



SPIN PHYSICS @ COMPASS

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University of Trieste and INFN Trieste

**on behalf of the
COMPASS Collaboration**

Spin-03

**X WORKSHOP ON HIGH ENERGY SPIN PHYSICS
Dubna, September 16 - 20, 2003**

COmmon
Muon and
Proton
Apparatus for
Structure and
Spectroscopy



NA58

Finland, France, Germany, India, Israel, Italy, Japan,
Poland, Portugal, Russia, Switzerland

Bielefeld, Bochum, Bonn, Burdwan, Calcutta, CERN,
Dubna, Erlangen, Freiburg, Heidelberg, Helsinki, Lisbon,
Mainz, Miyazaky, Moscow, Munich, Nagoya, Protvino,
Saclay, Tel Aviv, Torino, Trieste, Warsaw

28 Institutes, more than 200 physicists

Spin-03



- **Spectrometer and data taking 2002**
- **A first look at the 2002 data**
 - **Lambda**
 - **Exclusive ρ and ϕ , J/ψ**
 - **Transversity**
 - **Flavour separation**
- **Status of Δg at COMPASS**
 - **D^0 and D^* signal**
 - **High- p_T hadron pairs**
- **Perspectives**

COMPASS



- **experiment:** **thought of in** **April '94** **Trento workshop**
Nov. '94 **Trieste workshop**
Lol **March '95**
encouraged **June '95** **SPSLC in Cogne**
Proposal **March '96**
recommended **Sept. '96**
approved by RB **Feb. '97** **as NA58**
Technical run **2000**
Commissioning **2001**

- **since 2002 taking data**

with

a new spectrometer with outstanding performances

- **merging of two programmes:** **HMC** **CHEOPS**
(muon beam) **(hadron beam)**

Spin-03

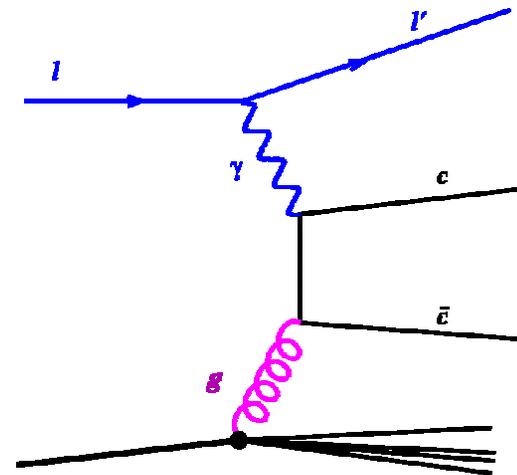
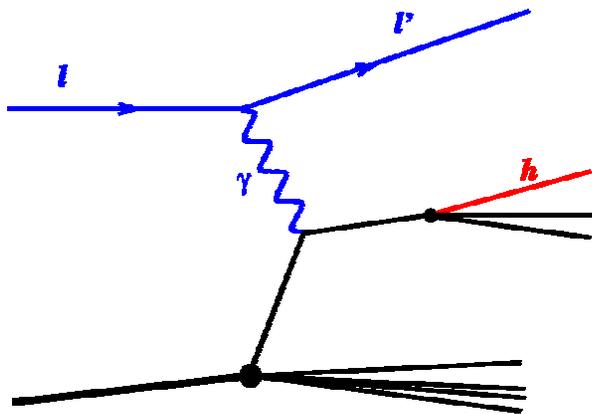
COMPASS Programme with the muon beam



to determine the polarised **parton** density functions in a **polarised nucleon** from measurements of **hadron asymmetries** in semi-inclusive polarised DIS, **both longitudinal and transverse**

specifically,

- to measure the gluon polarisation ΔG through open charm (Gluk and Reya, Altarelli and Stirling, 1988)



- flavour decomposition of g_1 from identified hadron asymmetries: $\Delta u, \Delta d, \Delta s$

- to measure h_1 , the new territory
- to measure the spin transfer in fragmentation from Λ production
- to remeasure with high statistics g_1 and g_2
-



▪ charmed hadrons

- production phenomena (p , π , K)
- leptonic decays
- semileptonic decays
- precision measurements of c-baryon lifetimes
- production and spectroscopy of cc-baryons

▪ gluonic states

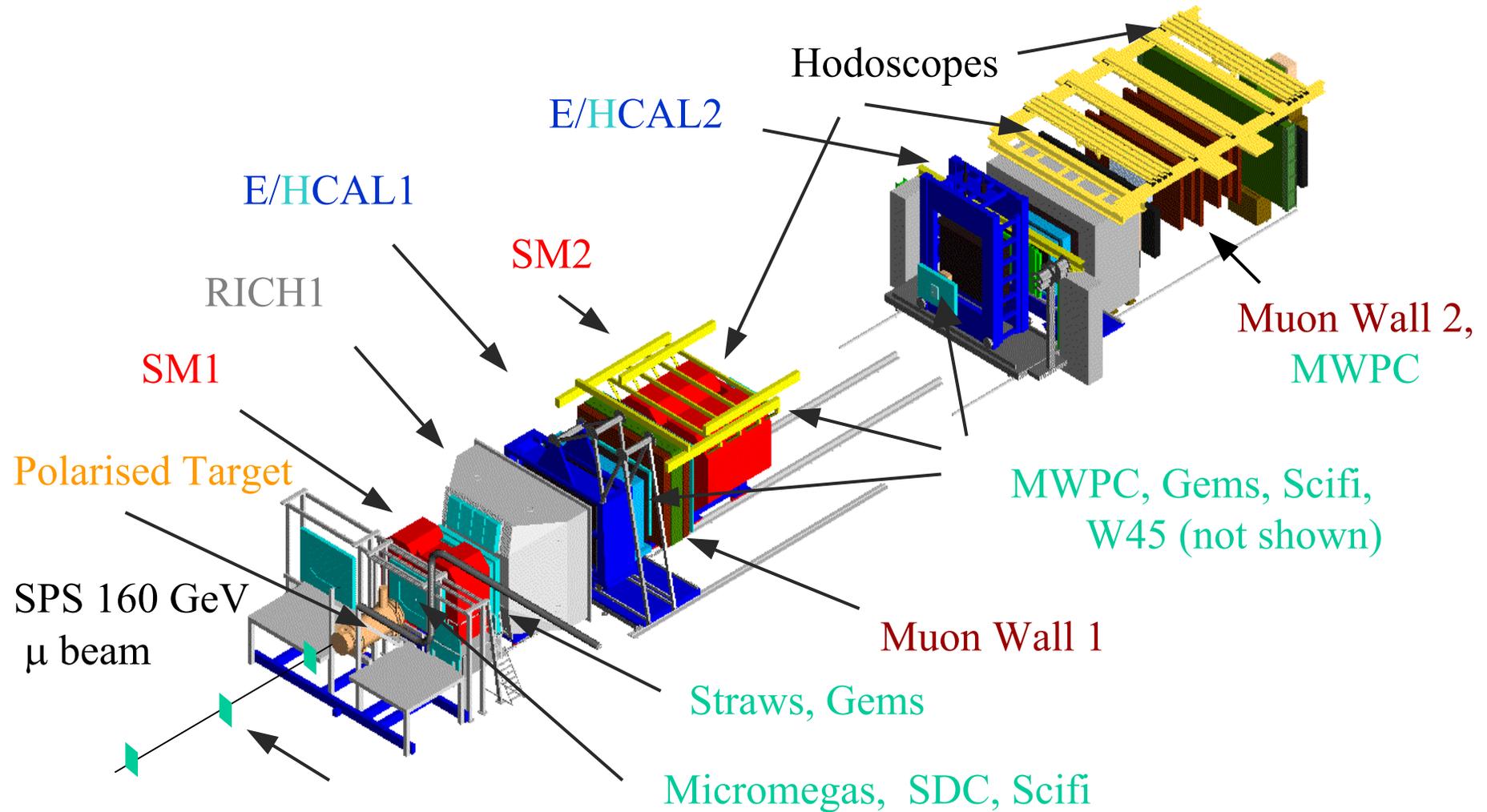
- search for glueballs in Pomeron-Pomeron scattering
- search for exotic states

▪ hadron structure

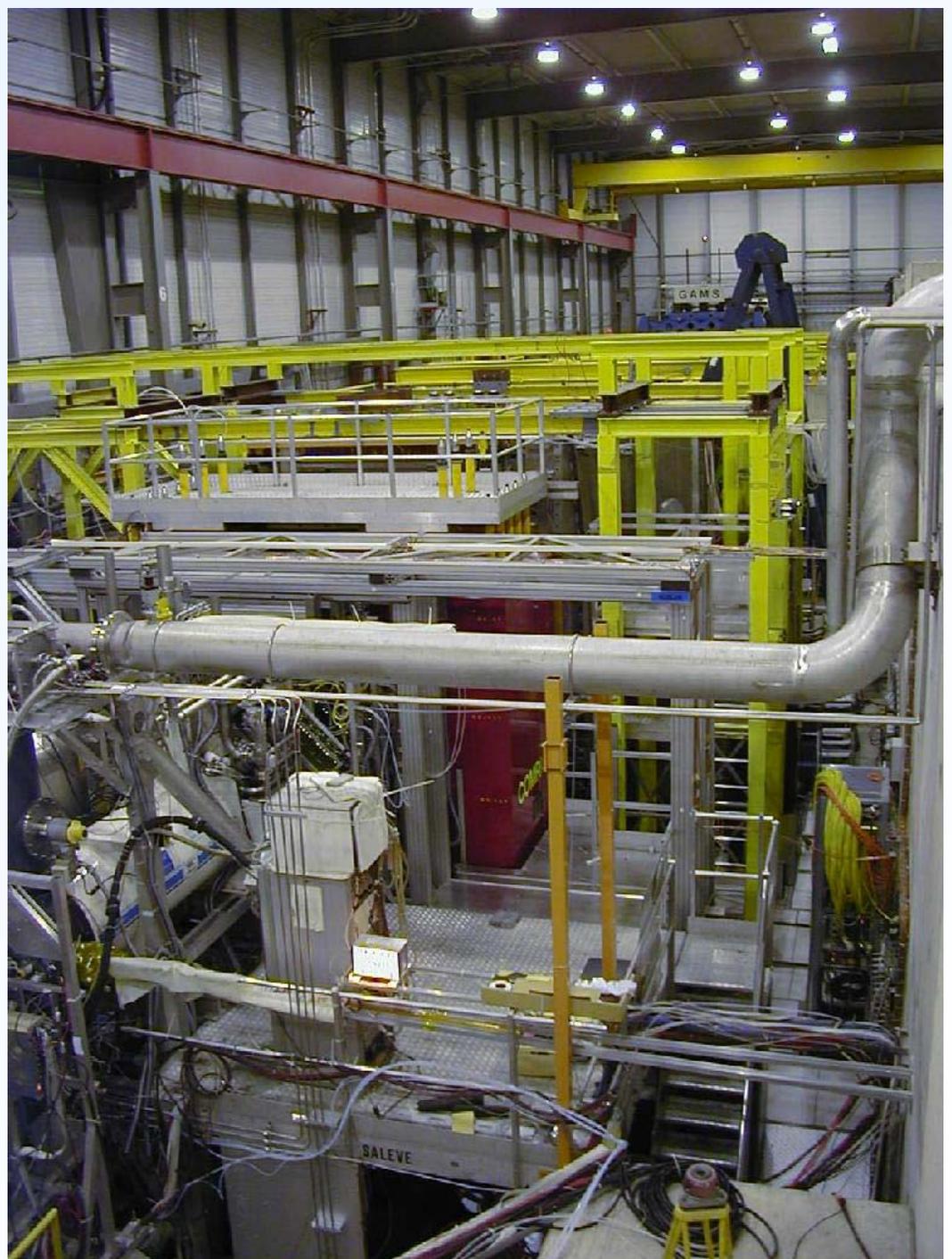
- polarizability in Primakoff reactions



The COMPASS Spectrometer

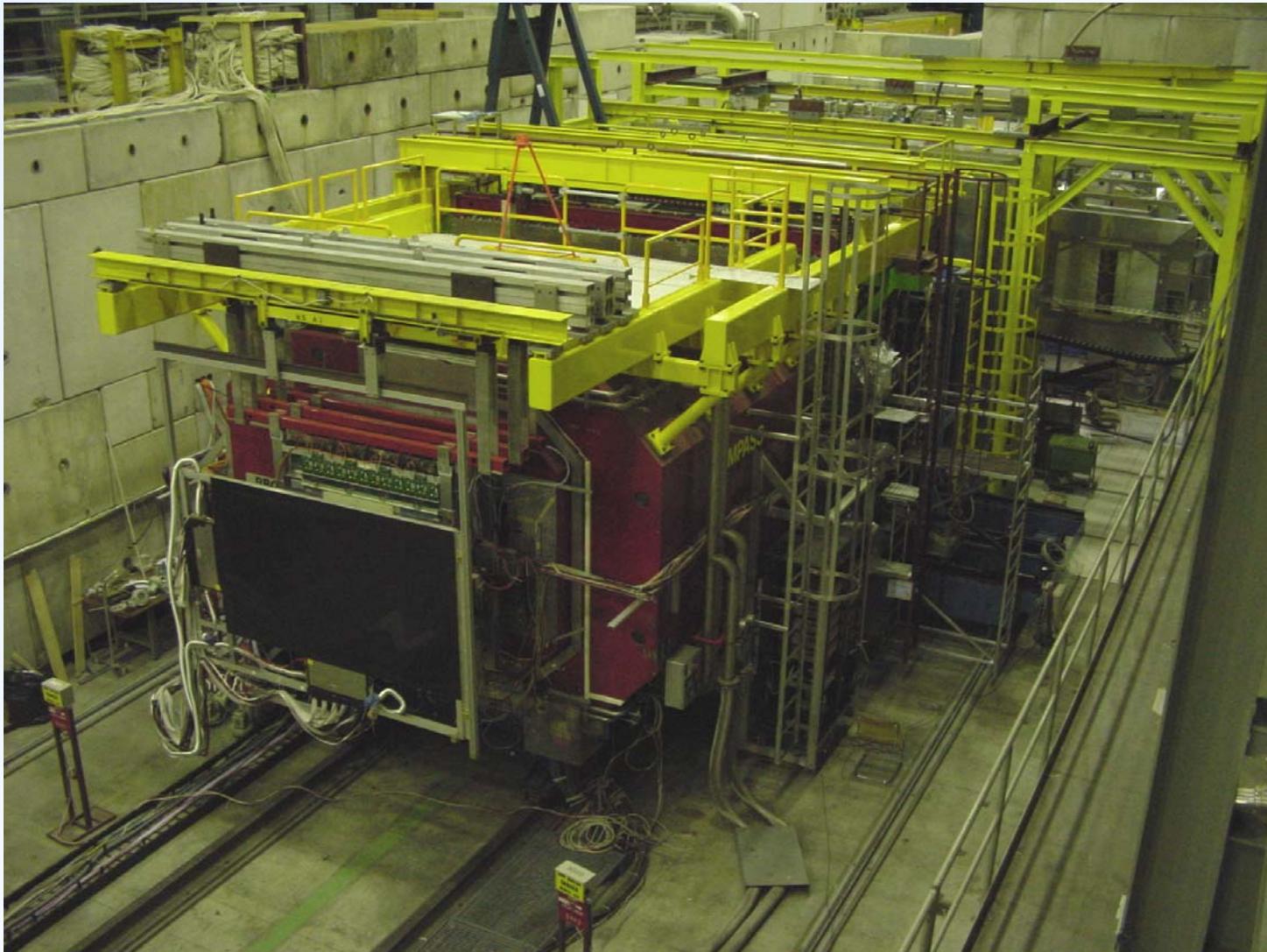


A look in Hall 888



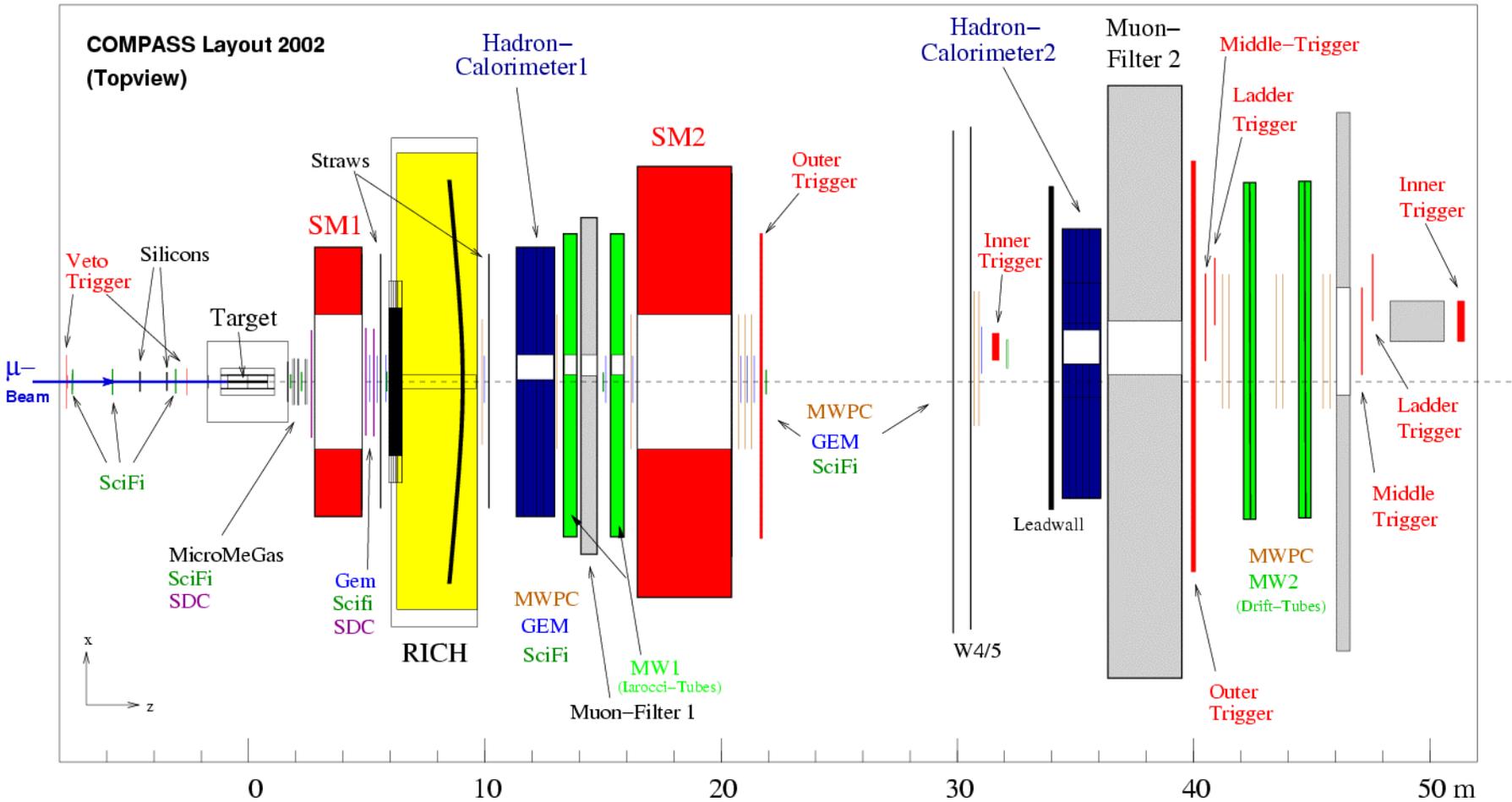


A look in Hall 888



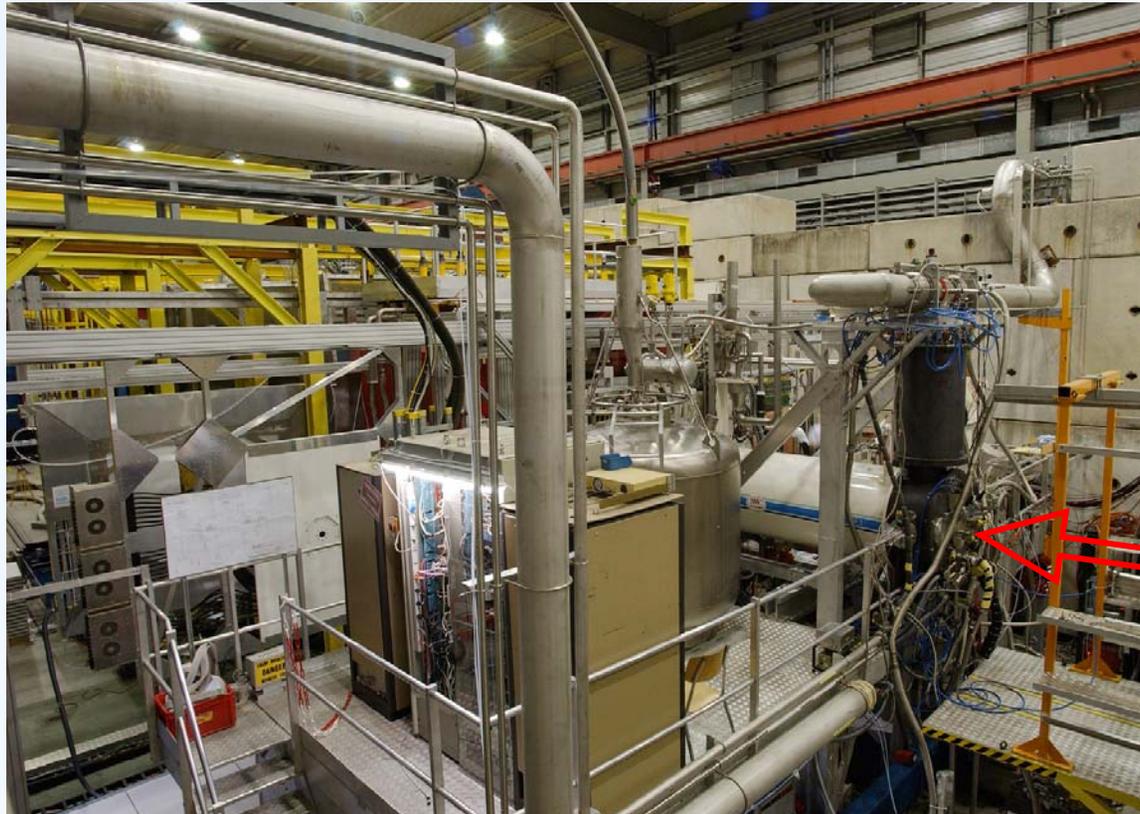
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Spectrometer 2002





Polarised target

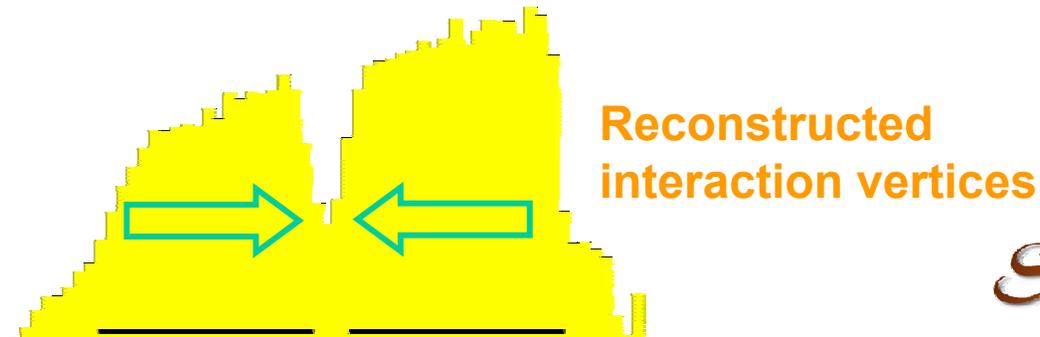
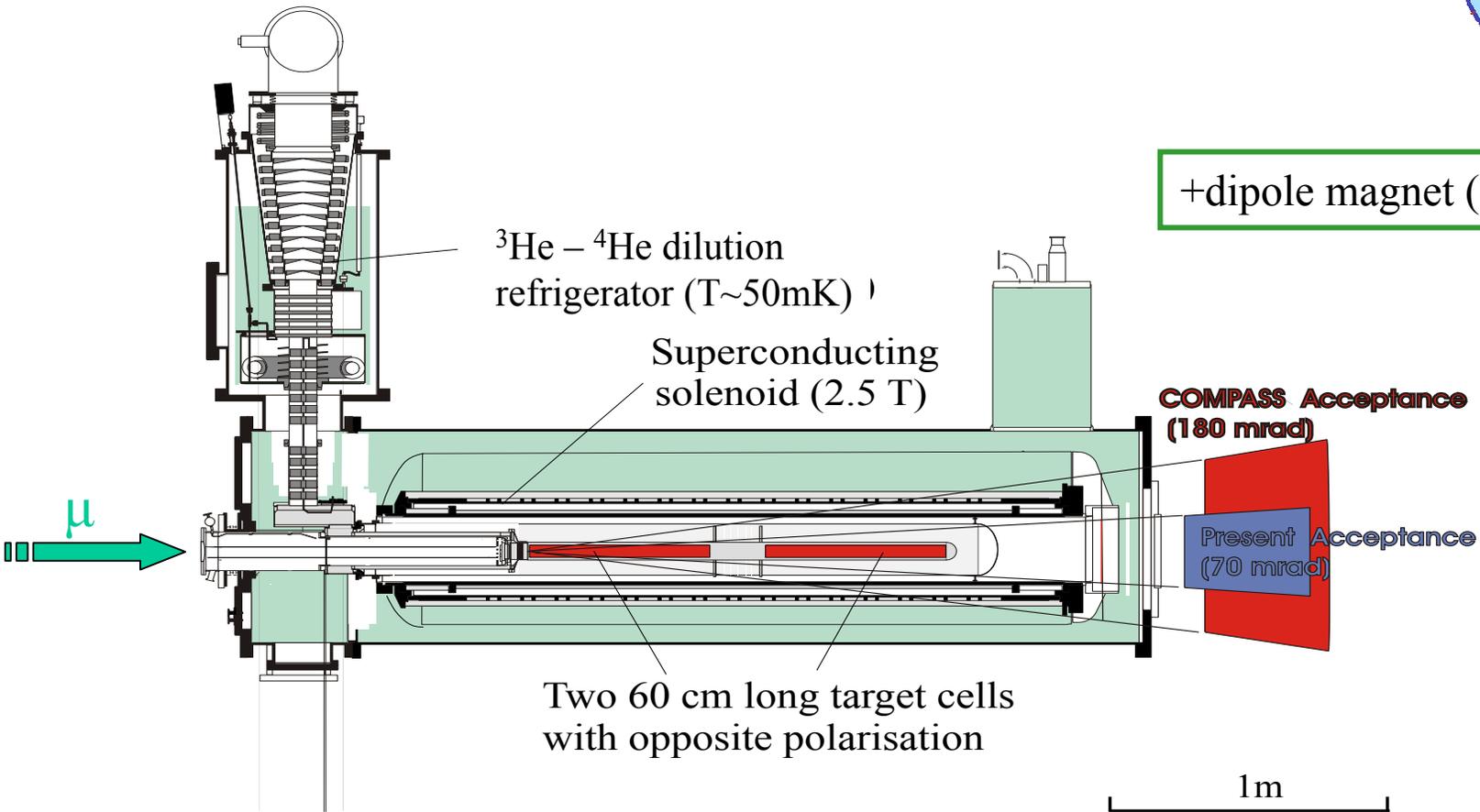


- ${}^6\text{LiD}$
- $\pm 50\%$ polarisation
- 50 % dilution factor
- 2.5 T
- 50 mK

μ



Target system

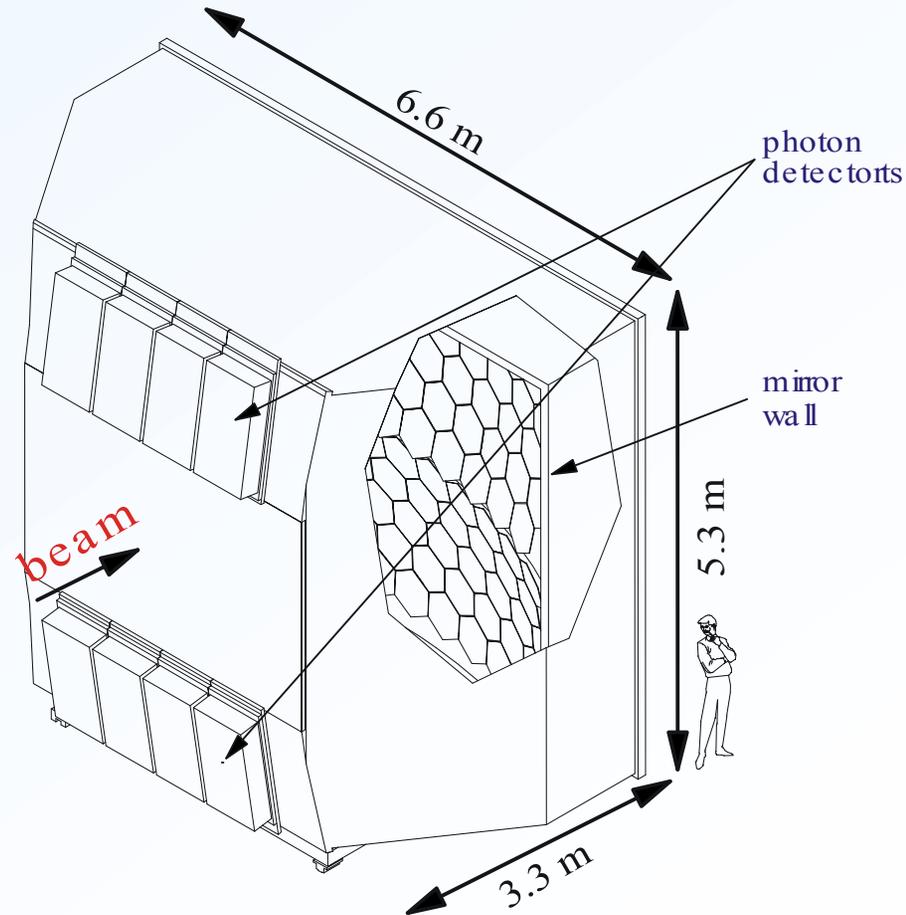




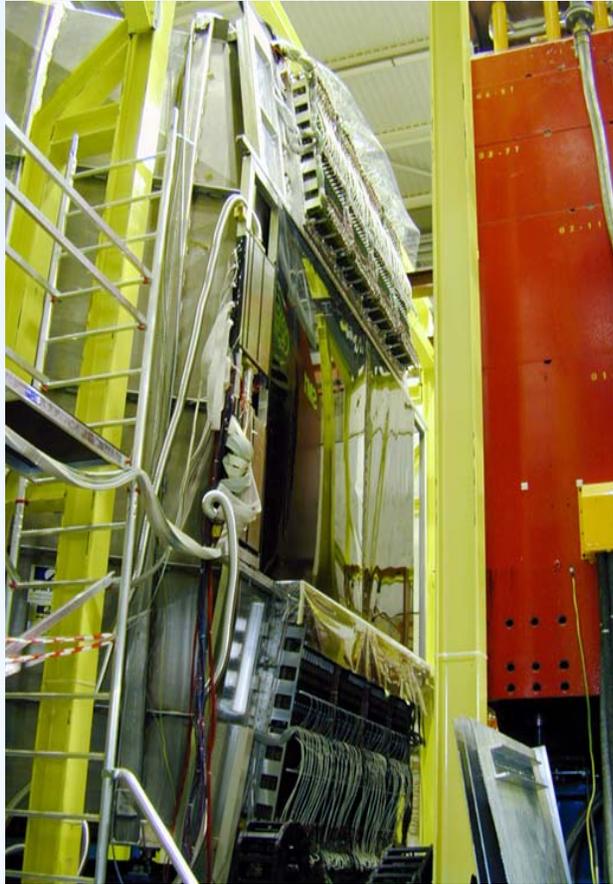
RICH1

Ring Imaging Cherenkov

- 90 m³ (3 m C₄F₁₀)
- 116 VUV mirrors (focal length 3.3 m)
- 5.3 m² UV detectors
 - MWPC CsI cathods
 - 8x8 mm² pad
- 84k analog r/o channels
- K/π separation up to ~40 GeV

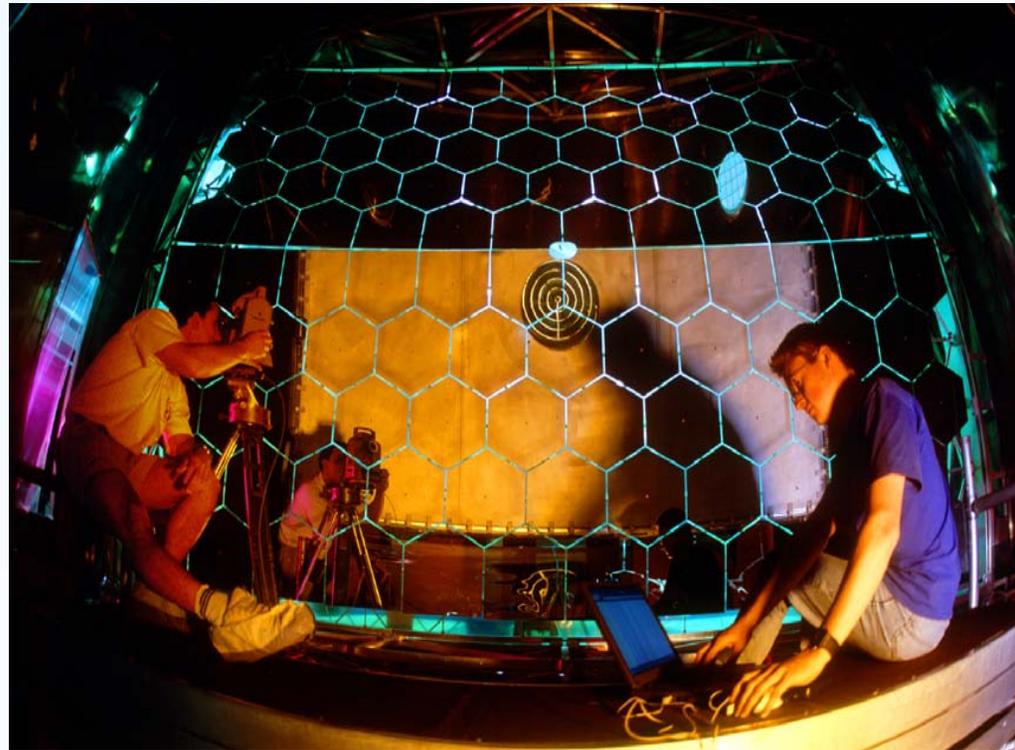


RICH1



PDs, 5.3 m²

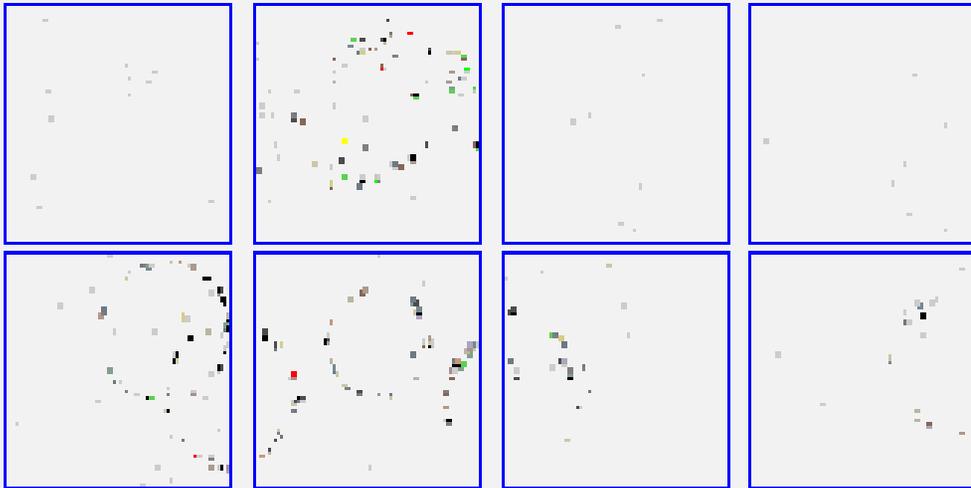
116mirrors, 20 m²



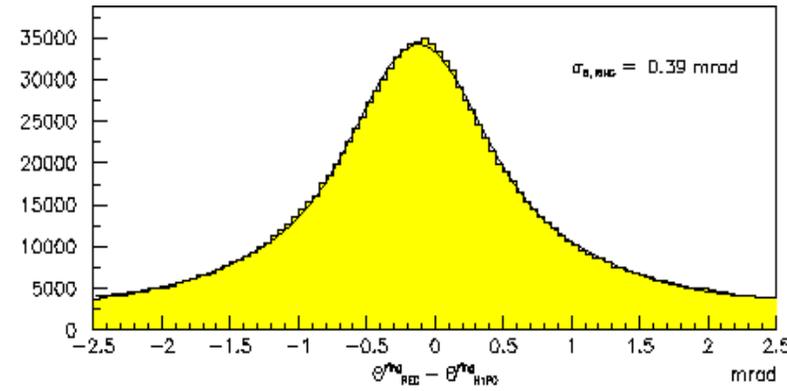


RICH1 performance

single event, low intensity
80 % C₄ F₁₀, 2050V



Cherenkov angle for rings
with $\beta \approx 1$



Data $\langle n \rangle = 15$ photons
 $\sigma = 0.39$ mrad

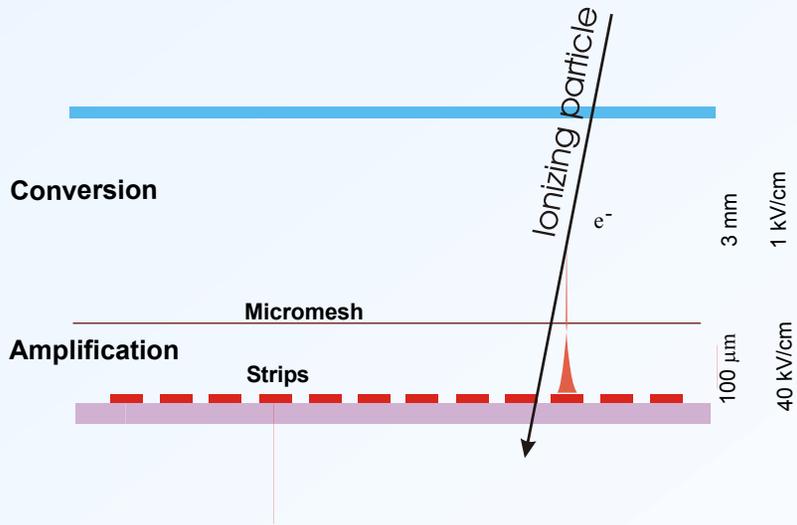
MC $\langle n \rangle = 25$ photons
 $\sigma = 0.23$ mrad

Spin-03

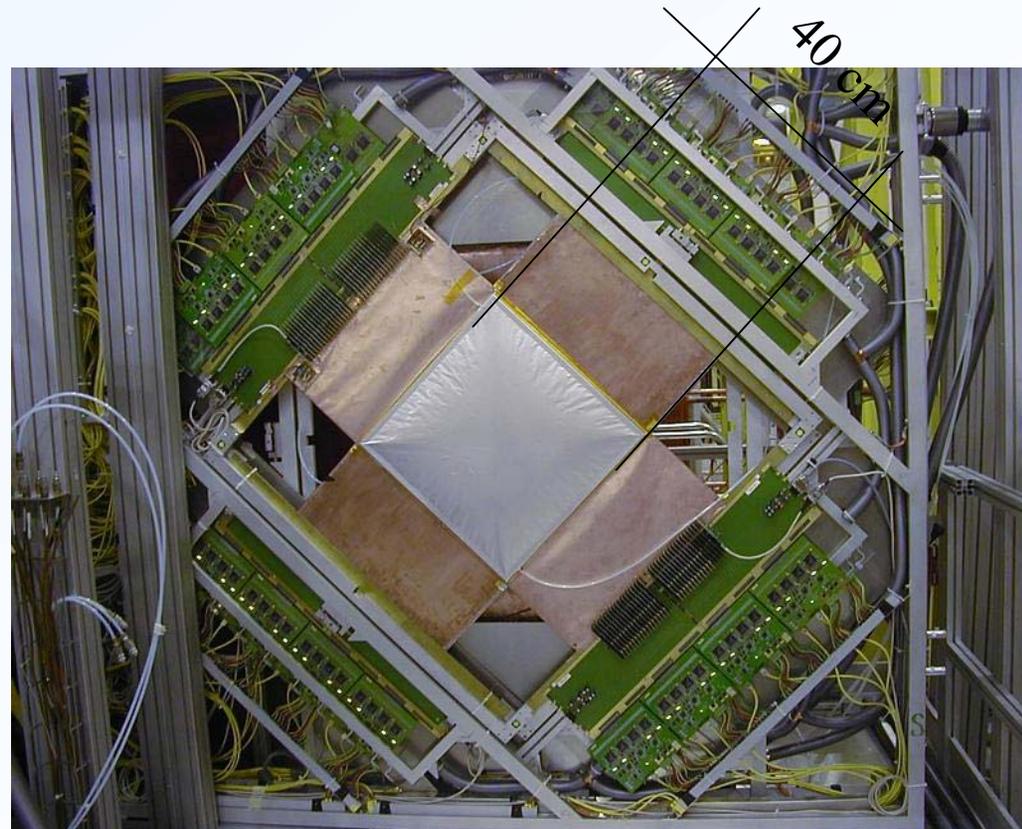


MicroMegas Micro Mesh Gas Detectors

Novel gaseous detector



40x40 cm²

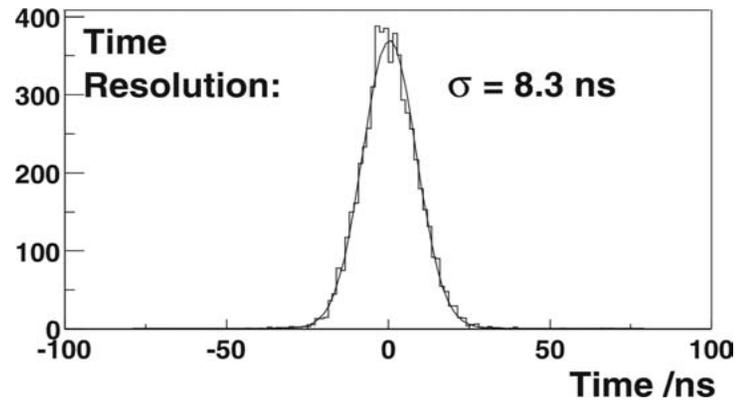


Spin-03

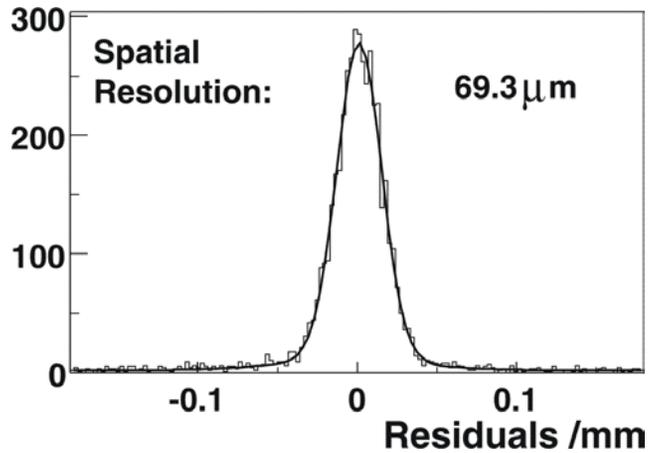
MicroMegas



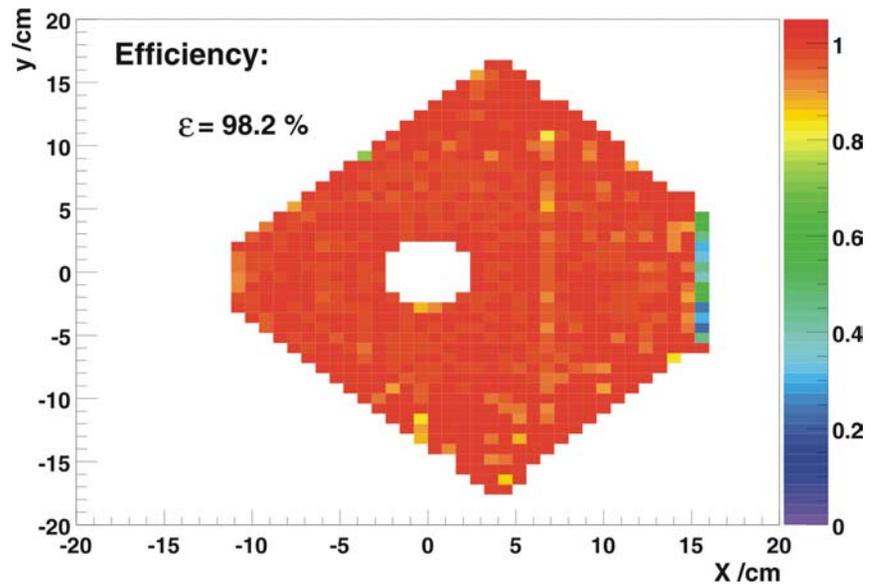
time resolution below 10 ns



spatial resolution below 70 μm



efficiency larger than 97%



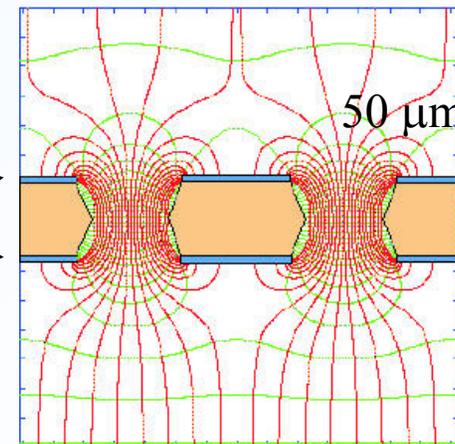
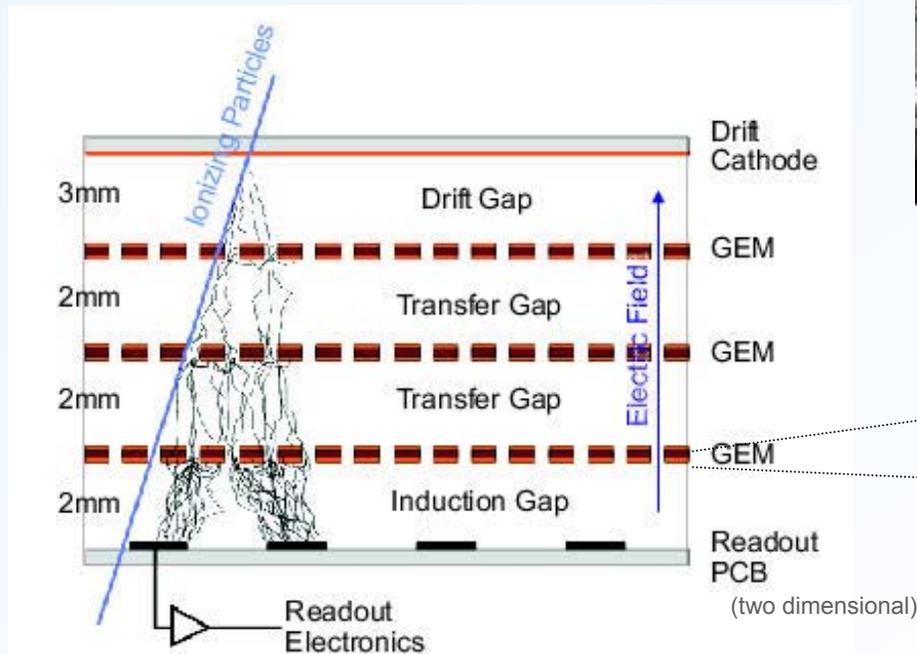
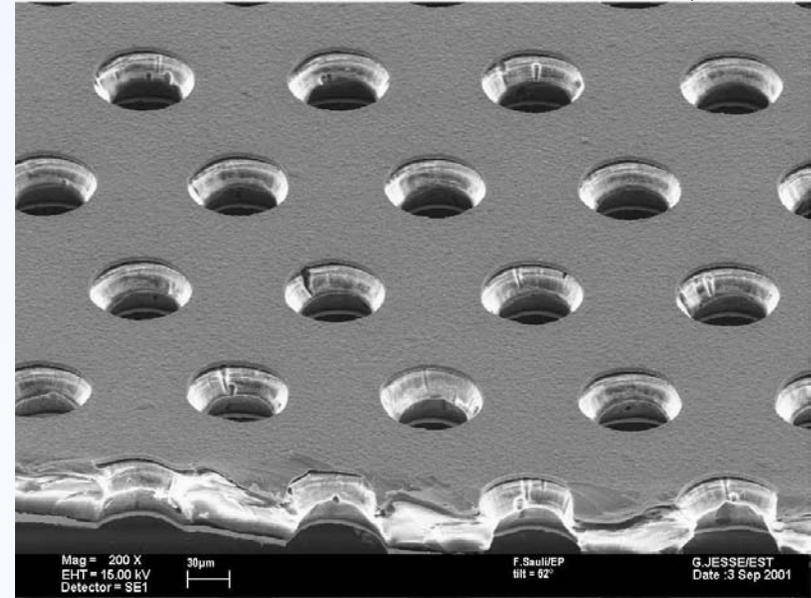
Spin-03



GEMs

- novel gaseous detector
- efficiency ~ 96 – 97%

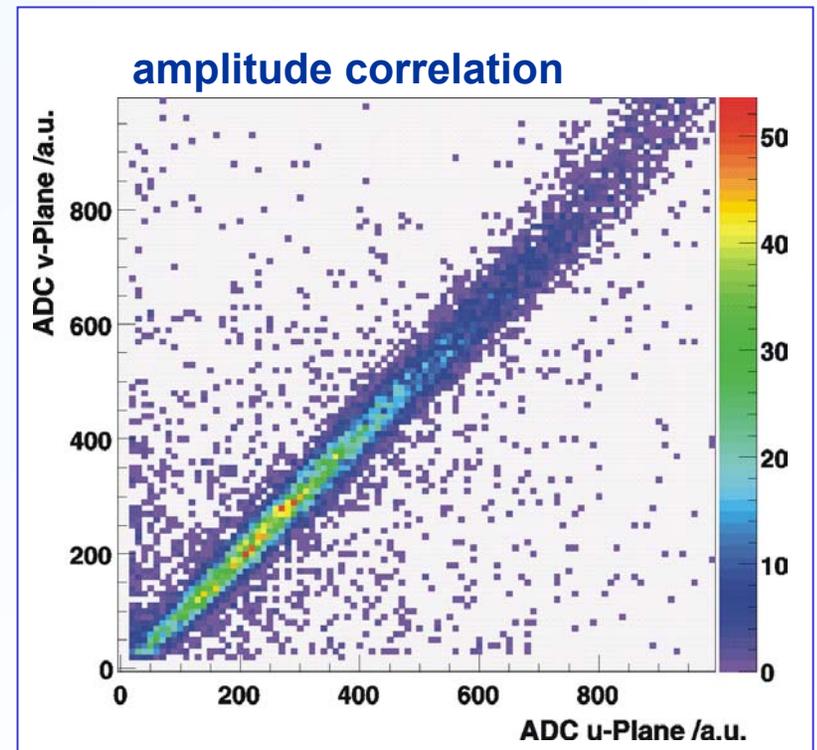
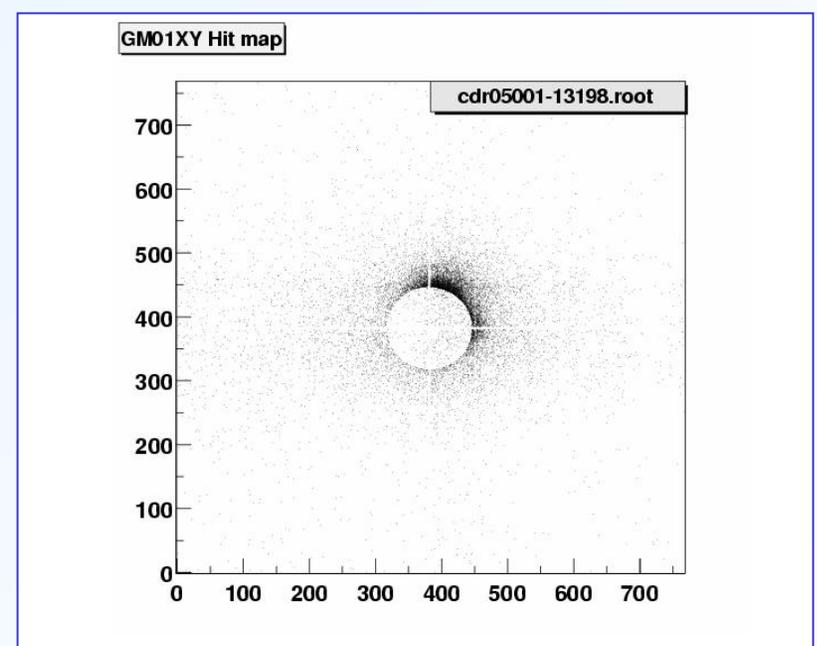
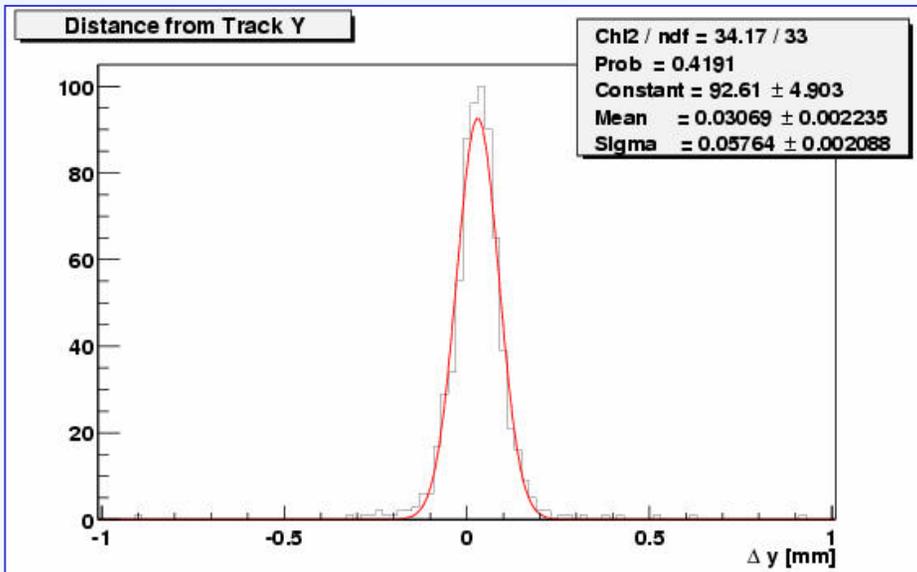
30 x 30 cm²



Spin-03

GEMs

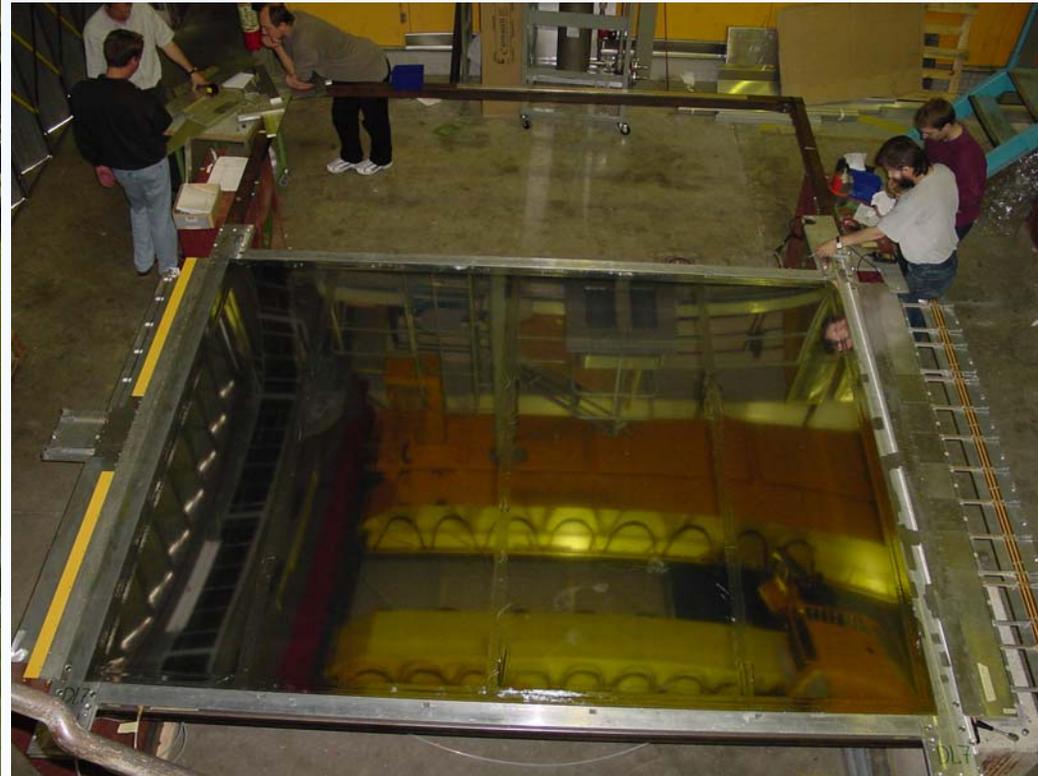
- two dimensional read-out
- spatial resolution $\sim 60 \mu\text{m}$
- time resolution $\sim 15 \text{ ns}$



STRAW Project



- 15 double layers
- 3250 x 2420 mm² with a 160 x 230 mm² hole
- 6 mm and 10 mm diameter straws



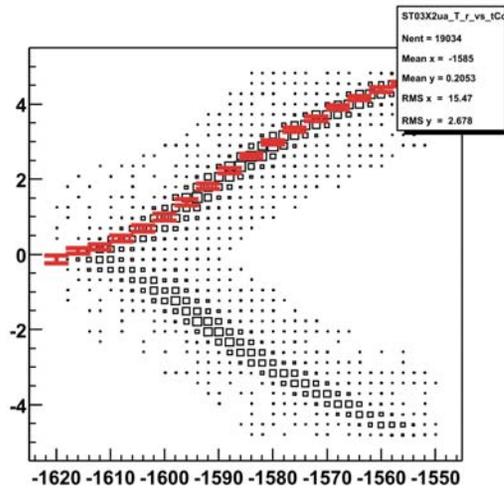
Spin-03



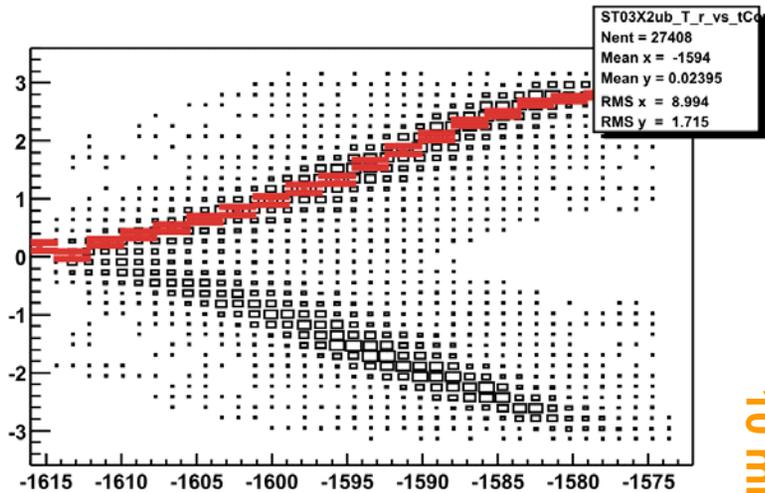
STRAW - tracking results

RT relations

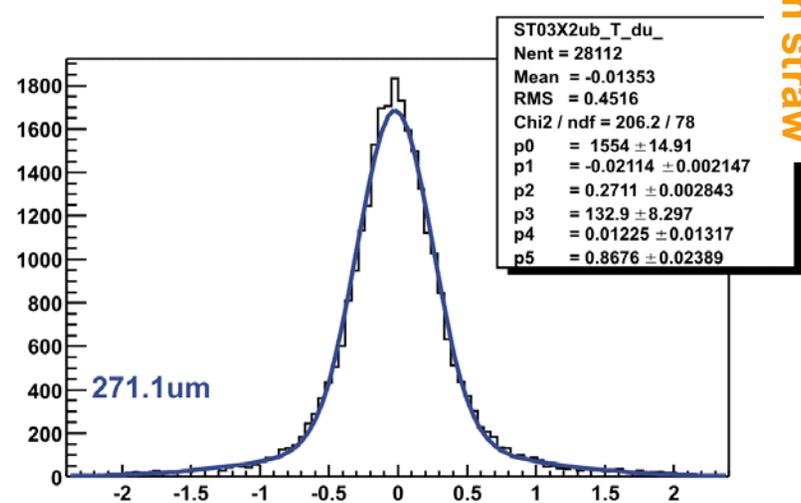
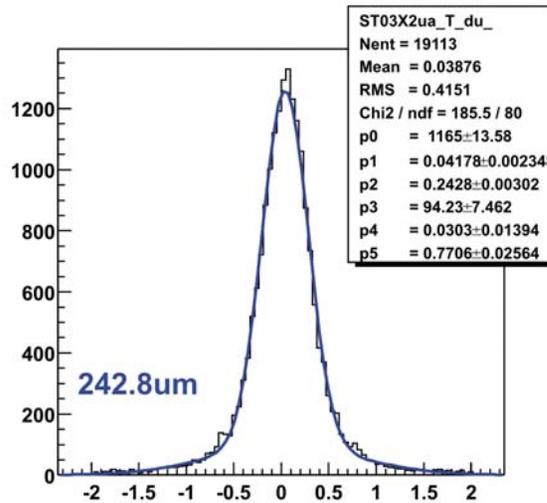
6 mm straw



10 mm straw



residuals





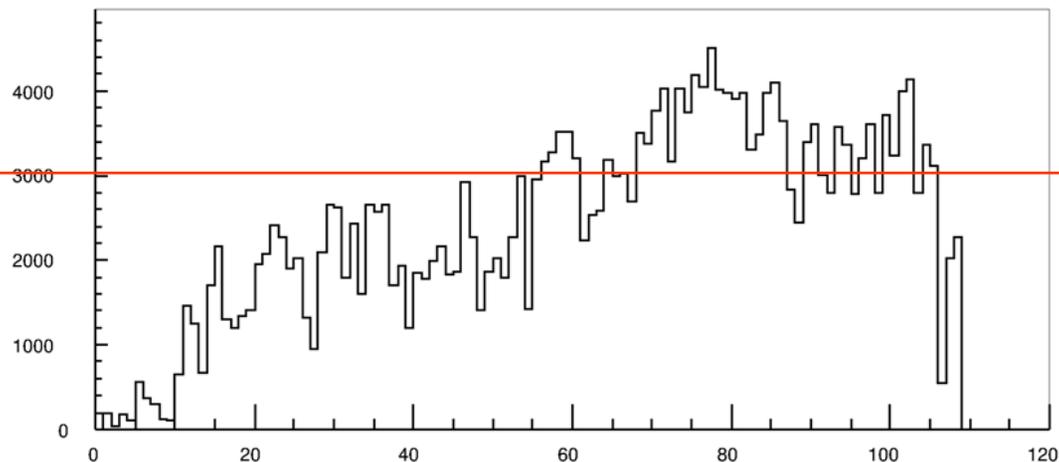
2002 Run

- *'initial spectrometer layout'* essentially complete
- 160 GeV/c muons, $2 \cdot 10^8 \mu^+ / 4 \text{ s}$ every 16.8 s, $P_{\text{beam}} \cong 80 \%$
- ${}^6\text{LiD}$ target, $P_{\text{target}} \cong 50 \%$
- polarisation reversal by magnet field rotation every 8 h
- 200 k readout channels, 35-40 kB/event
- data taking:
 - 24 days setup (about 2/3 of equipment new)
 - 57 days longitudinal target polarisation
 - 19 days transverse
- 5 billion events recorded, 260 TByte total

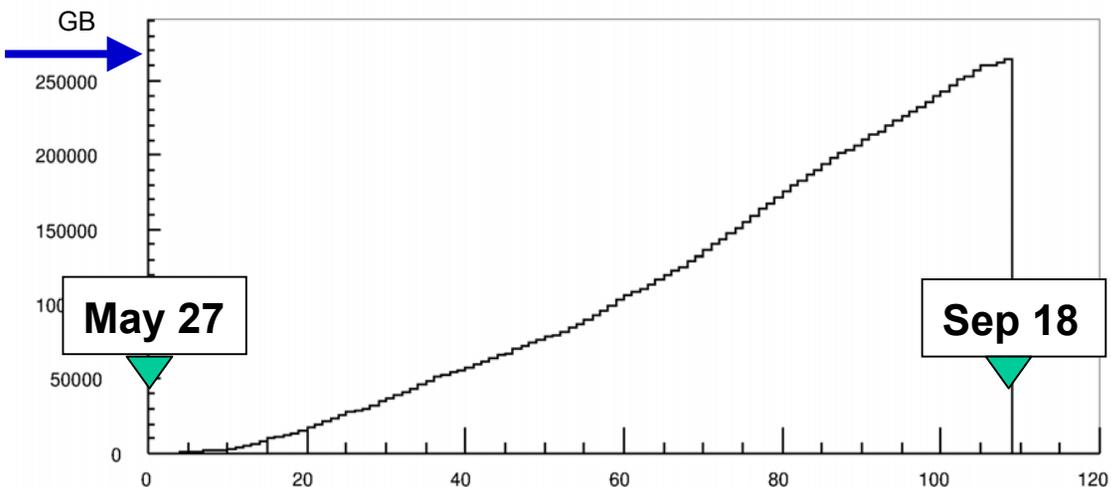


Central Data Recording

Design value: 35MB/s
3TB/day



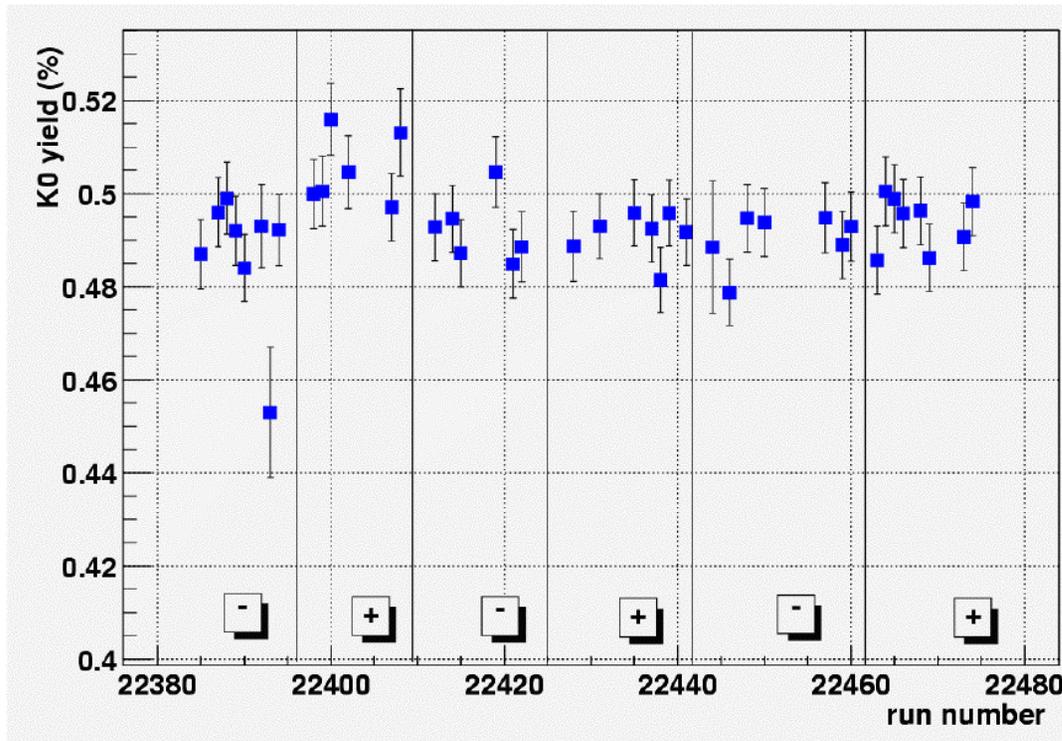
260 TByte in ~100 days
5 billion events





Reconstruction stability

K0 yield as function of run number



zero suppressed

target polarisation

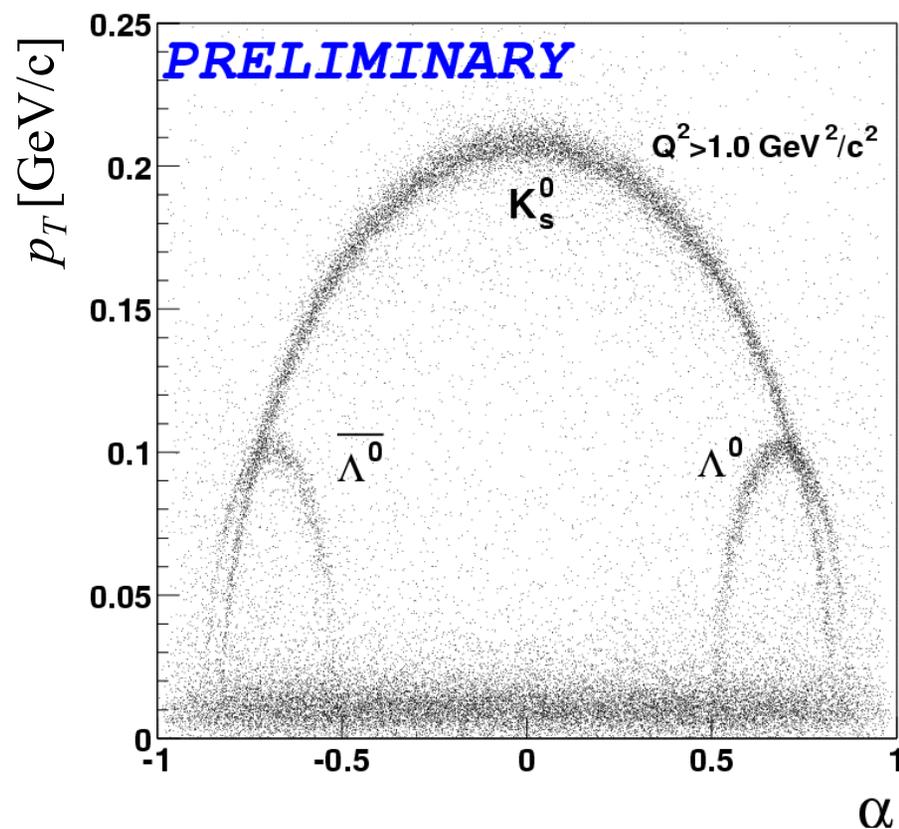


First Analysis Results

- Λ and $\bar{\Lambda}$ hyperon production → M. Sapozhnikov
- Vector meson production ρ , ϕ and J/ψ → J. Marroncle
- Flavour decomposition of polarized PDF
- Transversity and Collins asymmetry
- $\Delta G/G$ from open charm
- $\Delta G/G$ from high- p_T hadron pairs



Λ production



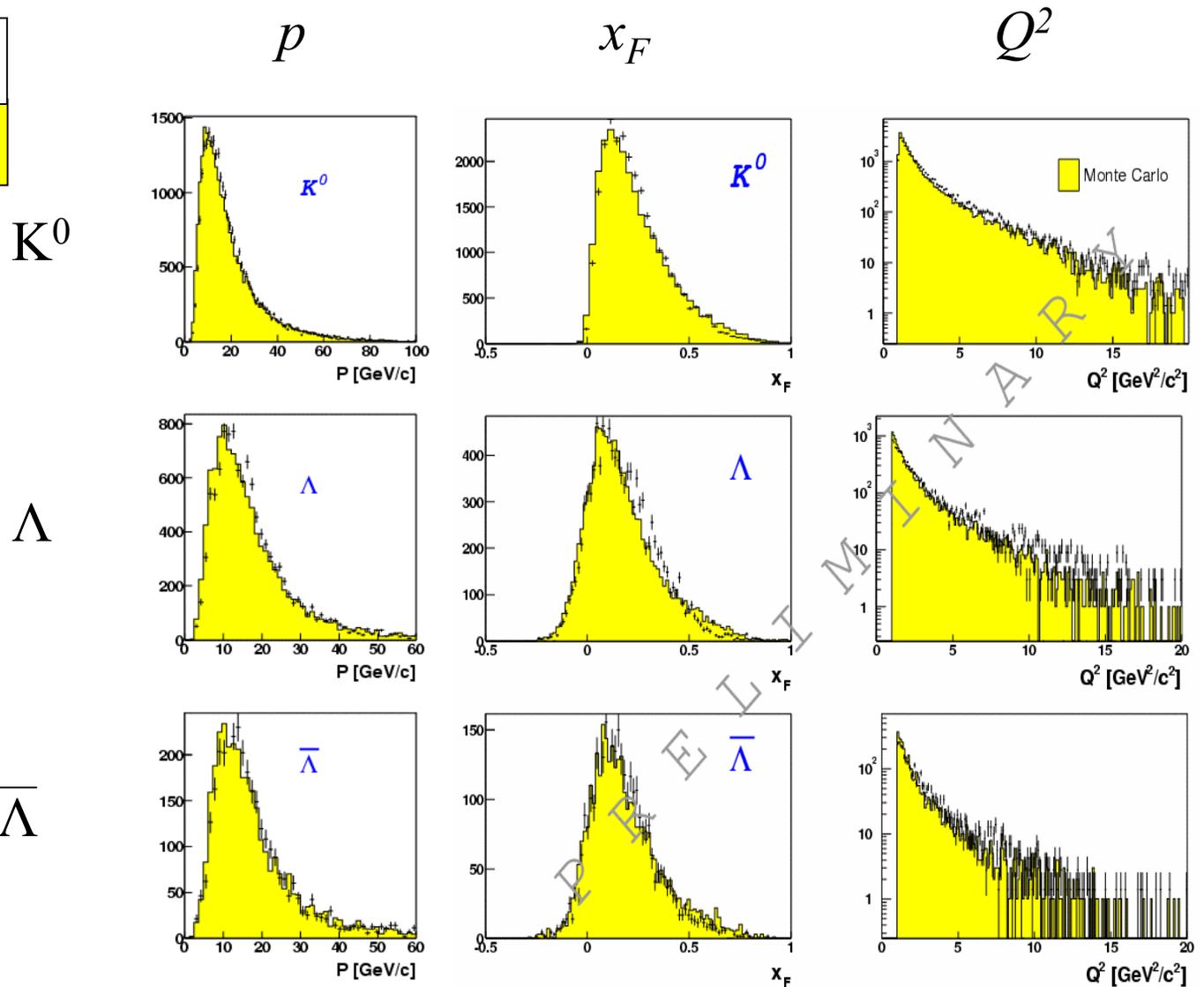
Armenteros-Podolanski

$$\alpha = \frac{P_L^+ - P_L^-}{P_L^+ + P_L^-}$$

Λ data vs MC

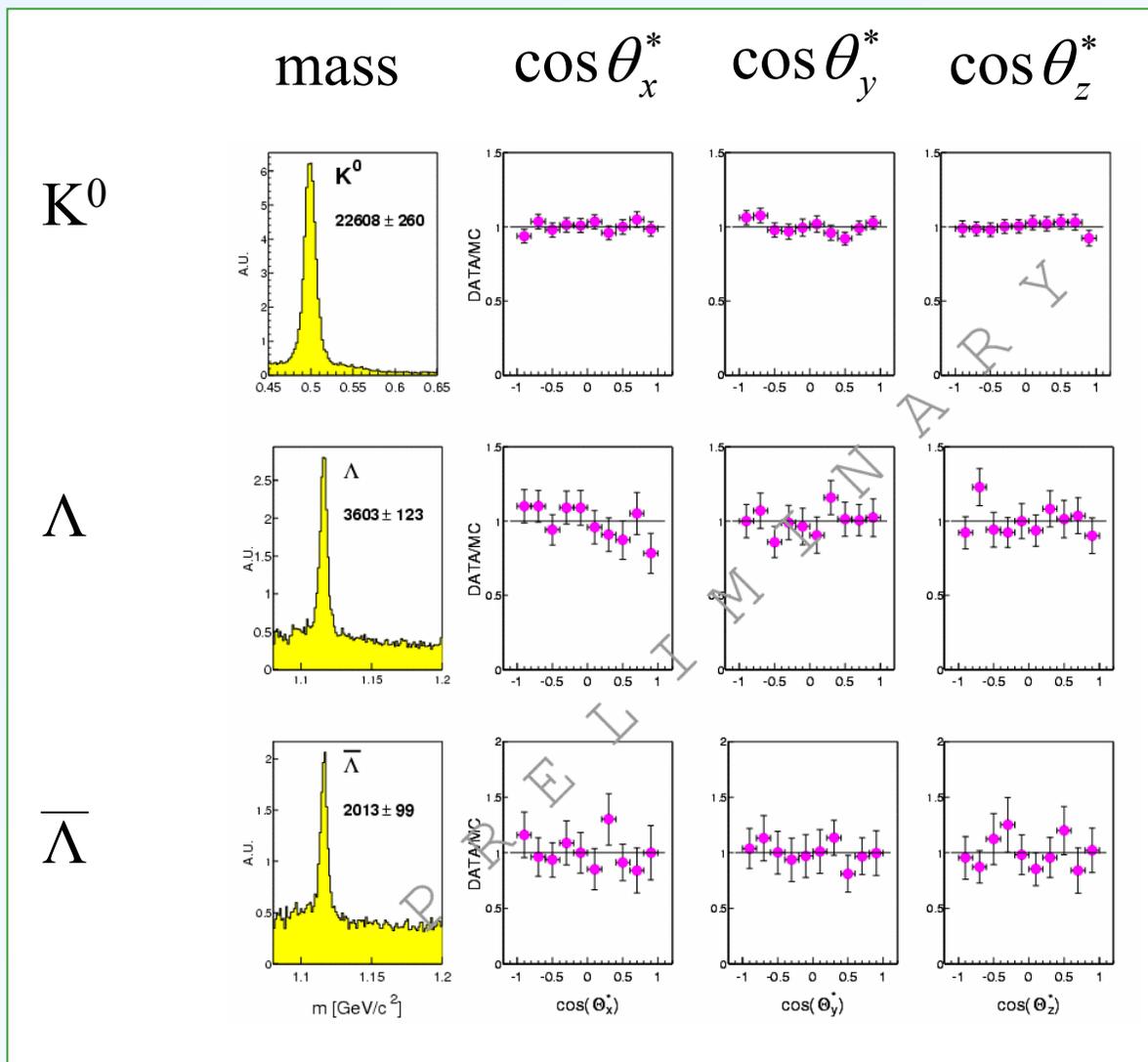


Data
Monte Carlo





Λ polarisation?



1/6 of 2002
Statistics

$$Q^2 > 1 \text{ GeV}^2$$

$$0.2 < y < 0.9$$

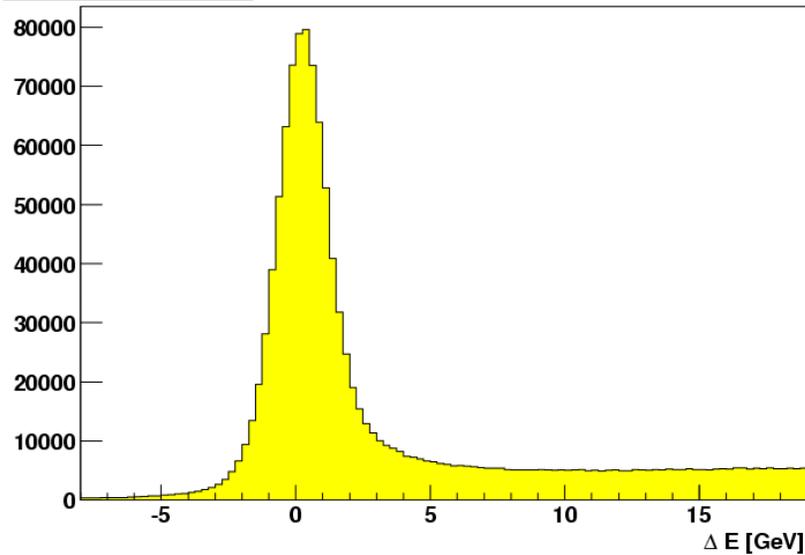
good potential
for polarisation
measurement



Exclusive ρ and ϕ production

meson	mass cut	statistics (1/6 of 2002)
ρ^0	$0.5 < m_{\pi\pi} < 1 \text{ GeV}$	$1.3 \cdot 10^6$
ϕ	$ m_{KK} - m_\phi < 9 \text{ MeV}$	$42 \cdot 10^3$

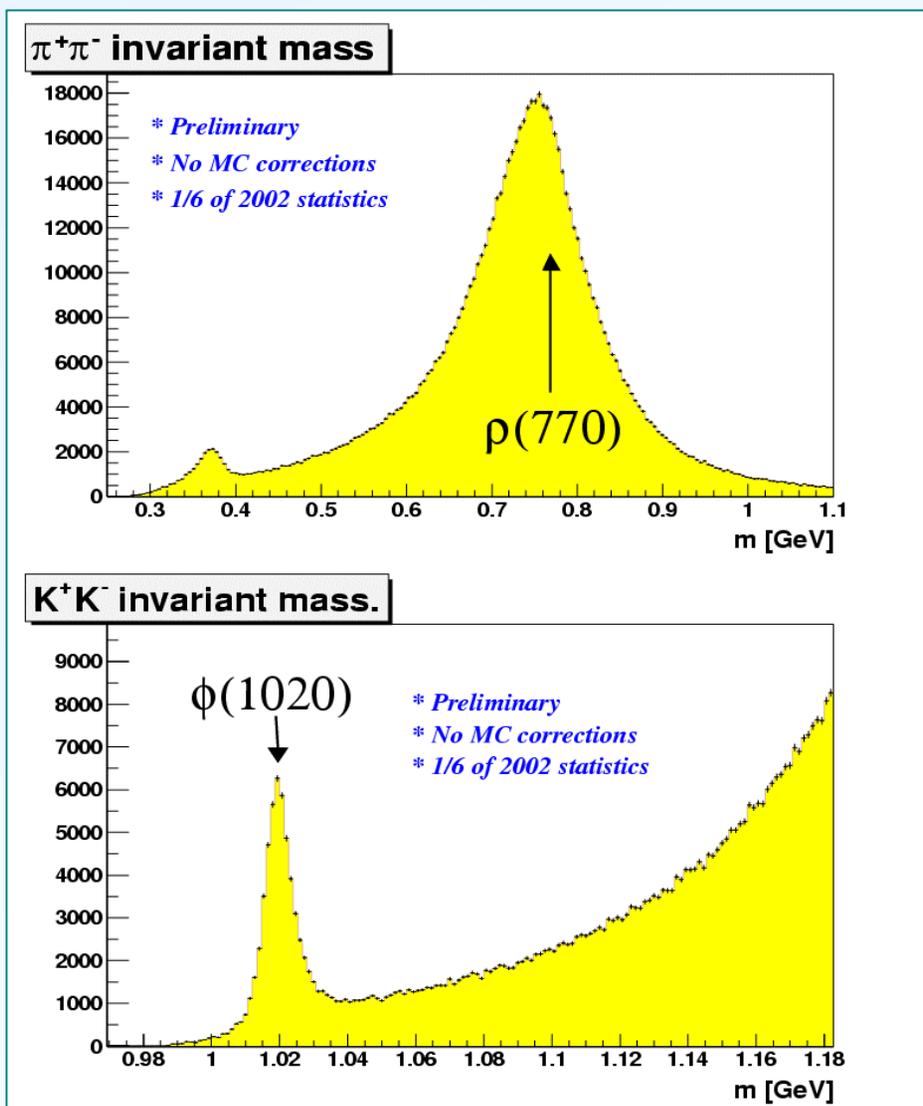
Missing Energy



- $|t'| < 0.5 \text{ GeV}^2$
- $7.5 < W < 16 \text{ GeV}$
- $Q^2 > 10^{-3} \text{ GeV}^2$



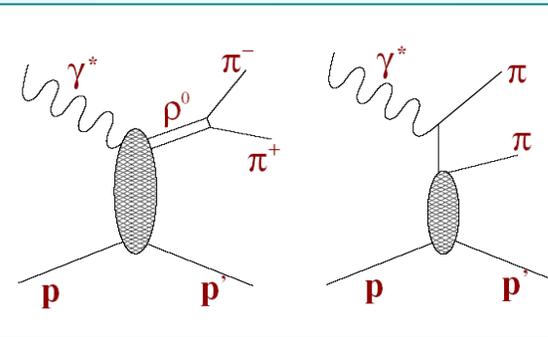
Invariant masses



- 16 % of total 2002 statistics
- no MC corrections yet

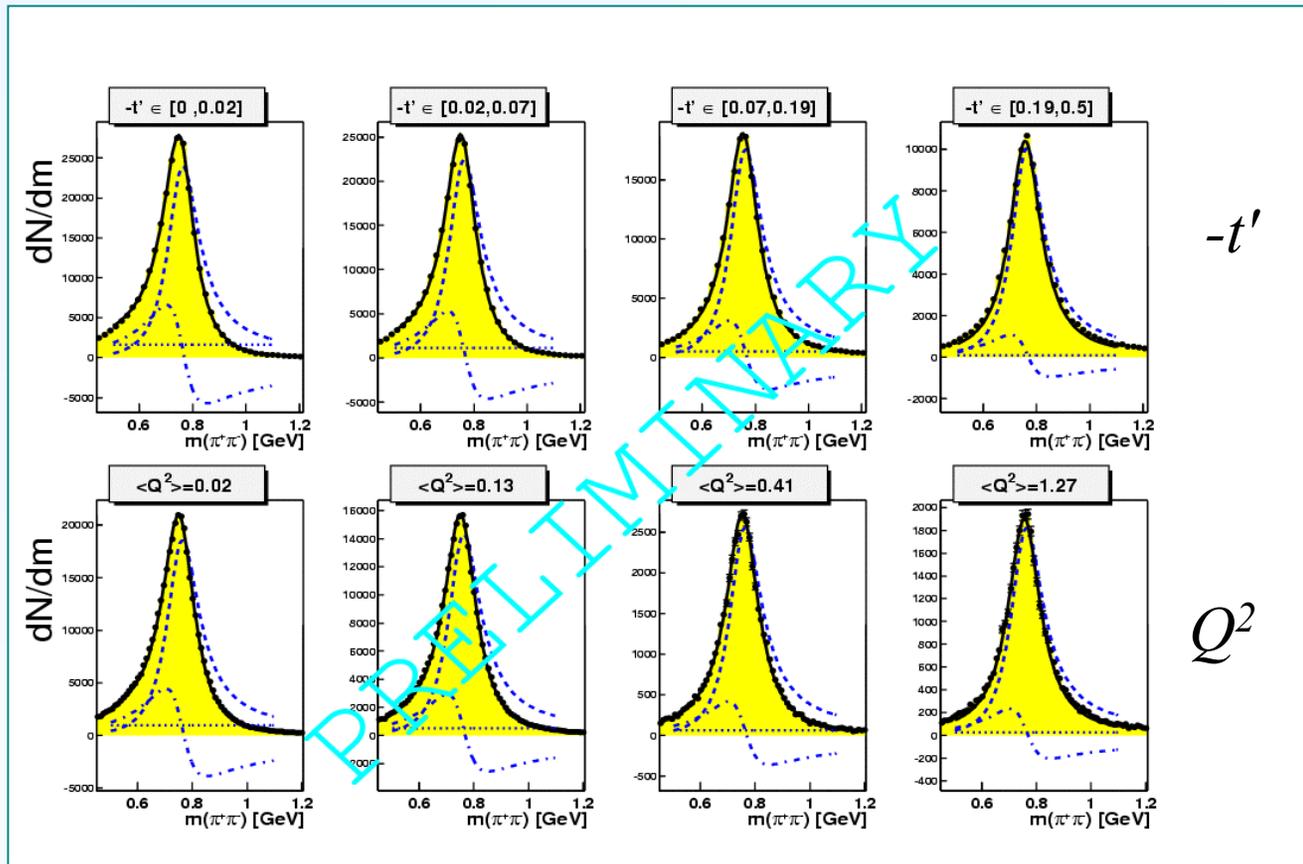


Interference of ρ^0 and $\pi\pi$



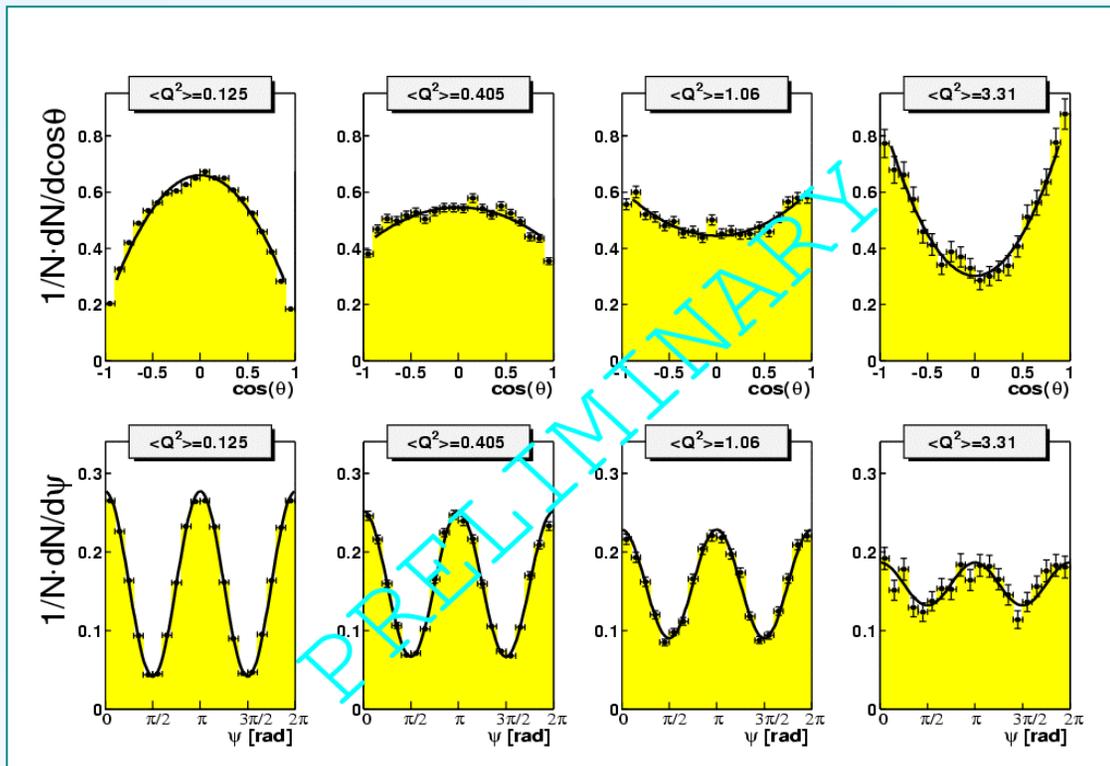
- Söding parametrization

- No accept. corr.



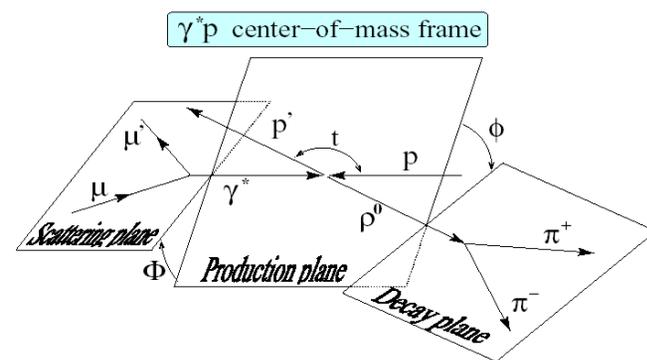


Angular distributions



$$p_T > 0.15 \text{ GeV}$$

$$Q^2 > 0.05 \text{ GeV}^2$$

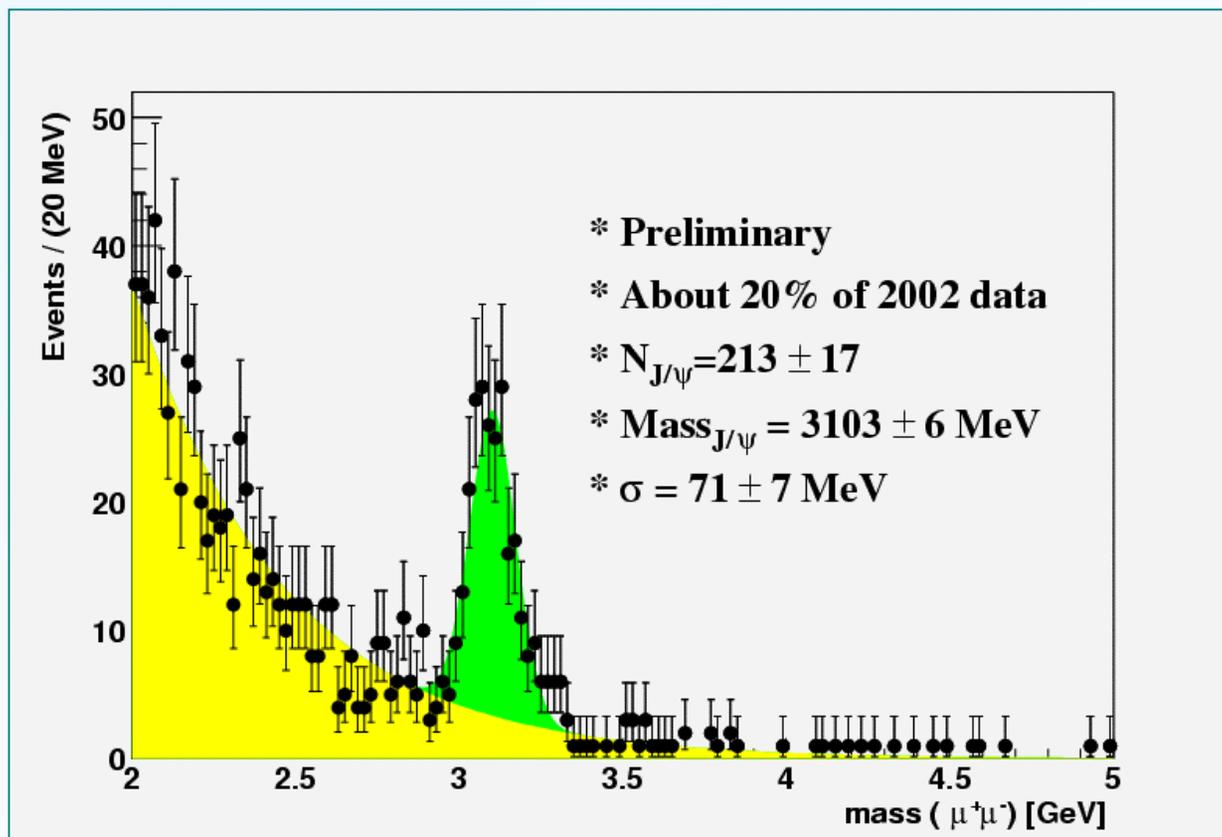




J/ψ production

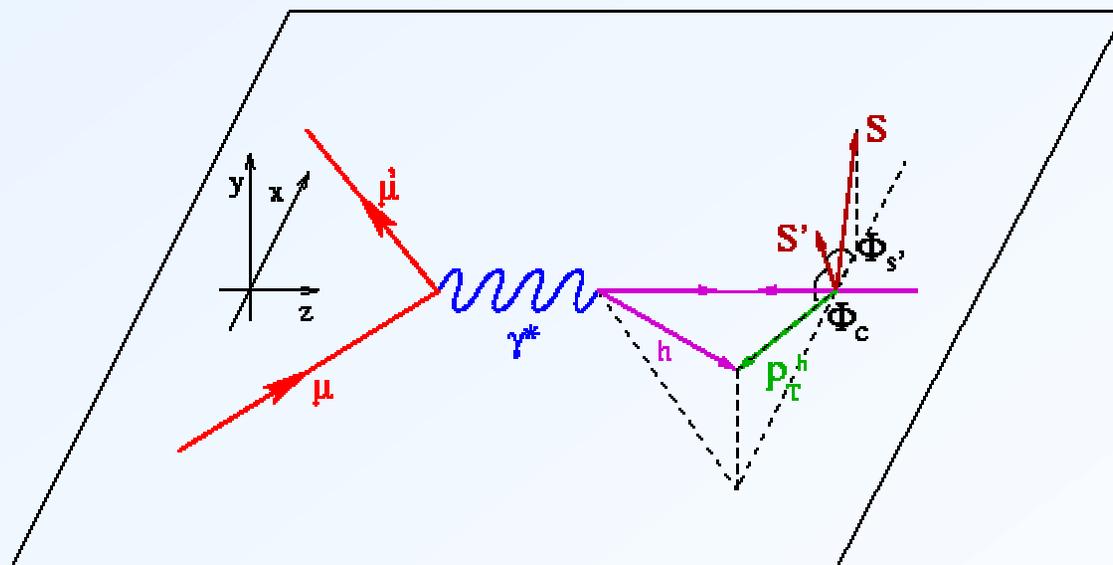
$$J/\psi \Rightarrow \mu^+ \mu^-$$

- first look
- mainly elastic

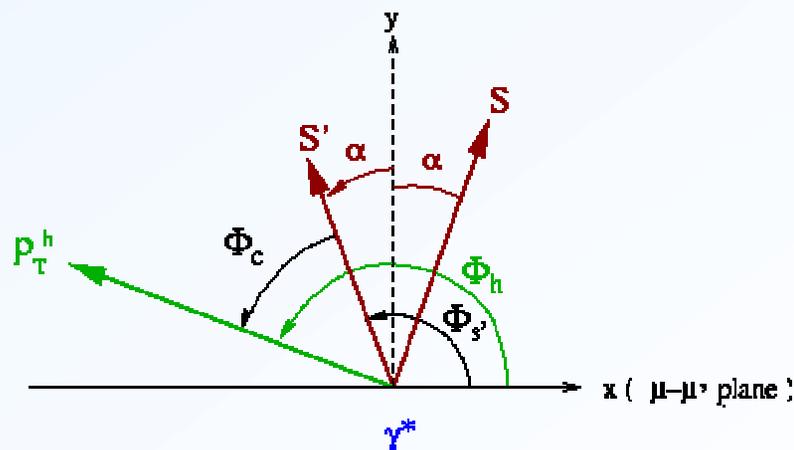




Collins angle $\Phi_C = \Phi_h - \Phi_{s'} = \Phi_h + \Phi_s - \pi$



□ Φ_h final leading hadron azimuthal angle around the quark direction

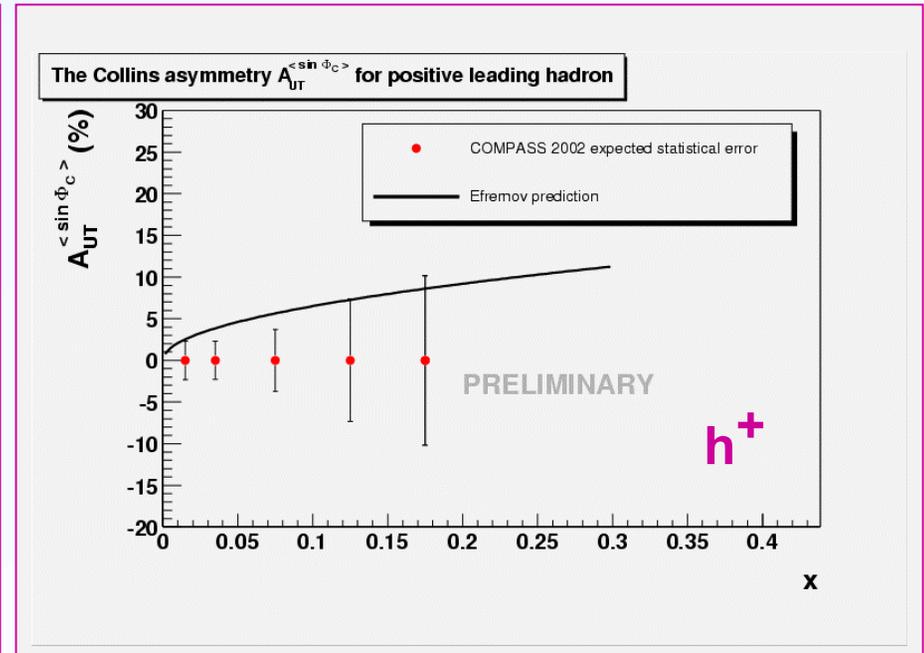
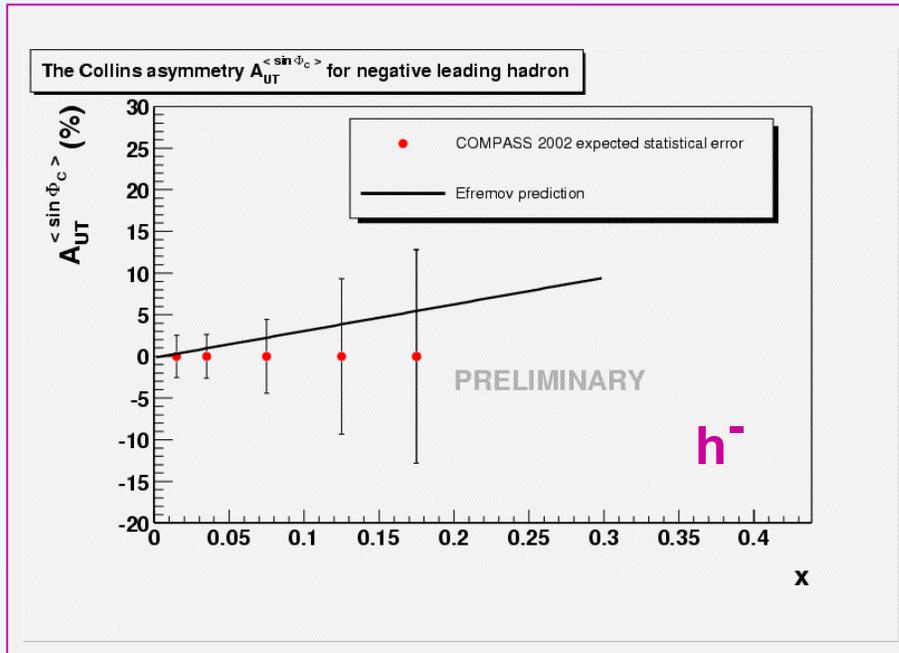


- $\Phi_{s'}$ azimuthal angle of the final quark spin around the quark direction
 $\Phi_{s'} = \pi - \Phi_s$
- Φ_s is the azimuthal angle of the final quark spin in a ref. System with z axis defined by γ direction and x-z plane defined by the scattering plane



Collins asymmetry

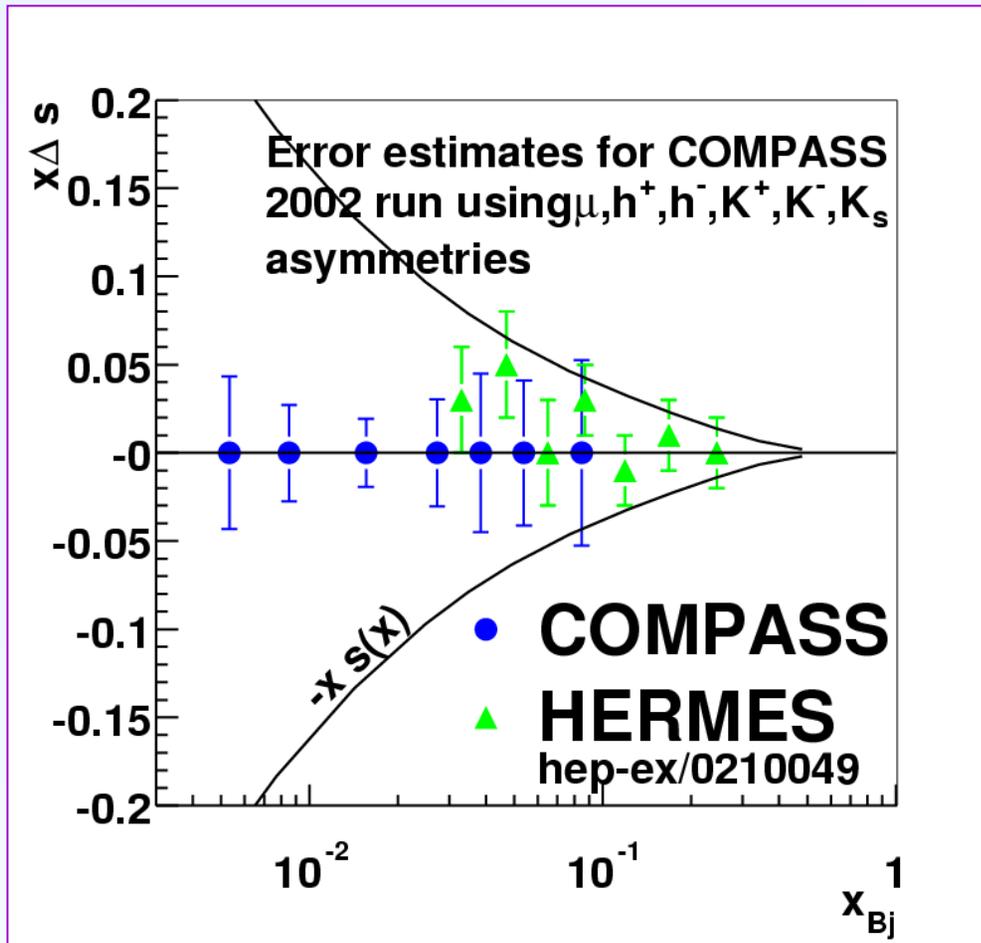
A_{UT} for positive leading hadron



Estimated error from 2002 data only,
extrapolated from analysed sample



Flavour separation Δq



Looks very promising in particular for Δs !

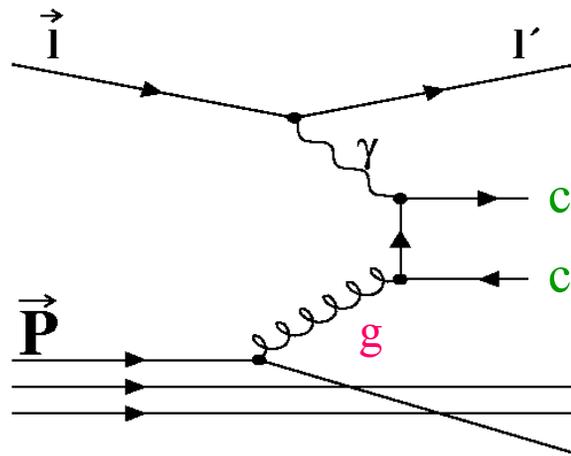
Can the first moment of Δs be **positive**?

Low-x data **essential**!



Open charm

Photon-gluon fusion: 1.2 D^0 per PGF $c\bar{c}$ event



$D^0 \Rightarrow K^- \pi^+ \quad \text{BR } 4\%$

or: $D^{*+} \Rightarrow D^0 \pi_s^+$

$\Rightarrow K^- \pi^+ \pi_s$

D^0 from D^* about 20 %



Open charm, cuts

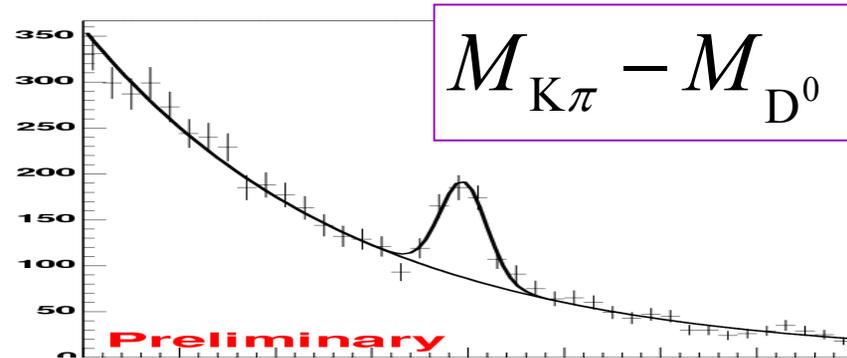
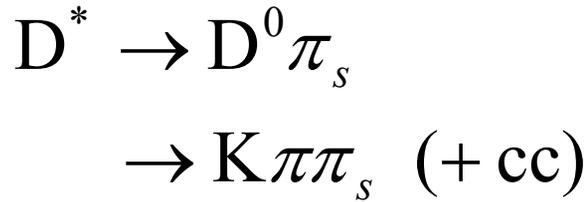
- most of 2002 data, prel. RICH and tracking
- $z_D > 0.2$ (background reduction)
- $|\cos(\theta^*)| < 0.85$ (background reduction)
- $10 < p_K < 35 \text{ GeV}/c$ (Rich πK sep.)
- define:

$$\Delta M_{K\pi\pi} = M_{K\pi\pi_s} - (M_{K\pi} + M_{\pi_s})$$

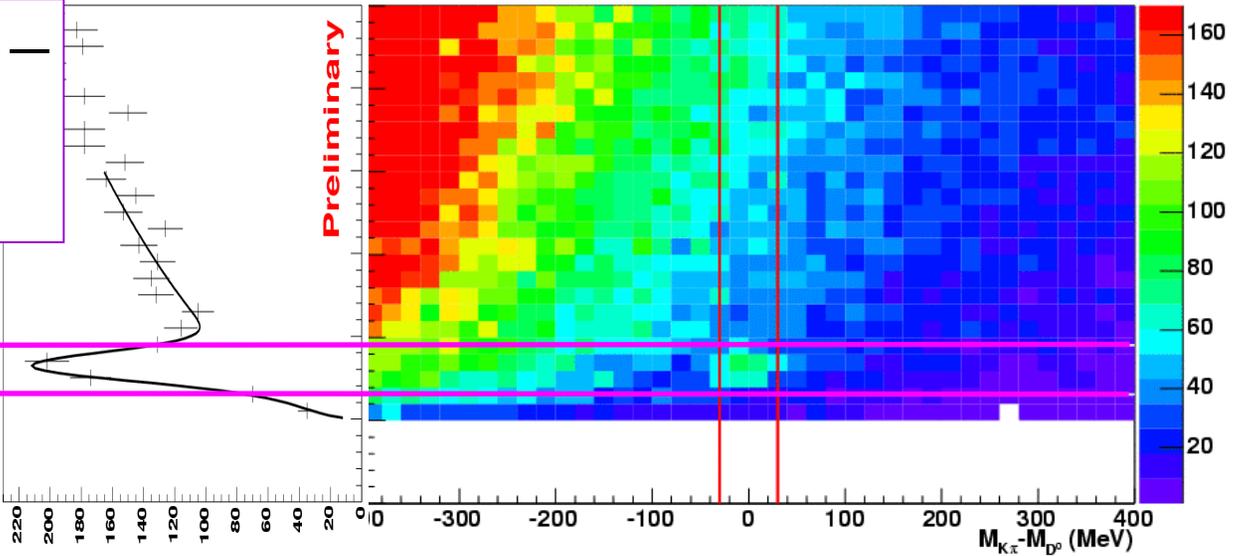
$$M(D^*) - [M(D^0) + M(\pi)]$$



$D^{*+} \rightarrow D^0 \pi_s^+$ tagging



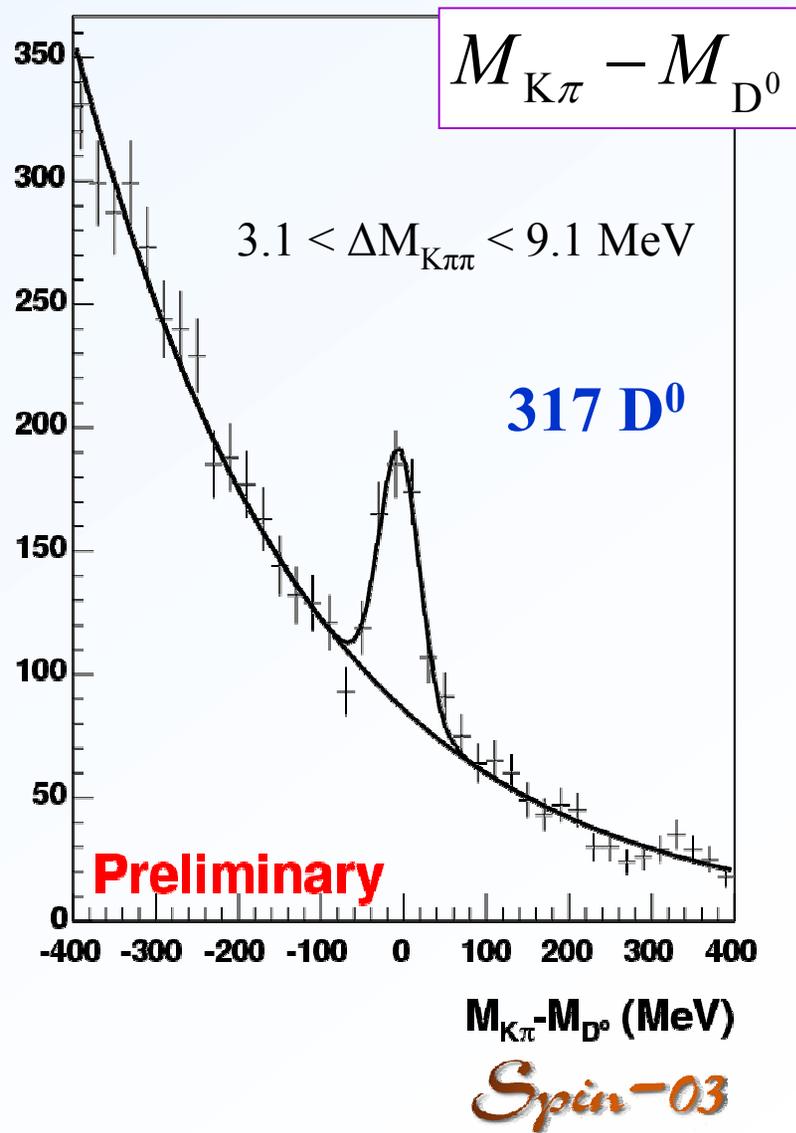
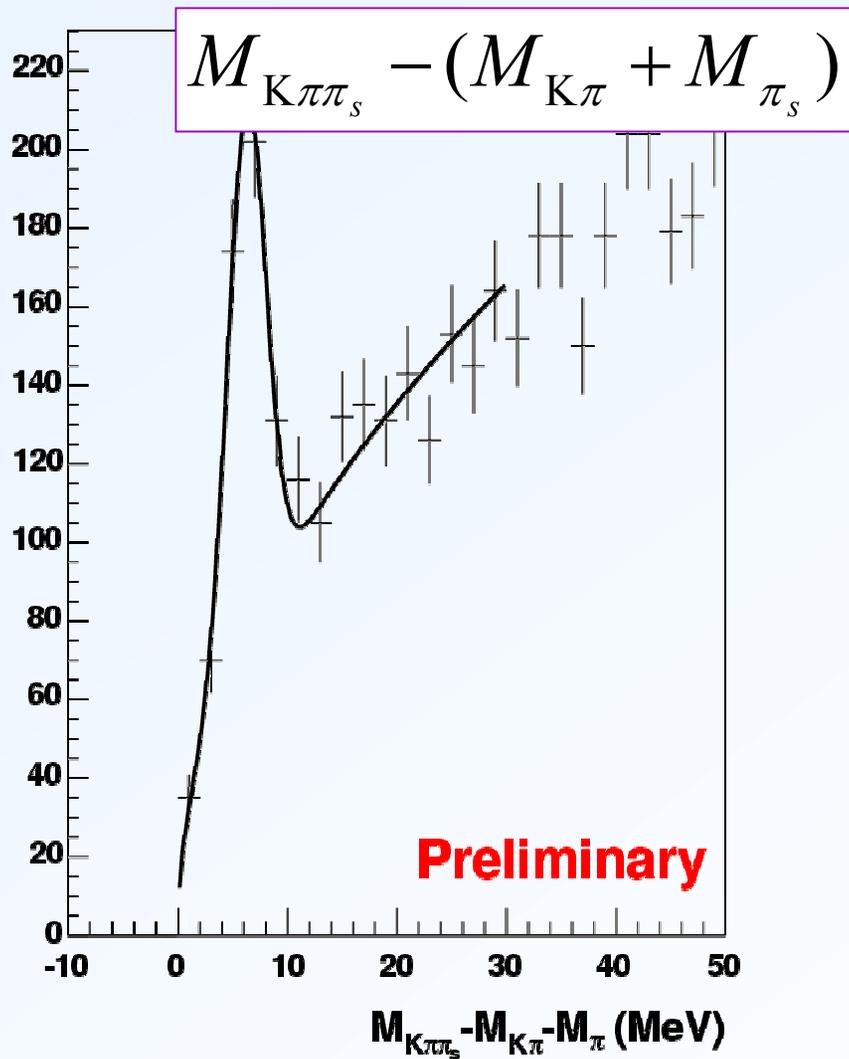
$$\Delta M_{K\pi\pi} = M_{K\pi\pi_s} - (M_{K\pi} + M_{\pi_s})$$



Choose:

$$3.1 < \Delta M_{K\pi\pi} < 9.1 \text{ MeV}$$

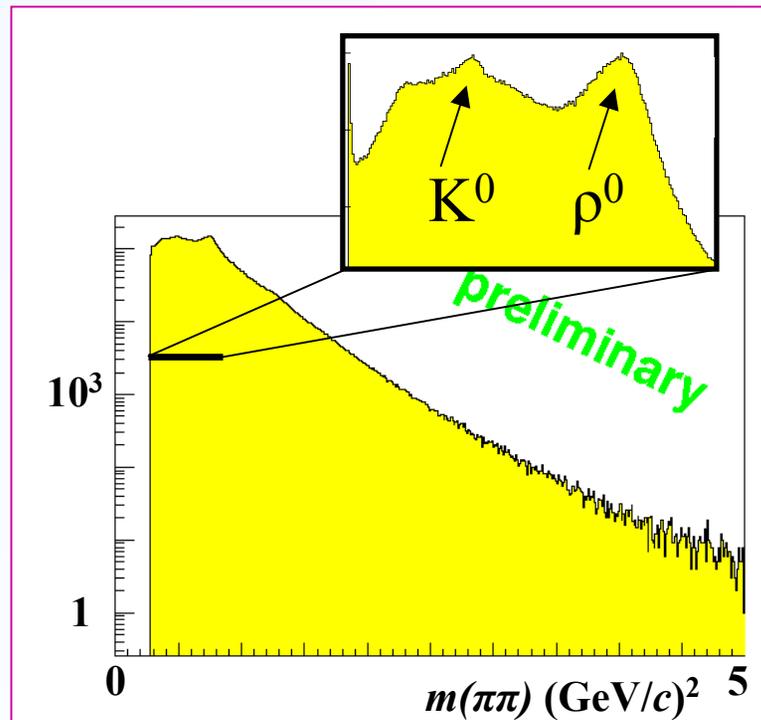
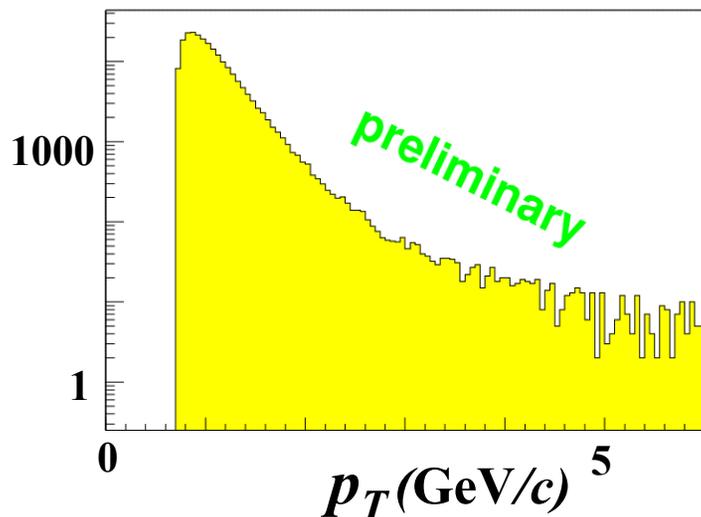
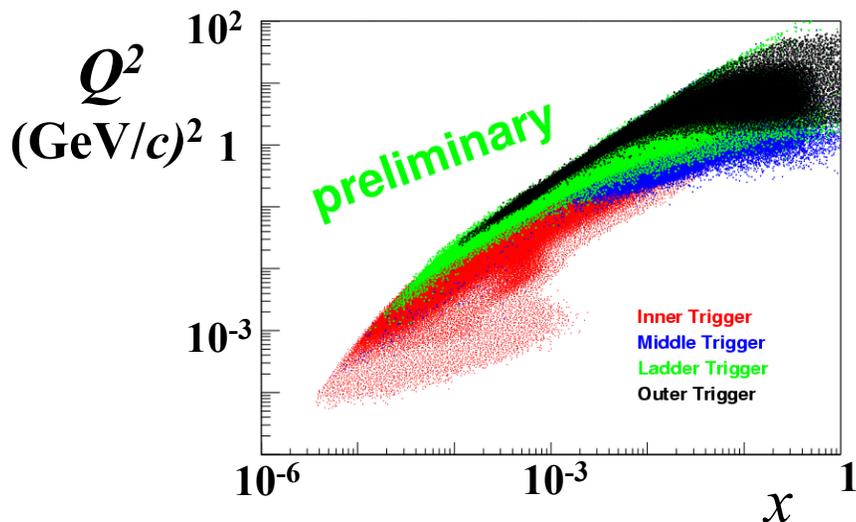
$D^{*+} \rightarrow D^0 \pi_s^+$ tagging





Δg : high- p_T hadron pairs

- $\mu, \mu' + 2$ hadrons
- in plots only 5% of 2002 data





Δg : high- p_T hadron pairs

- for $\Delta G/G$ analysis we'll use
 - $0.4 < y < 0.9, x_F > 0.1$
 - $p_{T,1}^2 + p_{T,2}^2 > 2.5 \text{ (GeV/c)}^2$ ($p_{T,i} > 1.1 \text{ GeV/c}$)
- extrapolated to full 2002 statistics
 - $Q^2 > 1 \text{ GeV}^2$: 18000 events
 - all Q^2 : 160000 events

from 2002 data: $\delta(\Delta G/G) \cong 0.31$; $Q^2 > 1 \text{ GeV}^2$
 $\cong 0.1$; all Q^2

Can data with $Q^2 < 1 \text{ GeV}^2$ be interpreted (resolved photon)?
note: 2002 data correspond about to Hermes 1996-2000, Hermes used all data



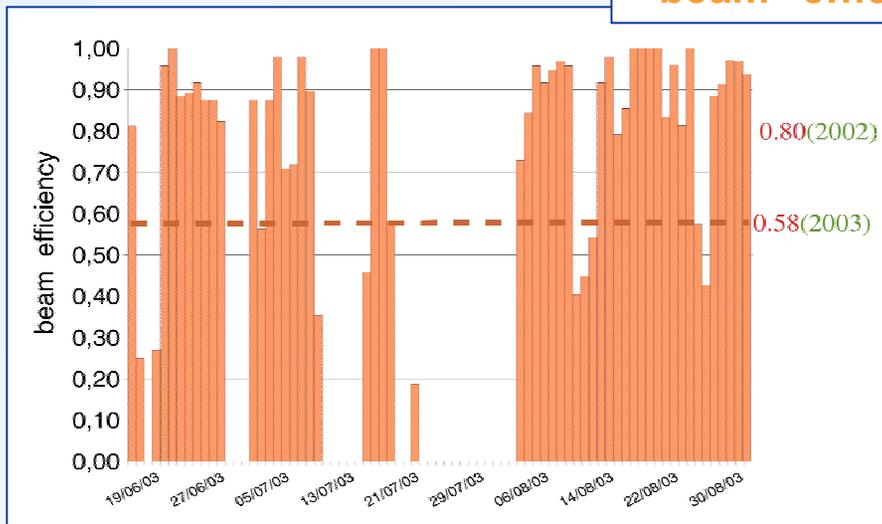
Outlook

- 2003 muon run, poor beam up to now
- 2004 long SPS run of 150 days (?)
 - muon plus 4 week hadron pilot run (?)
 - new target magnet with larger acceptance (?)
- 2005 CERN accelerator shutdown
- 2006 – 2010
 - request in preparation
 - CERN council: COMPASS should continue in 2006
- more hardware to come: ECAL (π^0), RICH, DAQ,...

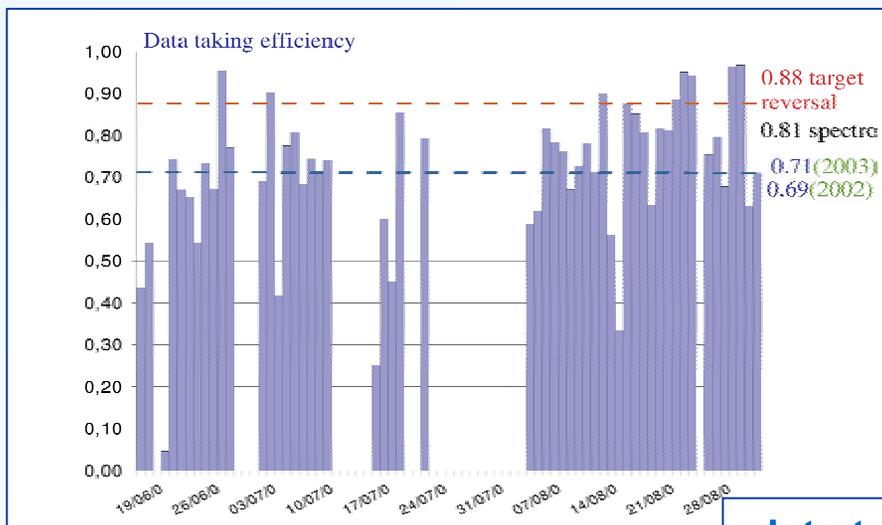
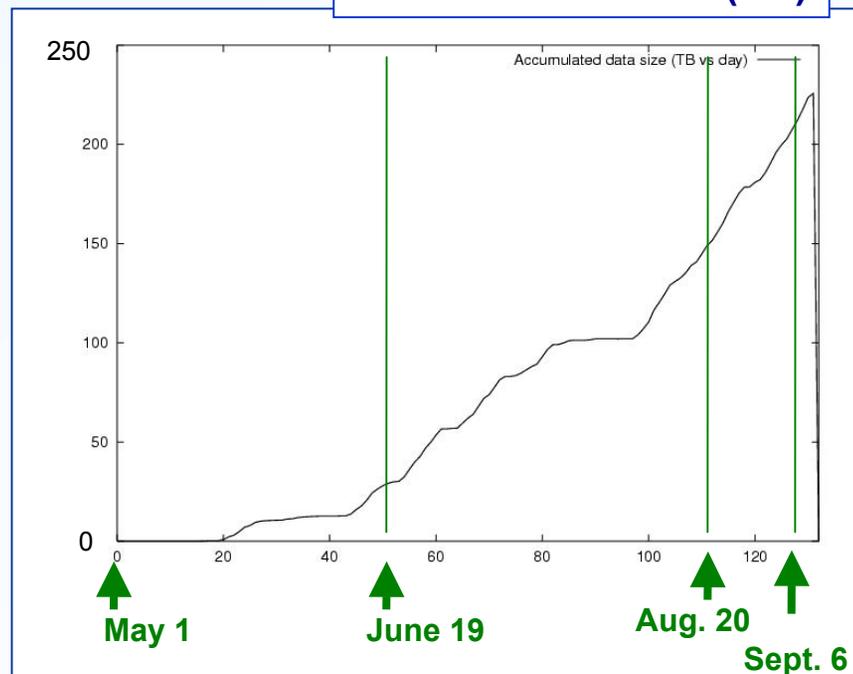
2003 run



"beam" efficiency



accumulated data (TB)



data taking efficiency

Summary



- COMPASS is up and running
- Lots of high statistics data to come
- First glance at open charm PGF with polarised target and beam
- Good perspectives for ΔG from high- p_T hadron pairs (π, K)
- Promising perspectives for running after 2005 and with LHC.



Thank you



**and
see you all in Trieste
@**

SPIN 2004

October, 10 - 16

Spin-03