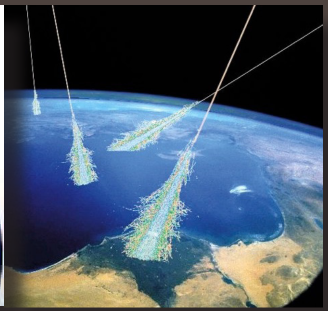
2017 – Deep Virtual Compton Scattering (GPDs)

2018 – Polarised Drell-Yan

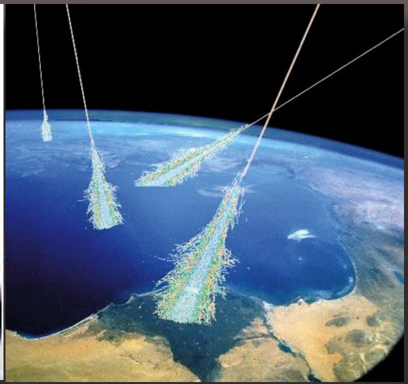
2019 – Shutdown

2020 and beyond – internal discussion in the COMPASS collaboration is ongoing, and we will certainly come up with the proposal (LoI) by the end of the year

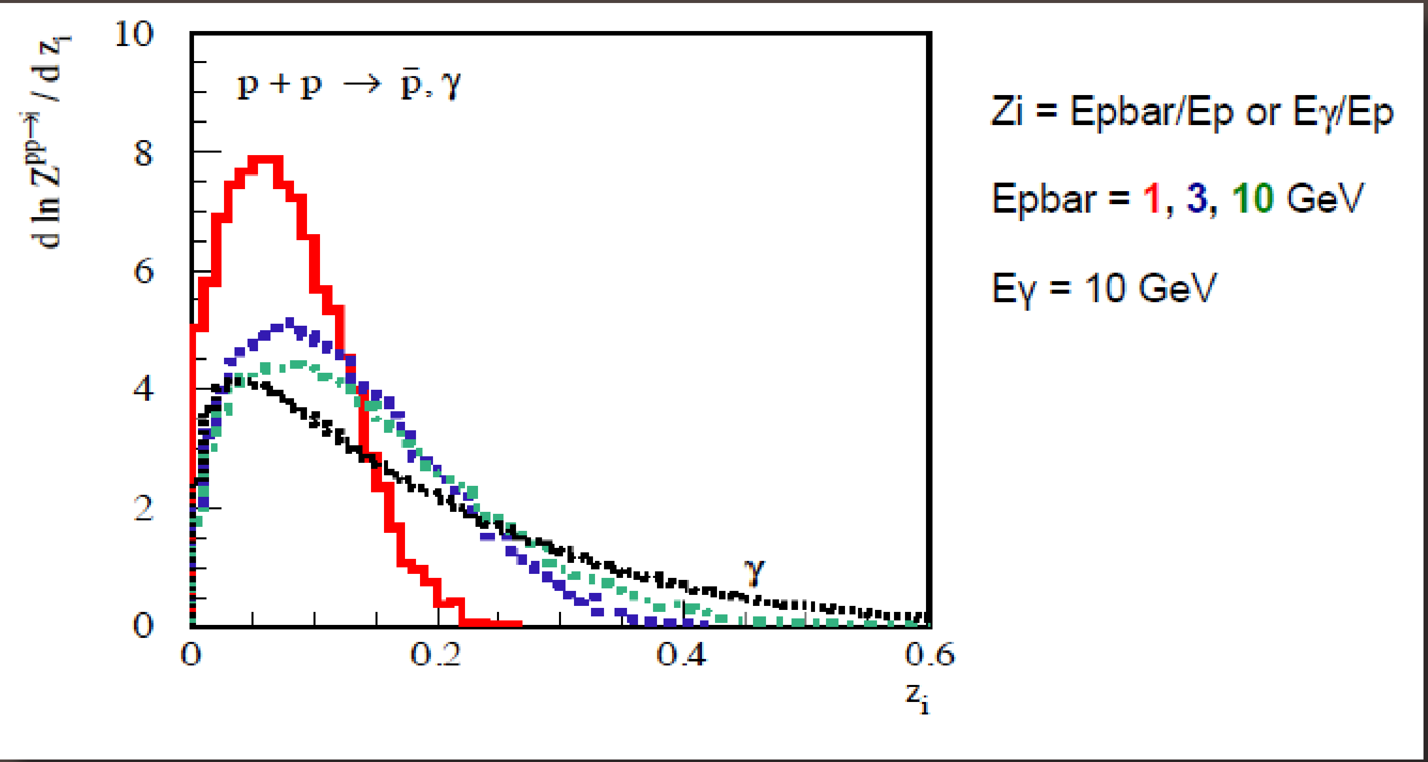
Astrophysics related measurements can become a part of the "beyond 2020" program



BACK-UP SLIDES

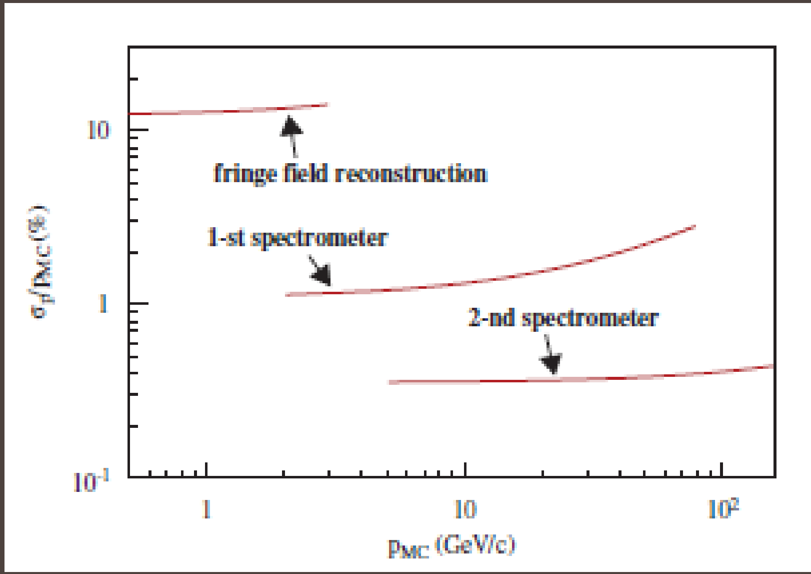


COSMIC RAYS ANTIPROTONS

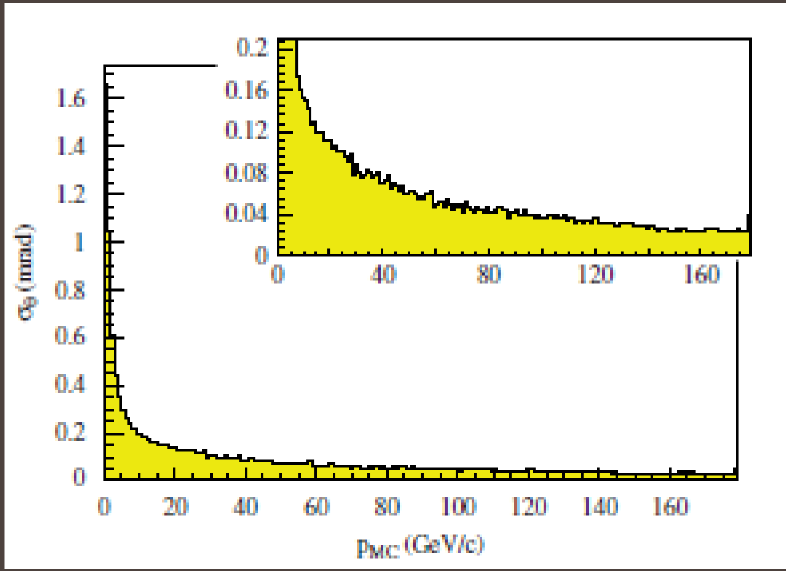


The bulk of antiprotons is produced by proton with kinetic energy 10-20 times larger AMS energies ~ 1-500 GeV in Epbar --> beam proton energies with ~ few GeV – 10 TeV

MOMENTUM AND ANGULAR RESOLUTION @ COMPASS



The relative error σp/p is about 0.5% for tracks reconstructed in both spectrometers (p >= 5 GeV/c) and about 1.2% for low momentum tracks reconstructed in the LAS only.



The error on the track polar angle at the interaction vertex (σ_θ) is of the order of 0.1 mrad for p about 30 GeV and increases for lower momenta

DATA SET C0LLECTED IN 2009

p + p -> pbar + X + p

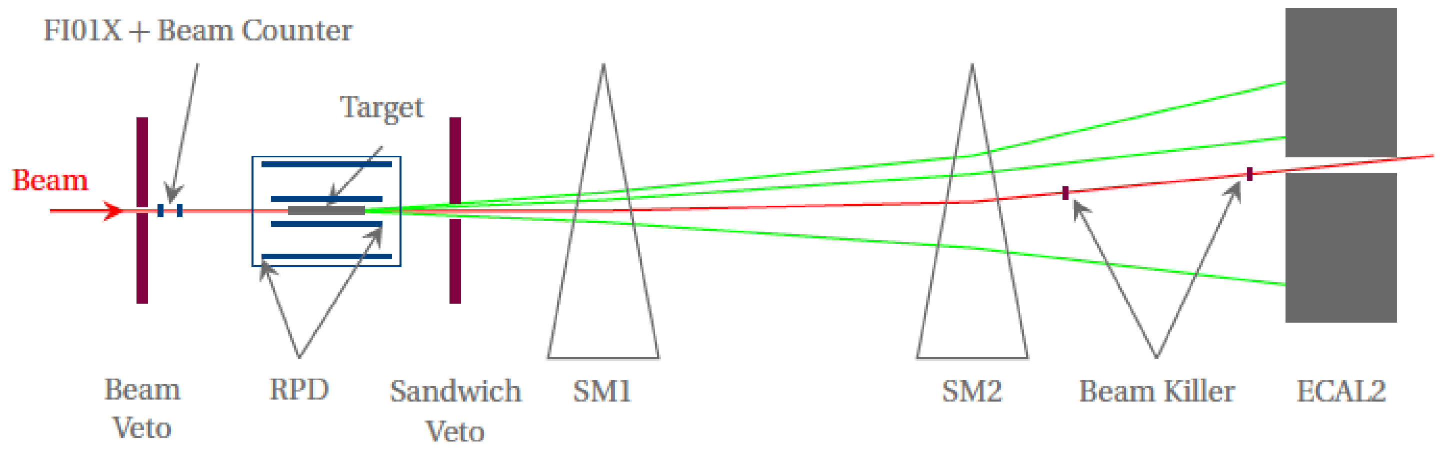


Figure 3.1: DT0 trigger scheme: Trigger (blue) and Veto (purple) components [59]. In the spectrometer, a non-interacting beam track (red) and an event with three charged tracks (green) is drawn for illustration.