Spin Physics with hadron beams @ COMPASS

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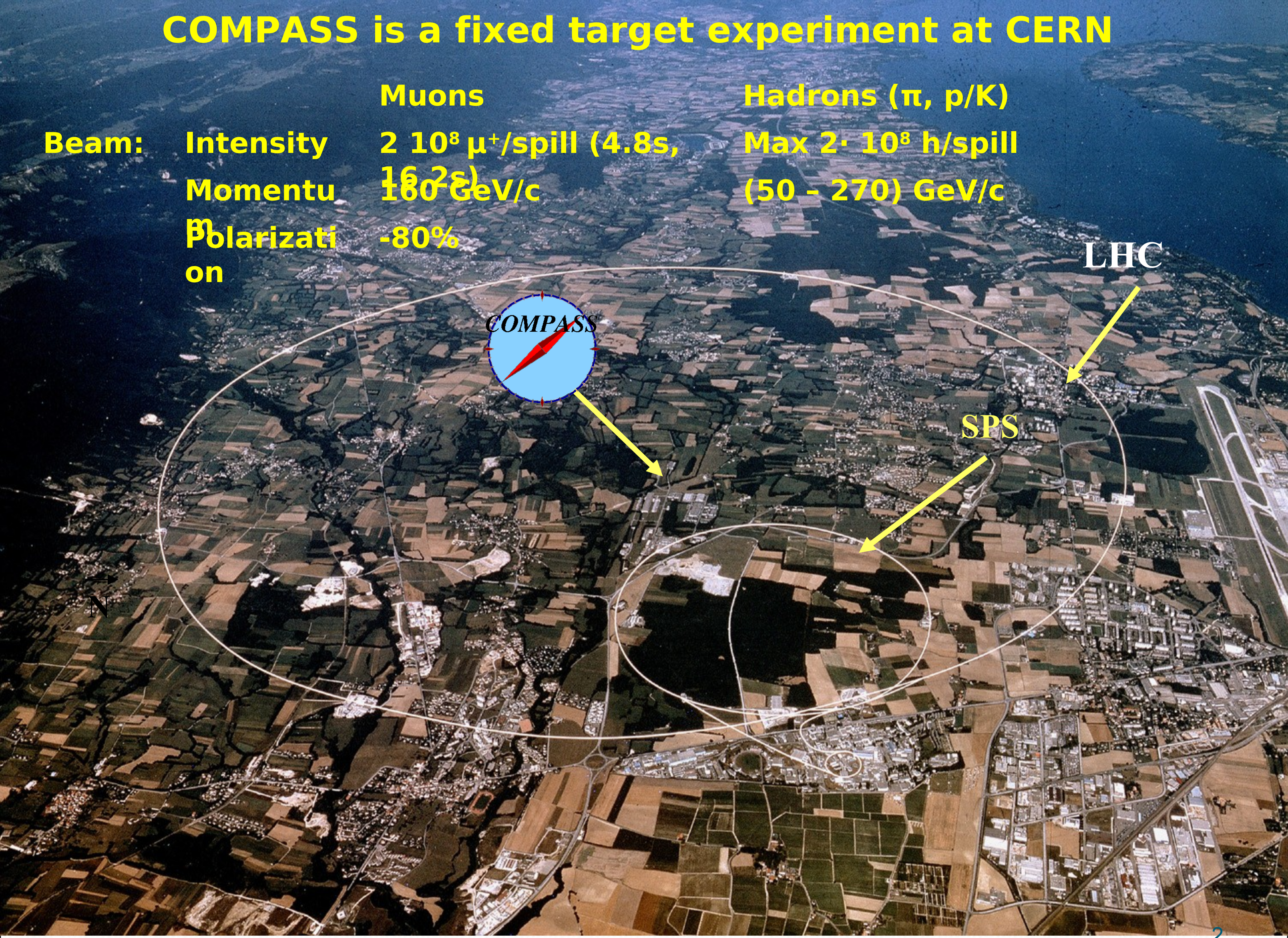
INFN Torino Congressino
Torino 11-01-2008

COMPASS is a fixed target experiment at CERN

		Muons	Hadrons (π, p/K)
Beam:	Intensity	2 10^8 μ^+/spill (4.8s, 16.2s)	Max 2· 10^8 h/spill
	Momentum	160 GeV/c	(50 – 270) GeV/c
	Polarization	-80%	



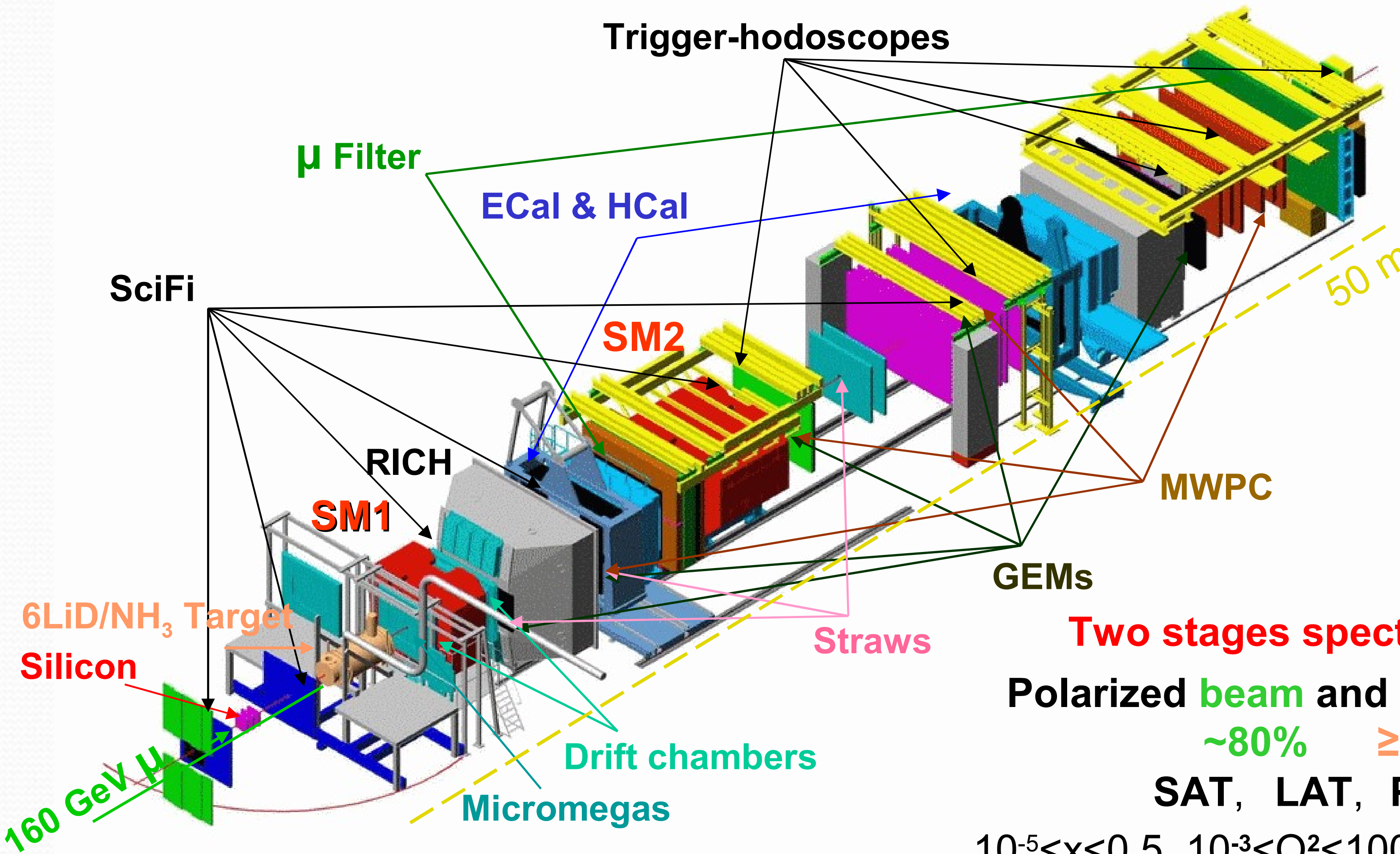
COMPASS

- 2001 → 2006 muon run with polarized (L,T) LiD target
- 2007 muon run with polarized (L,T) NH_3 target
- 2008 hadron run with liquid H_2

COMPASS contributes to the understanding

of the physics of the nucleon

The COMPASS Spectrometer



Two stages spectrometer

Polarized beam and target

~80% ≥50%;85%

SAT, LAT, PID

$10^{-5}<x<0.5$, $10^{-3}<Q^2<100$ (GeV/*c*)^2

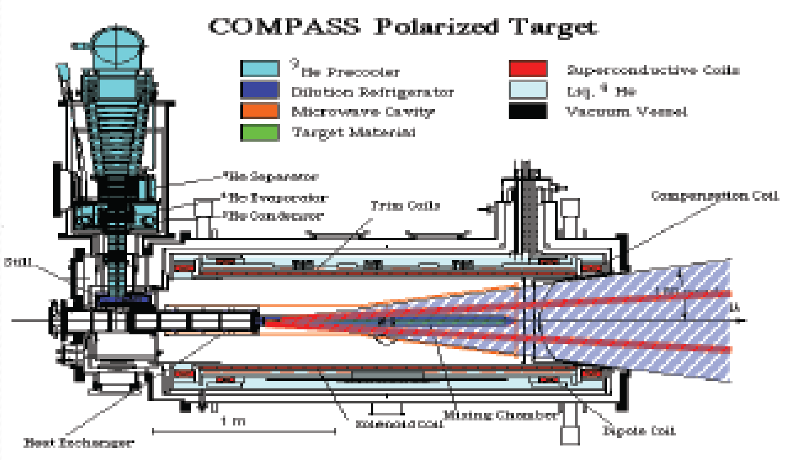
COMPASS 2006 upgrades

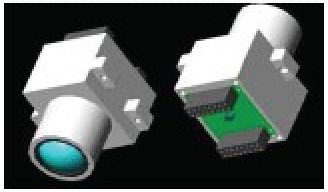
- New Solenoid magnet:
  Acceptance 70 mrad →180 mrad

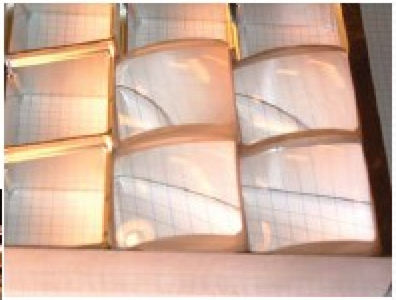
- RICH upgrade:
  Central region MAPMT system
  - More photons
  - Improved S/N

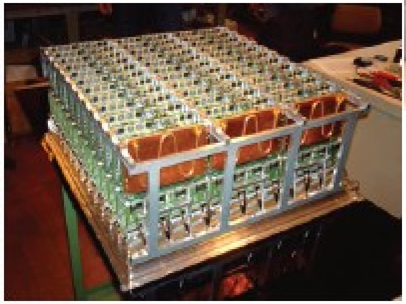
  Outer region sampling ADC
  - Improved S/N

- Other important upgrades:
  Large Drift Chamber
  RICHWall
  Full ECAL coverage
  Trigger

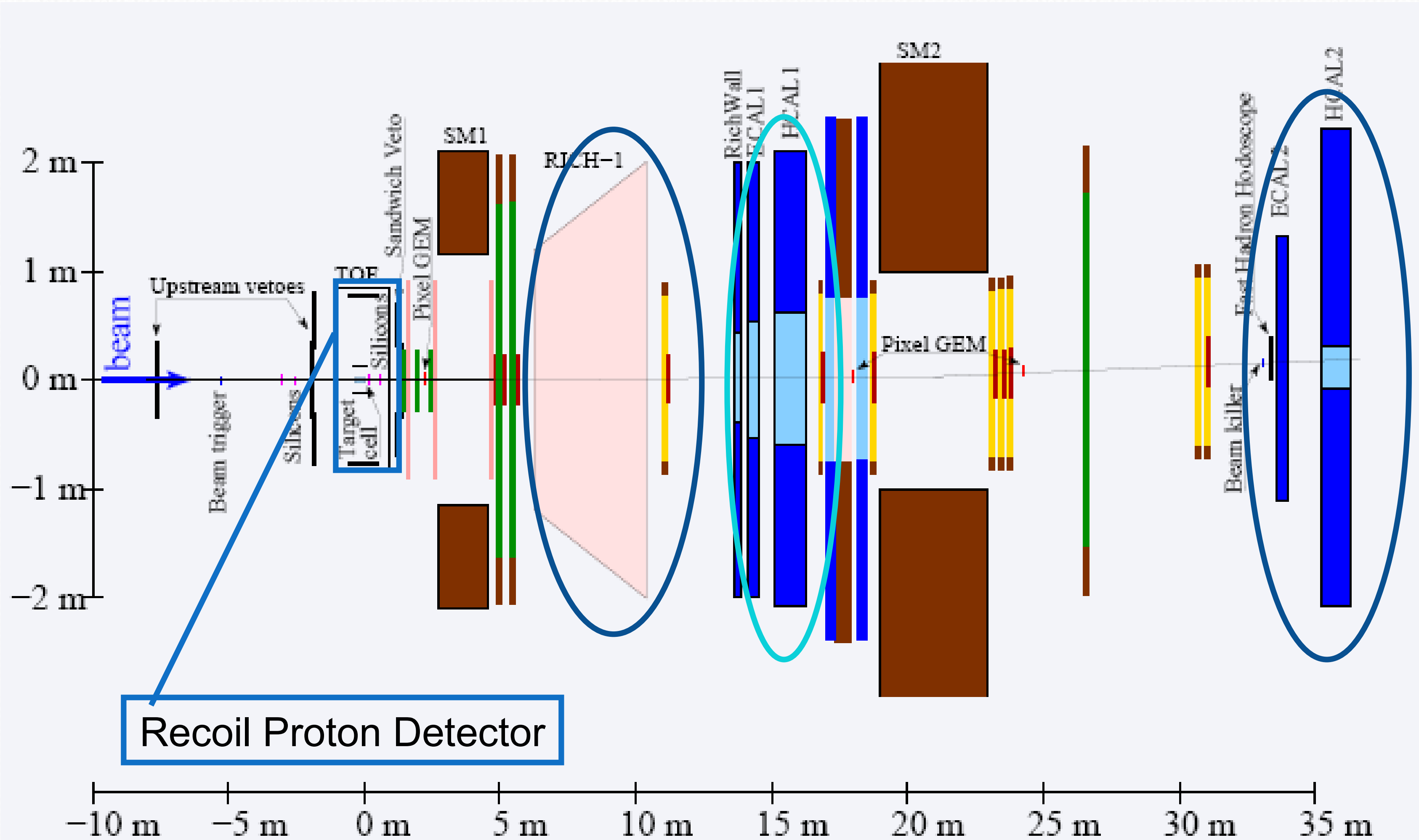








COMPASS 2008 hadron run



Beam: 190 GeV/c; $5 \cdot 10^6$ h/s; ~96% π^-, ~3.5% K^-, $\overline{0.}5$% p

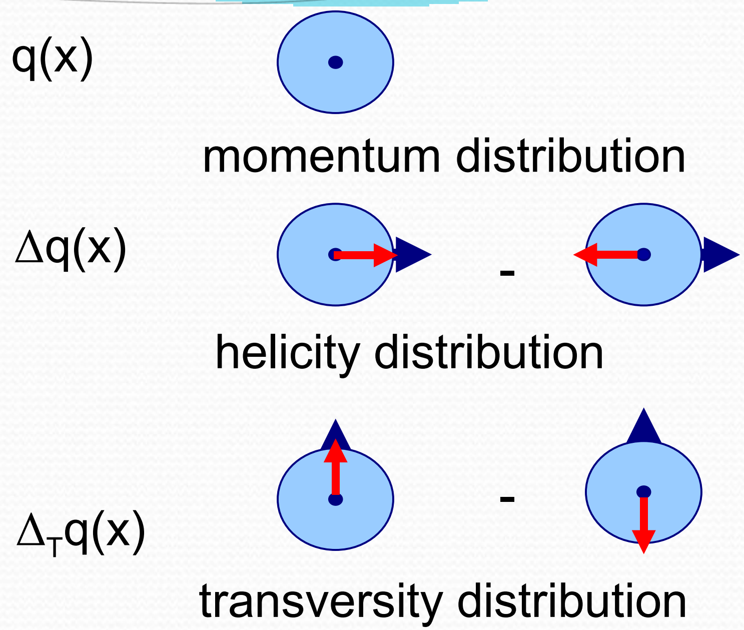
Data with π^-, K^- beams are collected in parallel

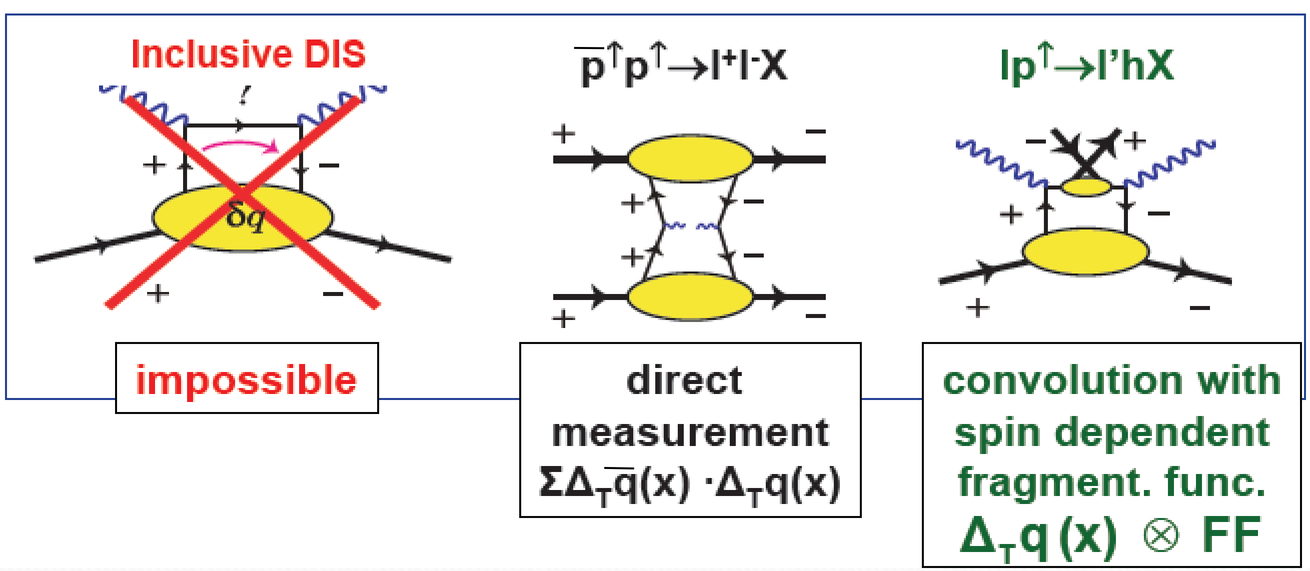
COMPASS > 2010

- Drell -Yan processes $\pi^{-}p \rightarrow l_1 l_2 X$:
  - Boer –Mulders Function
  - Transversity
  - Sivers Functions
  - …
- Deeply Virtual Compton scattering (DVCS) $\mu p \rightarrow \mu p \gamma$:
  - GPD functions
  - …

Distribution functions

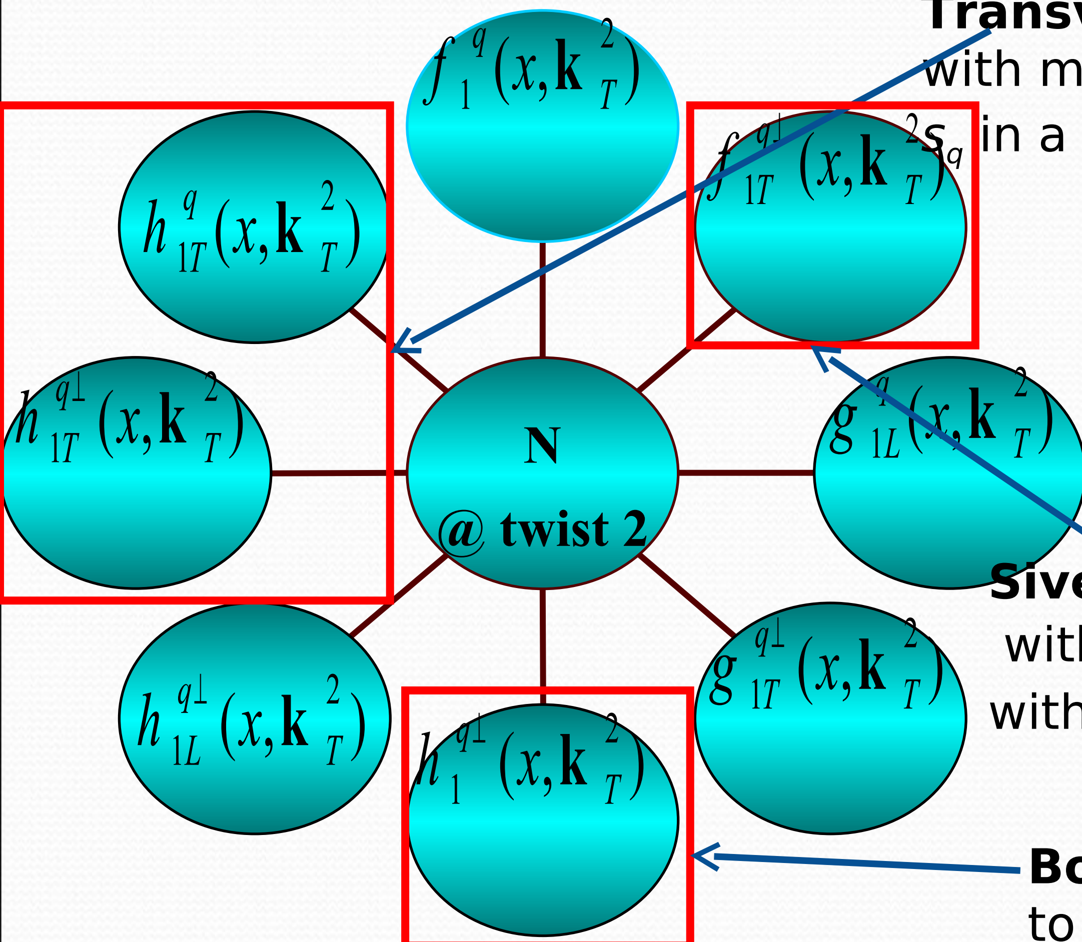
3 independent structure functions describe the spin structure of the nucleon





TMD quark DFs of Nucleon

actorization: Collins, Soper (81,82); Ji, Ma, Yuan (03, 04); Collins, Metz (04)



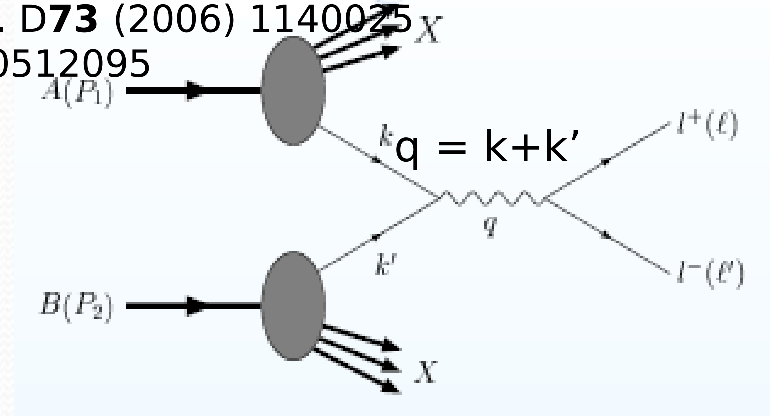
Transversity: Probability to find a quark with momentum *xP*, k_T and transverse spi s_q in a proton with transverse spin *S*

Sivers Func.: Probability to find a qua with momentum xP and k_T in a proton with transverse spin *S*

Boer-Mulders Func.: Probability to find a quark with momentum xP and k_T and spin s_q

COMPASS DY : $\pi^- p \rightarrow \mu^+ \mu^- X$

ianconi, Radici Proc. Int. Work. (Trasversity 2005), Phys. Rev. D**73** (2006) 114002
. Sissakian et al., Phys. Rev D. D72, 054027 *2005), hep-ph/0512095



Use of **unpolarized** Drell-Yan $\pi^- p \rightarrow \mu^+ \mu^- X$

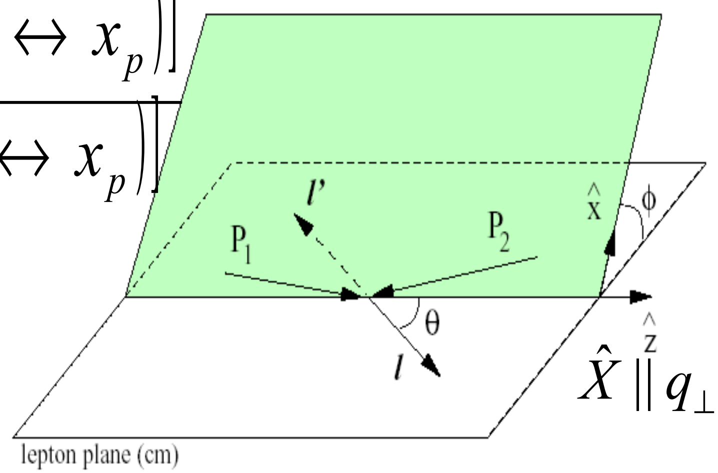
$$\hat{R} = \frac{\int d^2 q_T \left[|q_T|^2 / M_\pi M_p \right] \cdot \left[d\sigma^0 / d\Omega \right]}{\int d^2 q_T \sigma^0}$$

can be parametrized: $\hat{R} = \frac{3}{16\pi} \left(\gamma \left(1 + \cos^2\theta \right) + \hat{k} \cos 2\phi \sin^2\theta \right)$

q_T transverse momentum of virtual photon.

All angles are defined in the Collins-Sofer frame.

$$\hat{k}\left(x_\pi, x_p\right) = 8 \frac{\sum_q e_q^2 \left[\bar{h}_{1q}^{\perp(1)}\left(x_\pi\right)|_\pi \cdot h_{1q}^{\perp(1)}\left(x_p\right)|_p + \left(x_\pi \leftrightarrow x_p\right) \right]}{\sum_q e_q^2 \left[\bar{f}_{1q}^{(1)}\left(x_\pi\right)|_\pi \cdot f_{1q}^{(1)}\left(x_p\right)|_p + \left(x_\pi \leftrightarrow x_p\right) \right]}$$



First Mom. of Boer-Mulders function

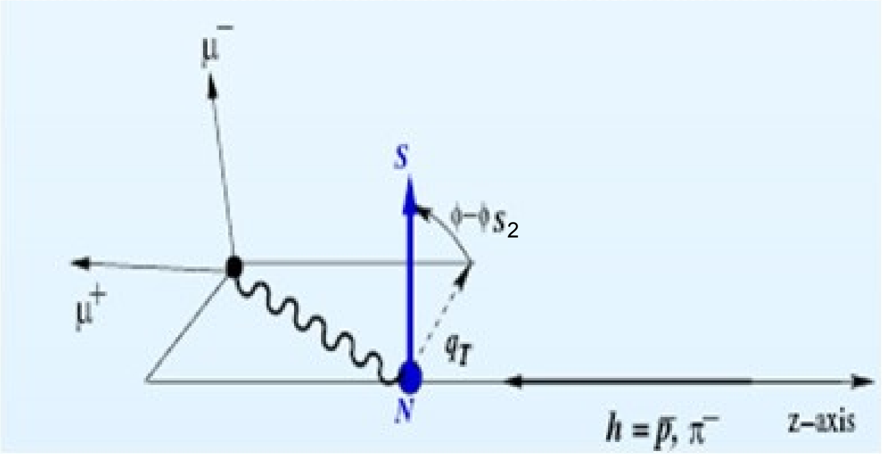
COMPASS DY : $\pi^- p^\uparrow \rightarrow \mu^+\mu^- X$

Use of single **polarized** Drell-Yan $\pi^- p^\uparrow \rightarrow \mu^+\mu^- X$

$$SSA = \frac{d\sigma^\uparrow - d\sigma^\downarrow}{d\sigma^\uparrow + d\sigma^\downarrow}$$

: azimuthal angle of the target spin vector wrt the lepton plane

: target spin vector



$$A^{\sin(\psi)} = \frac{\int d\Omega d\phi_{S2} \int d^2 q_T (|\,q_T\,|/M_\pi) \sin\psi \left[d\sigma(S_{pT}) - d\sigma(-S_{pT})\right]}{\int d\Omega d\phi_{S2} \int d^2 q_T \left[d\sigma(S_{pT}) + d\sigma(-S_{pT})\right]}$$

$\Psi = \Phi + \Phi_{s2}$
Transversity

$\Psi = \Phi - \Phi_{s2}$
Sivers

COMPASS DY : $\pi^- p^\uparrow \to \mu^+ \mu^- X$

Transversity:

$$A^{\sin(\phi+\phi_{S2})}(x_\pi, x_p) = -\frac{1}{2}\frac{\sum_q e_q^2\left[\bar{h}_{1q}^{\perp(1)}(x_\pi)\cdot h_{1q}(x_p) + h_{1q}^{\perp(1)}(x_\pi)\cdot \bar{h}_{1q}(x_p)\right]}{\sum_q e_q^2\left[\bar{f}_{1q}(x_\pi)\cdot f_{1q}(x_p) + (x_\pi \leftrightarrow x_p)\right]}$$

Sivers:

$$A^{\sin(\phi-\phi_{S2})}(x_\pi, x_p) = 2\frac{\sum_q e_q^2\left[\bar{f}_{1q}^{(1)}(x_\pi)\cdot f_{1T}^{\perp(1)}(x_p) + f_{1q}^{(1)}(x_\pi)\cdot \bar{f}_{1T}^{\perp(1)}(x_p)\right]}{\sum_q e_q^2\left[\bar{f}_{1q}(x_\pi)\cdot f_{1q}(x_p) + (x_\pi \leftrightarrow x_p)\right]}$$

$$f_{1T}^{\perp}|_{DY} = -f_{1T}^{\perp}|_{SIDIS}$$

Collins , P.L. **B536** (02) 43

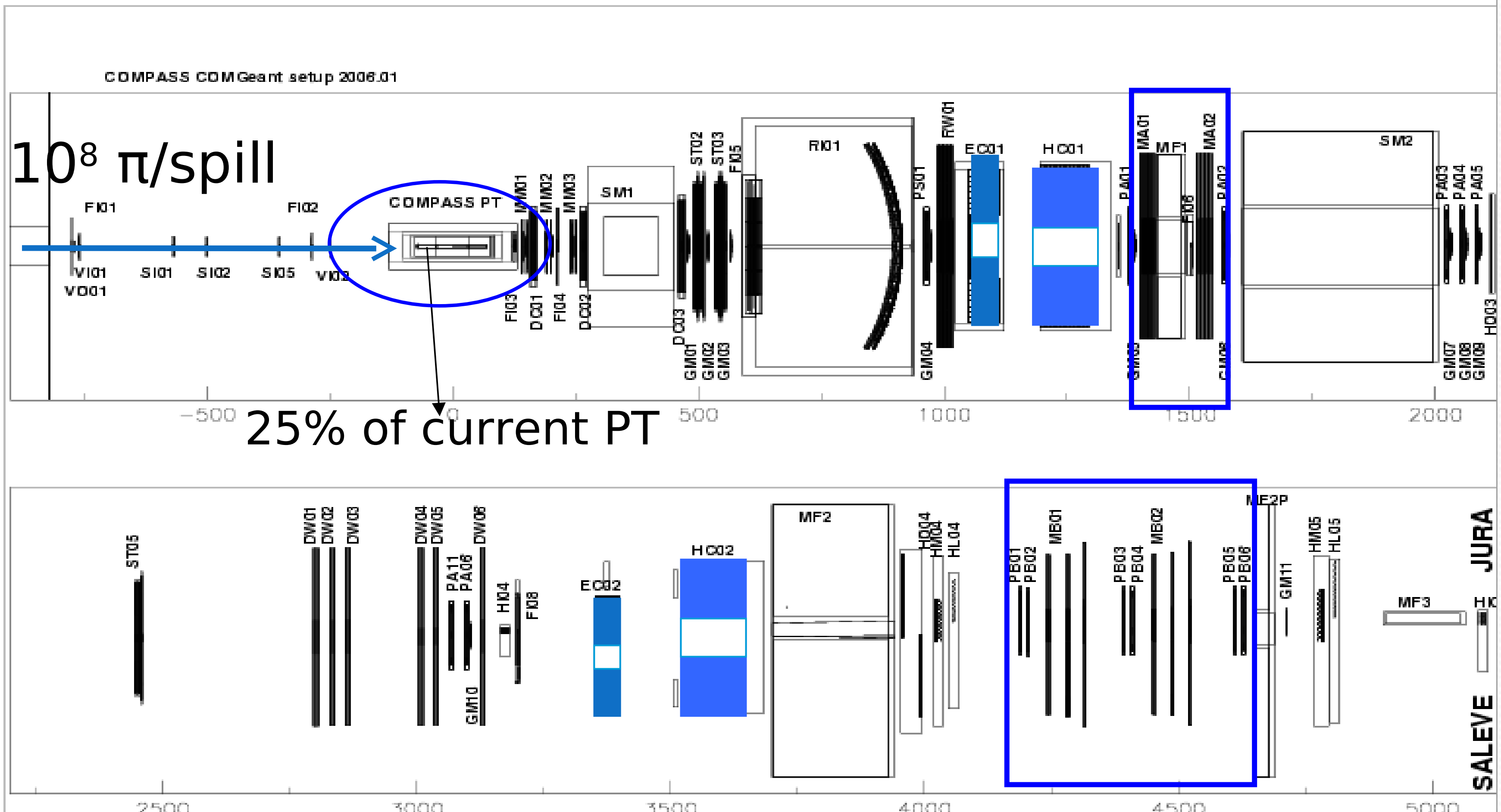
Drell-Yan @ COMPASS

$\pi^- p^\uparrow \rightarrow \mu^+\mu^- X$; $\pi^- p \rightarrow \mu^+\mu^- X$

Unique COMPASS environment:

- Intense (10^8 h/spill) hadron beam
- Large acceptance polarized NH_3 target
- Trackers standing high rates
- Multipurpose spectrometer:
  - Advanced and flexible triggering system with the possibility to trigger on muons, electrons and hadrons
  - Good hadron/electron/muon identification
  - Large muon/electron acceptance
  - High capacity DAQ system
- COMPASS is a **running** experiment

COMPASS spectrometer layout



Trigger system to be implemented for:

- ($\mu^+\mu^-$) ; (e^+e^-);
- at least one hadron in the final state

Kinematic range

Valence quarks region (x1, x2) > 0.1
has to be covered

x_1 → x-Bjorken of incoming quark
x_2→ x-Bjorken of target quark
√s → cm energy

$$0 < x_1 x_2 = \frac{M^2}{S} \leq 1 \qquad Q^2 = M^2$$

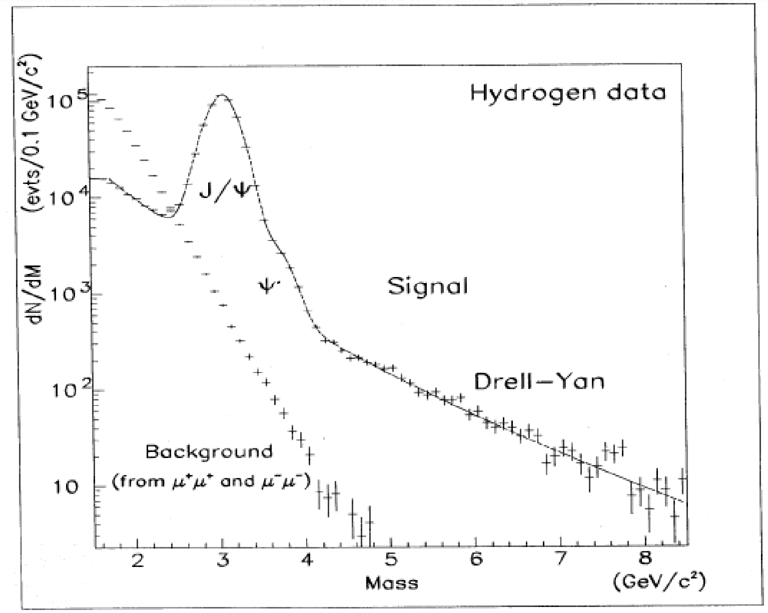


Figure 1: Mass spectra of background and signal for p-p events.

Enriched data sample at big Q^2

M must be large enough to apply pQCD

$E_{\pi\text{-beam}}$= 50-160 GeV

Very preliminary DY events estimation

- Target: two cells L_{NH3}=15 cm each
- Target material: NH_3
- Density of NH_3: ρ_{NH3} = 0.85 g/cm3
- PT material filling factor F_f = 0.6
- Number of nucleon in NH_3 molecule: A_{NH3} =17
- π- beam intensity: $I_{beam} = 2\times10^7$ h/s
- $N_A = 6.0\times10^{23}$ mol^{-1}

Luminosity: $L = L_{NH3} \times N_{cell} \times \rho_{NH3} \times F_f \times N_A \times 1/A_{NH3} \times I_{beam} \approx$

$$\mathbf{1.1\times10^{31}\ cm^{-2}\ s^{-1}}$$

Very preliminary DY events estimation

- Compass DY pairs reconstruction efficiency (acceptance included) : A ≈ 0.4
- DY cross section on NH_3: $\sigma_{NH3} = N_{nucl} \times \sigma_{\pi p}$, where N_{nucl}=17
- D_{spill} = 5 s (duration of spill),
- N_{spill} =4000 (number of spills per day),
- E_{sps}= 80% (efficiency of the machine)
- Duration of the Run 150 days: D_{RUN}=150

$$Rate = L \times N_{nucl} \times \sigma_{\pi p} \times A \times D_{spill} \times N_{spill} \times E_{SPS} \times D_{RUN}$$

DY cross section and statistics estimation for 150 days of running

S [GeV^2]	M ($\mu^+\mu^-$) [GeV] 2.5-4.	M ($\mu^+\mu^-$) [GeV] 4.-9.
100	0.35 nb	0.[illegible] nb
200	0.65 nb	0.10 nb
300	0.78 nb	0.15 nb
S [GeV^2]	M ($\mu^+\mu^-$) [GeV] 2.5-4.	M ($\mu^+\mu^-$) [GeV] 4.-9.
100	78500	6700
200	146000	22440
300	175000	33660

VERY PRELIMINARY

Cross section values were taken from AB_5 A.Bianconi generator cross-checked with PYTHIA data (A.Nagaytsev, Dubna), without J/Ψ contribution

Expected statistical errors:

Assuming:

- the polarization of the NH_3 target → 85%
- target dilution factor → 3/17
- $N_{tot.exp}$ → $3.3 \cdot 10^4$ DY-events

$$\delta A \approx \frac{1}{P_T \times f \times \sqrt{N_{tot.\exp}}} \approx 3\%$$

without taking into account uncorrelated background

(depends on trigger selectivity)

Drell-Yan Beam Test @ COMPASS, 11-12 November 2007

DY Beam Test, 11-12 November 2007

Important checks:

- Hadron beam intensity & new optics (160 GeV/c negative pion beam)
- Radiation conditions in the experimental hall with:
  - COMPASS Polarized Target (full length (1.20 m)~ 1 int.lenght);
  - operation with high intensity hadron beam: 2×10^{7} hadrons/spill

  L ~10^{31} cm^{-2} s^{-1} (~ equivalent to 10^{8} hadrons/spill on 0.25 int.lenght PT)
- COMPASS PT performance with the high intensity hadron beam
- COMPASS spectrometer performance with high intensity hadron beam
- J/Ψ event rates (good normalization for DY and background)
- Signal/Background level and trigger rates

h/spill

- Very stable spectrometer and PT behaviour (only minor problems with few detectors)

- We are confident that we can run at luminosity of $\sim 10^{31}$ $cm^{-2} s^{-1}$ so that makes DY program feasible
  - 2.2×10^{7} h/spill and full size PT (1 int.length↔ 1.2 m)
  - 10^{8} h/spill and 0.25 of full PT (~0.3 m)

- Another crucial issue – background level – can be evaluated after data analysis (reconstruction of events in progress)

Time line

- EoI → first quarter of 2008
- LoI → by summer 2008

- COMPASS spectrometer upgrade preparation: 2009-2010
  - Muon trigger in LAS
  - Modification of the central part of ECal1

- First data with pion beam after 2010

- T6 line upgrade (antiproton and kaon beam): 2013-2014?

INTERNATIONAL WORKSHOP ON HADRON STRUCTURE AND SPECTROSCOPY

31th March - 2nd April 2008

www.iwhss08.to.infn.it

Sezione di Torino

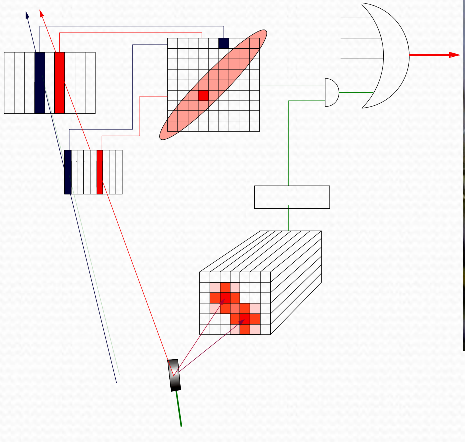
COMPASS

Dip. Fisica Generale A. Avogadro

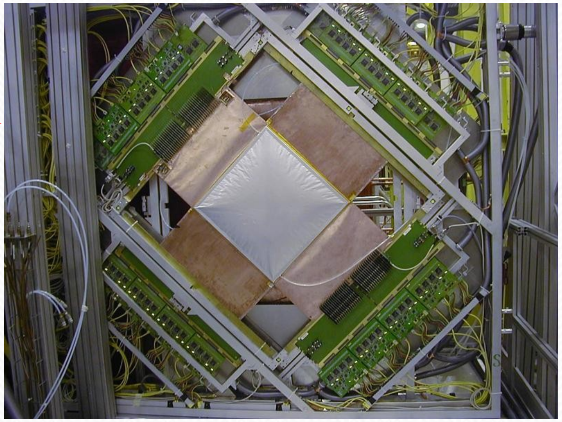
Univ. Piemonte Orientale

DiSTA
Dipartimento di Scienze e Tecnologie Avanzate

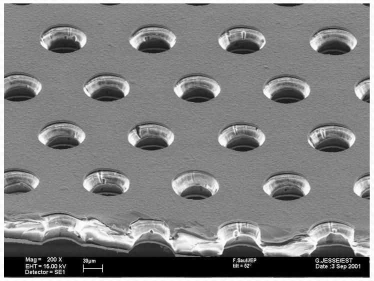
Many new technologies for tracking and PID



Trigger-System

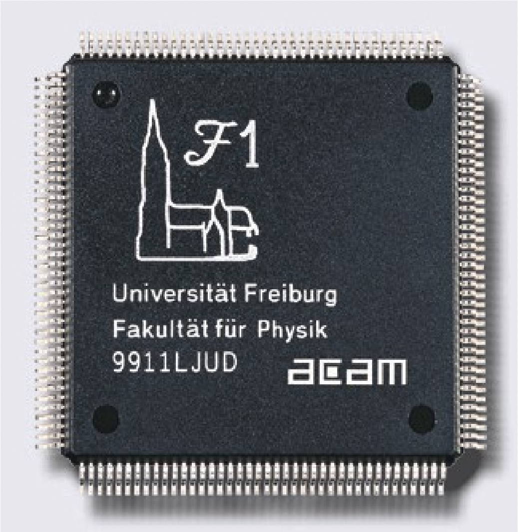


MicroMegas

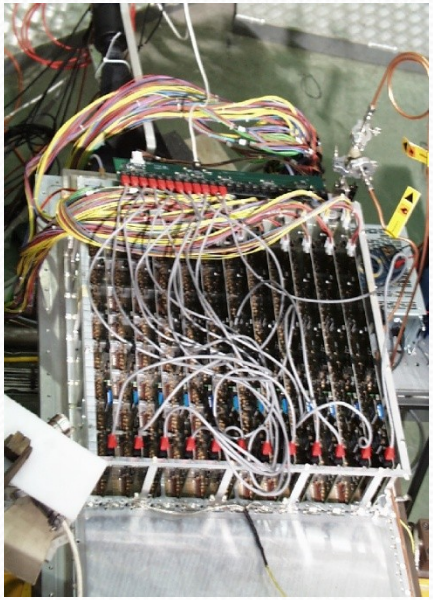


GEM

Straws



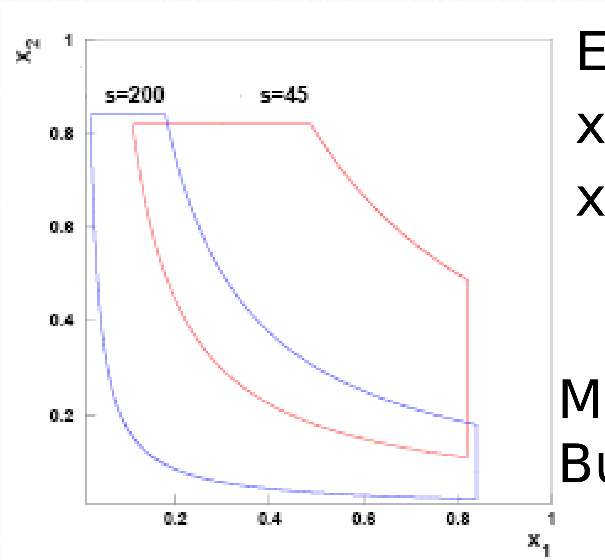
Readout electronics



RICH readout

Scintillating fiber trackers

Kinematic range



$E_{\pi\text{-beam}}$ = 50-270 GeV

x_1 → x-Bjorken of incoming quark

x_2 → x-Bjorken of target quark

$$x_1 x_2 = \frac{M^2}{S} \qquad Q^2 = M^2$$

M must be large enough to apply pQCD

But production rate falls off rapidly with M^{-4}

M interval out of the resonances region has to be selected (3.5 GeV/c^2 < M < 9.0 GeV/c^2)

Valence quarks region (x1, x2) > 0.1 has to be covered

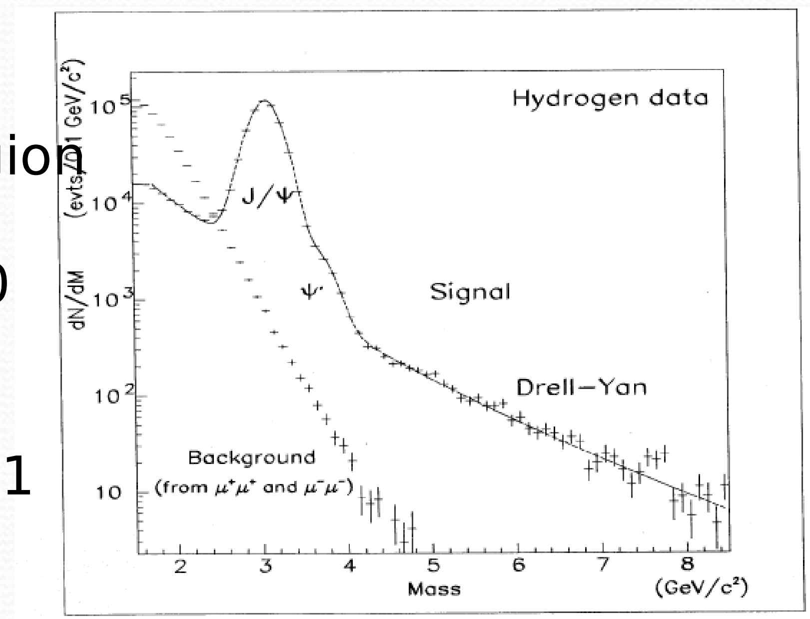


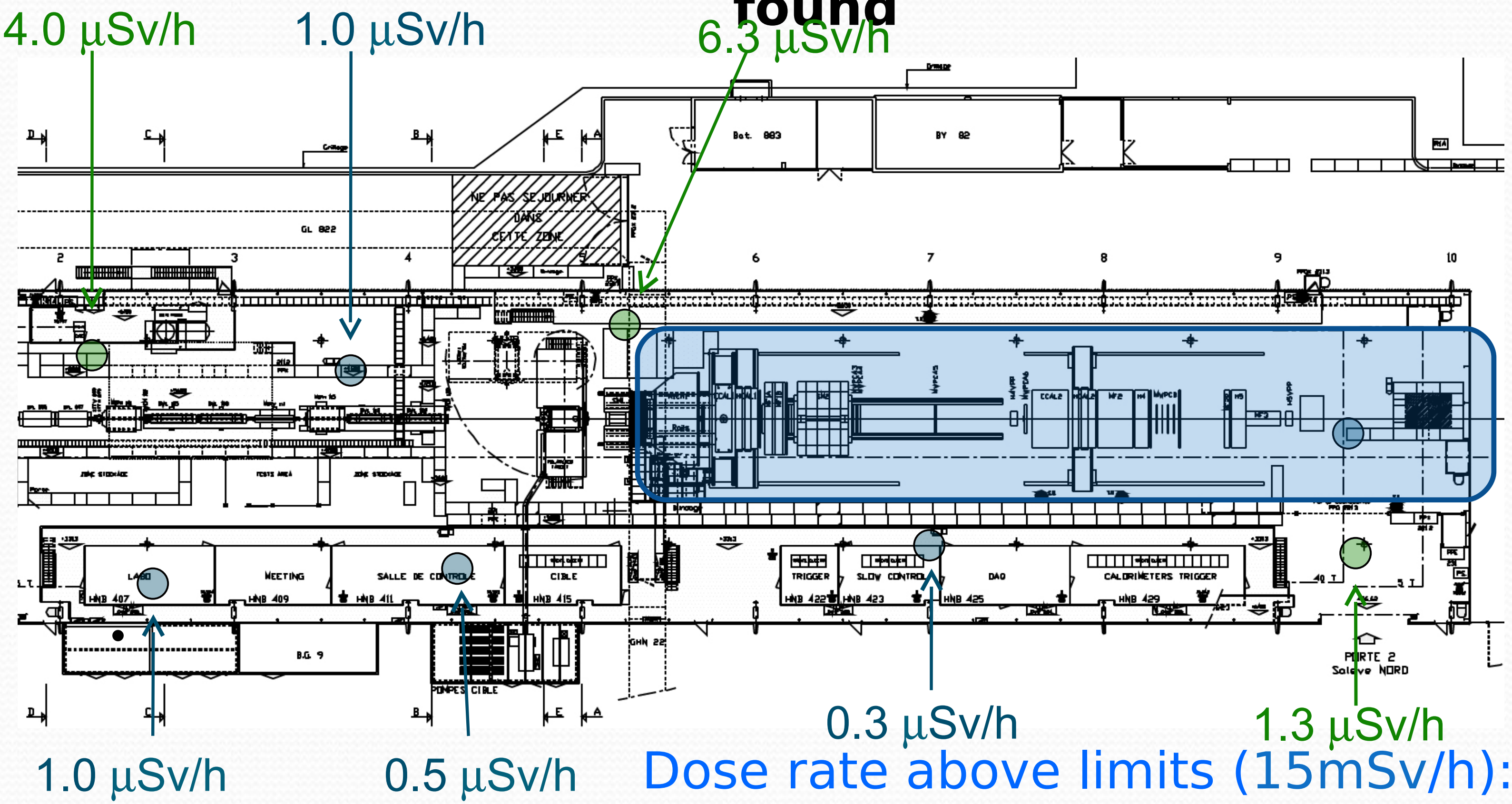
Figure 1: Mass spectra of background and signal for p-p events.

Dose rate measurements

Heinz Vincke

2.2×10^{7} hadrons per spill (supercycle time 20.4s)

No (additional) activation of beam line components was found



Dose rate above limits (15mSv/h):

Outside at Door PPX 221.1

Probably on balcony on Jura side upstream of target