A complete experiment for GPDs Measurements using COMPASS at CERN after 2010

Hard exclusive production of mesons ($\rho,\omega,\phi\ldots, \pi,\eta\ldots$)

selection of γ^*_L (SCHC for ρ)

separation of

$\mathbf{H},\mathbf{E}$ (with ρ,ω,φ…) and $\widetilde{\mathbf{H}},\widetilde{\mathbf{E}}$ (with π,η…)
quark flavor H^u, H^d, H^s…
quark gluon contributions

Deeply virtual Compton scattering (+BH)

if E_μ (or x_{bj}) is large: DVCS >> BH $\Rightarrow \sigma_{DVCS}$

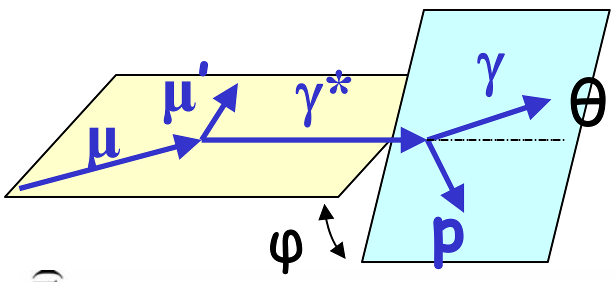
if not $\Rightarrow$ interference DVCS.BH

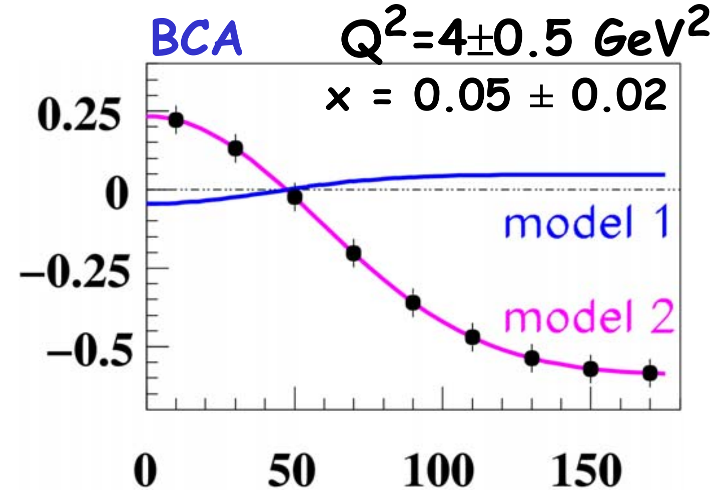
$$\sigma^{\overleftarrow{\mu}+} + \sigma^{\overrightarrow{\mu}-} \sim \mathcal{I}m\, H(x=\xi,\xi,t)$$

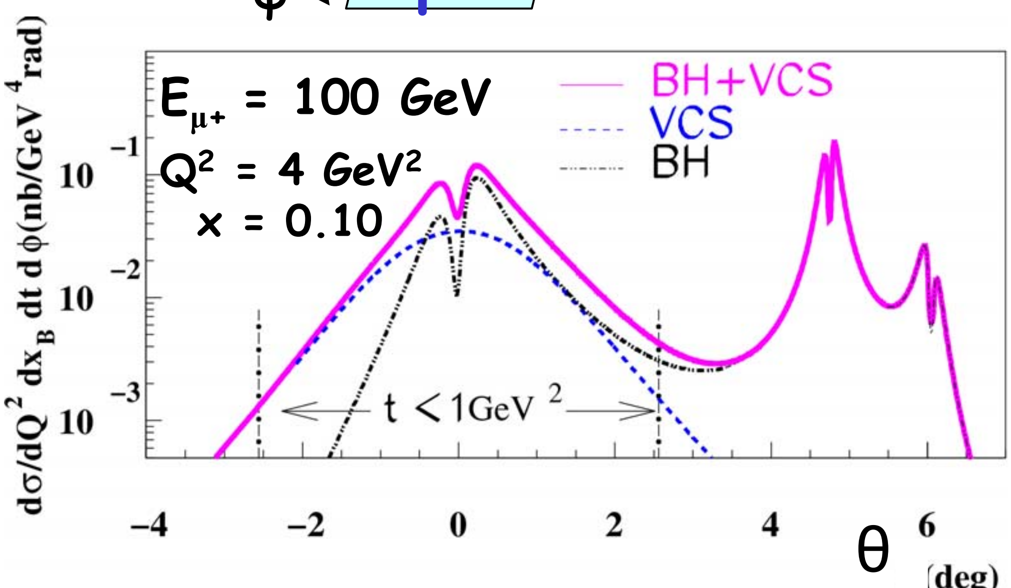
$$\sigma^{\overleftarrow{\mu}+} - \sigma^{\overrightarrow{\mu}-} \sim \mathcal{P}\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi}$$

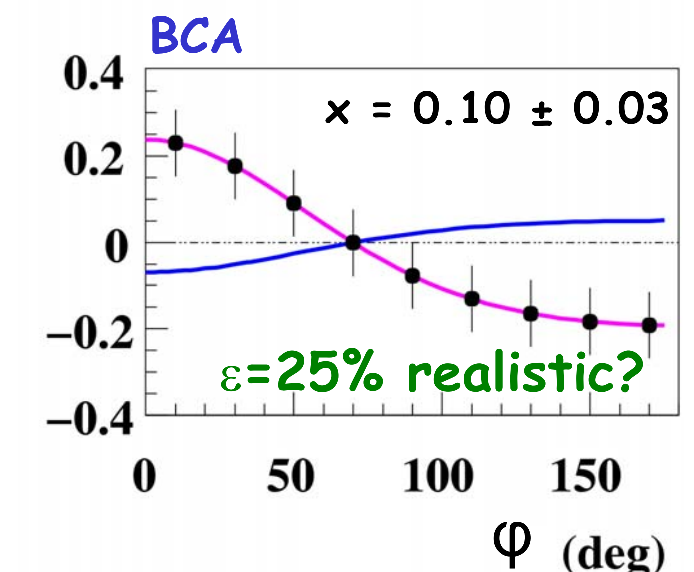
Deeply Virtual Compton Scattering
Beam Charge Asymmetry (BCA) measured with the 100 GeV muon beam at COMPASS

$$\sigma^{\overleftarrow{\mu}+} - \sigma^{\vec{\mu}-} \sim \mathcal{P}\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-\xi}$$







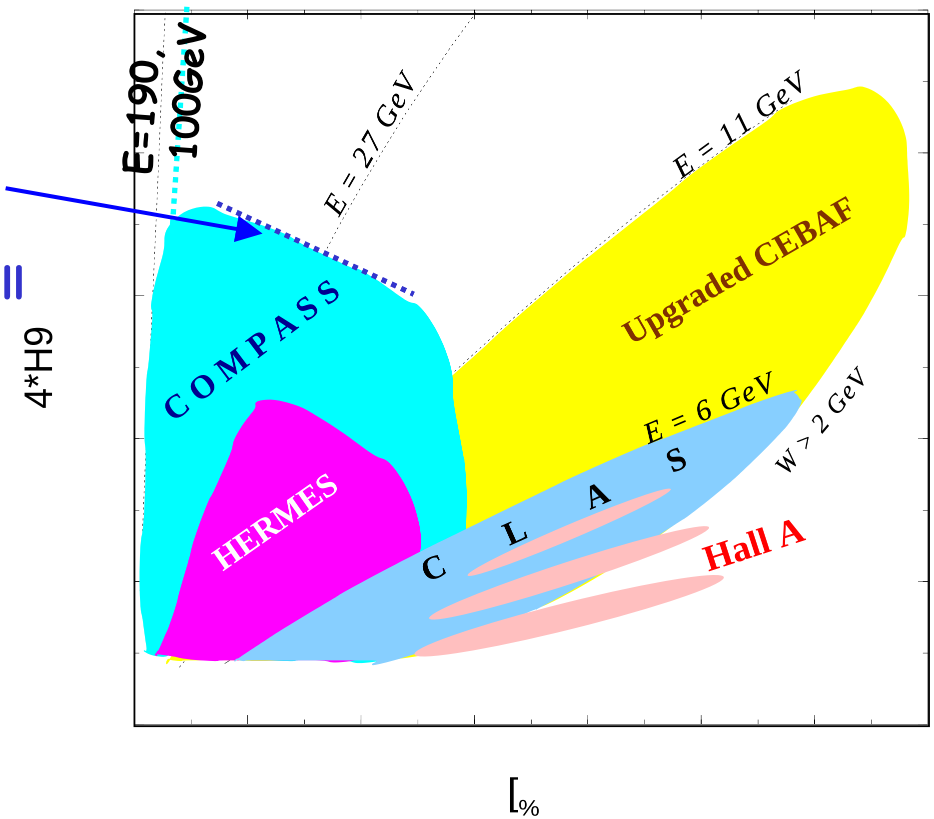


Complementarity of the experiments in the world

Limitation by luminosity

now Nμ= 2.10⁸μ per SPS spill
⇒ $Q^2 < 7\ GeV^2$

if Nμ × 10
⇒ $Q^2 < 30\ GeV^2$



$0.0001 < x_{Bj} < 0.01$
Gluons

H1 and ZEUS

Valence and sea quarks
And Gluons

Hermes
COMPASS

Valence quarks

JLab

General requirements

The highest luminosity

$N\mu = 2.10^8$ per SPS cycle (Radio Protection limit)

duration 5.2s repetition each 16.8s

With a new 2.5m long liquid hydrogen target

$\Rightarrow L = 1.3\ 10^{32}\ cm^{-2}s^{-1}$

In 2011, with the Linac4 what could be the limitation?

What is the impact of an increased intensity on the detectors?

Precise absolute luminosity measurement

With NMC it has been achieved within a 1% accuracy

The integrated muon flux is measured continously by 2 methods

1) By sampling the beam with a random trigger (α emitter Am^{241})

2) By sampling the counts recorded in 2 scintillator hodoscope planes used to determine incident beam tracks

The beam tracks are recorded off-line, in the same way as the scattered muon tracks to determine the integrated usable muon flux

To test again for meson production

μ+ and μ- beams

Requirements:
- same energy
- same and maximum intensity
- opposite polarisation to a few %

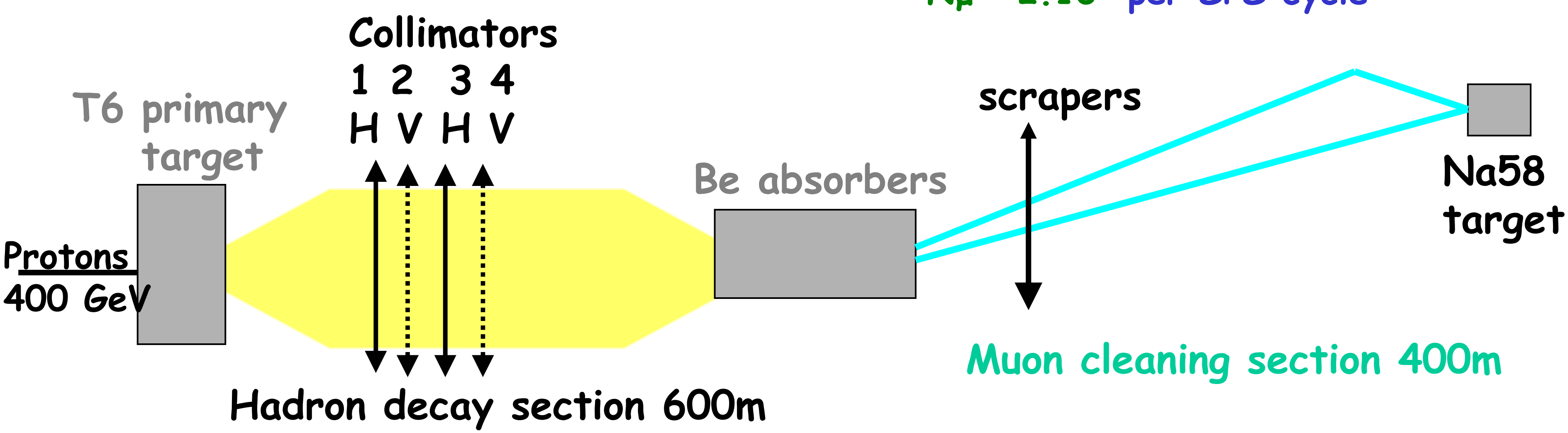
Solution proposed by Lau Gatignon:

1) To select P_π=110GeV and P_μ=100GeV to maximise the muon flux

2) To keep constant the collimator settings which define the π and μ momentum spreads (fixed Collimators 1H and 3H and Scrapers 4V and 5V)
   ⇒ Pol μ+=-0.8 and Pol μ-=+0.8

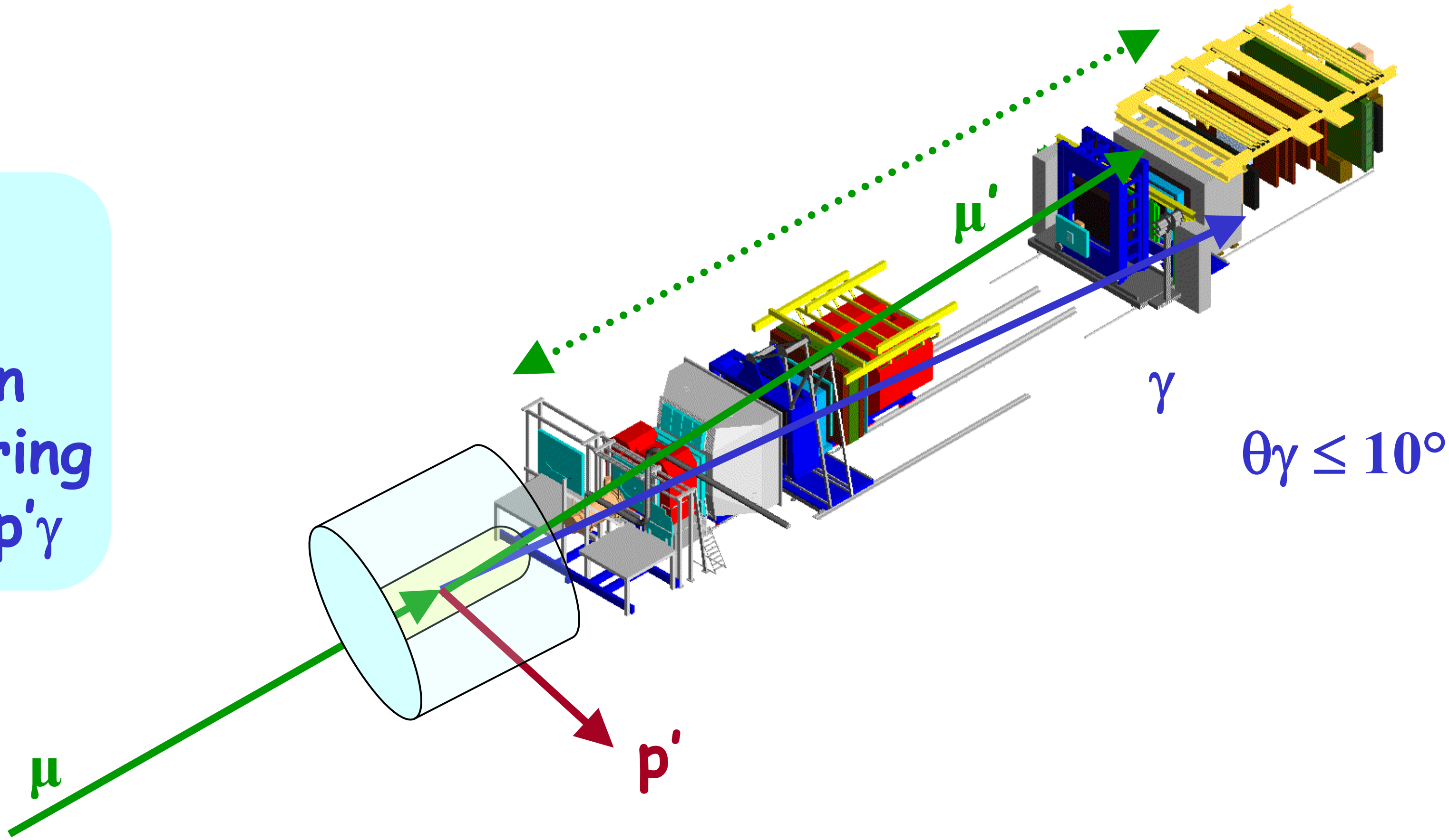
3) To fix Nμ-~2.10^8 per SPS cycle with the 500mm Be T6 target

4) To use a shorter target to find also Nμ+~2.10^8 per SPS cycle



Necessity to complete at large angle the high resolution COMPASS spectrometer

Deeply
Virtual
Compton
Scattering
$\mu p \rightarrow \mu' p' \gamma$



By a recoil detector to insure the exclusivity of the reaction

Resolution needed

At these energies (for μ, μ', and γ)
the missing mass technique is not adapted

$$\Delta M^2_{required} = (m_p+m_\pi)^2 - m_p^2 = 0.25\ GeV^2$$

$$\Delta M^2_{observed} = \Sigma_i\ \partial M^2/\partial i \times \Delta i \text{ with } i = P\mu, P\mu', P\gamma, \theta\mu, \theta\mu', \theta\gamma, \ldots$$

ex: $\Delta M^2(P\mu)\ \sim 2 \times 4.10^{-3} \times 100 = 0.8\ GeV^2$

Q2=4 x=0.1 $\Delta M^2(P\gamma)\ \sim 1 \times 3.10^{-2} \times 20 = 0.6\ GeV^2$

$$\Rightarrow \quad \Delta M^2_{observed} > 1\ GeV^2$$

Need of a recoil detector
to insure the exclusivity

Competing reactions to DVCS

DVCS: $\mu p \rightarrow \mu p \gamma$

HEπ°P: $\mu p \rightarrow \mu p \pi^\circ$
↳ $\gamma\gamma$

Dissociation of the proton:
$\mu p \rightarrow \mu N^* \pi^\circ$
↳ $N\pi$

DIS: $\mu p \rightarrow \mu p X$
with 1γ, $1\pi^\circ$, $2\pi^\circ$, η…

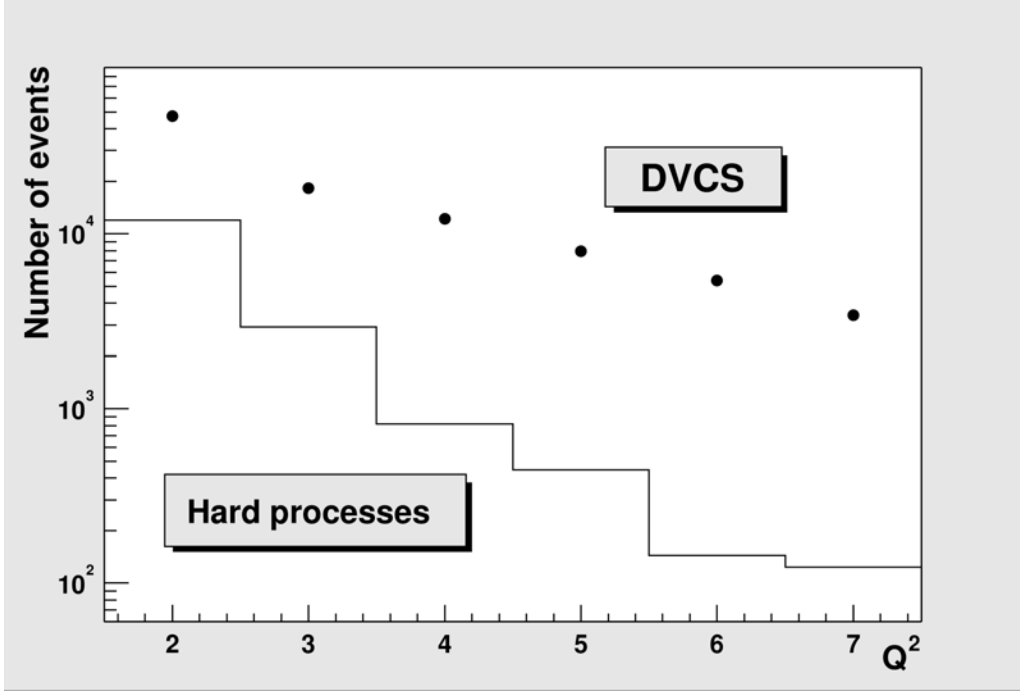
Beam halo
with hadronic contamination
Beam pile-up
Secondary interactions
External Bremsstrahlung

Simulation to improve

Selection DVCS/DIS

with PYTHIA 6.1

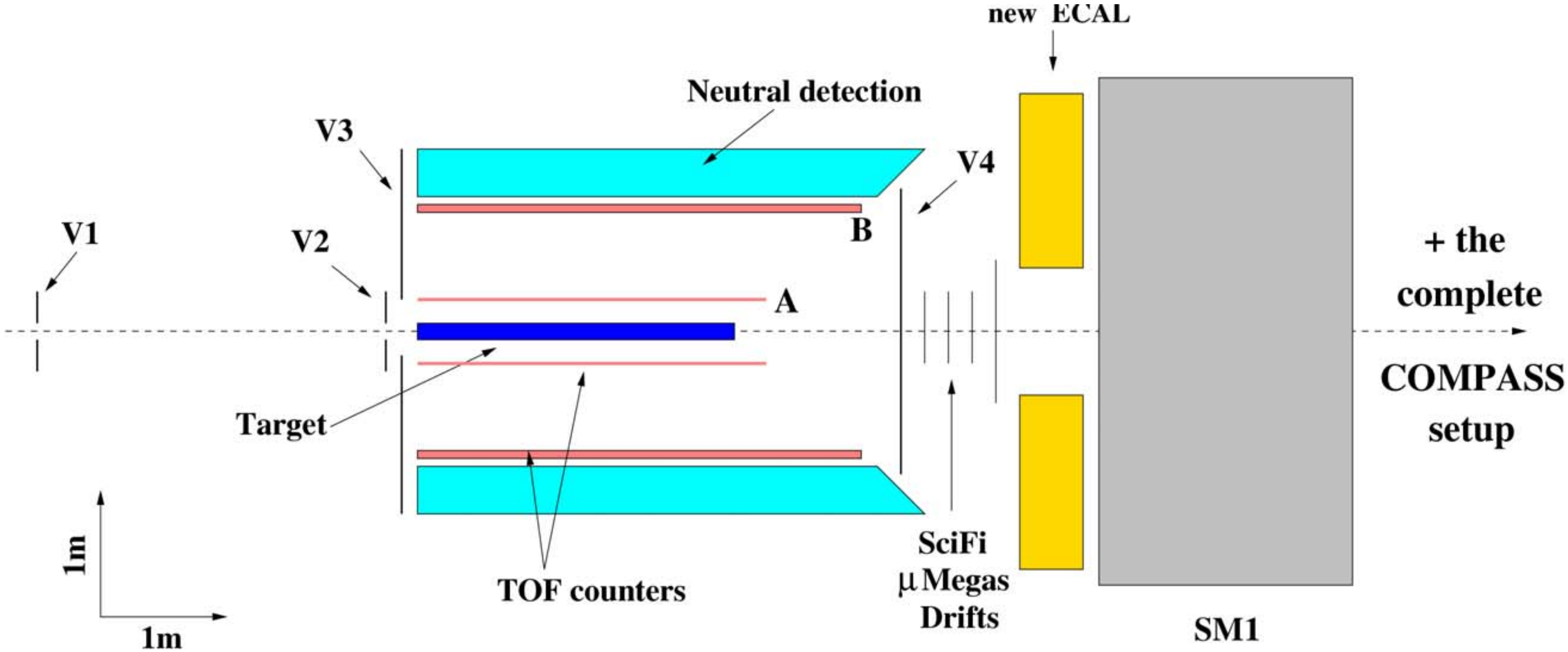
Tune parameters:
- maximum angle for photon detection 24°
- threshold for photon detection 50MeV
- maximum angle for charged particle detection 40°



Additional equipment to the COMPASS setup

A possible solution:

(proposed in the Workshop on the Future Physics at COMPASS 26 Sept 2002)



Goal of the JRA in the EU FP6:
Realisation of a prototype detector consisting of a 45° sector

Key role of the Calorimetry

ECAL2 from 0.4 to 2°	mainly lead glass GAMS
ECAL1 from 2 to 10°	good energy and position resolution for 2 photons separation in a high rate environment
ECAL0 from 10 to 24°	to be designed for background rejection

⇒ **Intensive Study of photon and pi0 production**

Requirements for a recoil detector @ COMPASS

Requirements:
- be large and hermetic
- identify protons and measure their low momentum

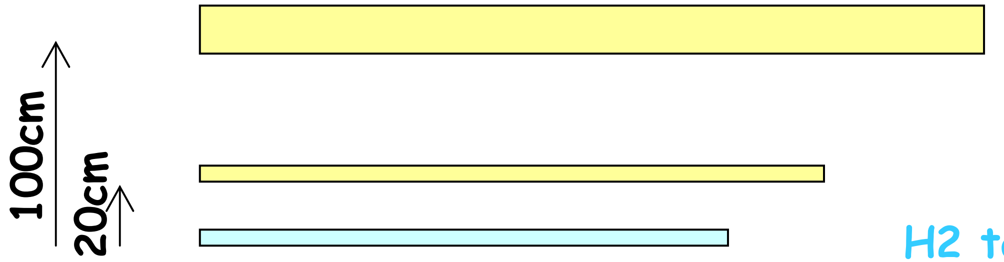
$$250\ \text{MeV}/c \leq P \leq 750\ \text{MeV}/c$$

↙ limited by thickness of target: $t_{min} = 0.06\ \text{GeV}^2$

↘ ideal for proton/pion separation: $t_{max} = 0.60\ \text{GeV}^2$

- momentum resolution from 2 to 5 %
- polar and azimuthal angle resolution from 1 to 2 degree
- longitudinal vertex reconstruction 1 to 2 cm

Economy ⇨ Time of Flight of large volume, of typical resolution of 200 ps



B L=400cm t=5cm

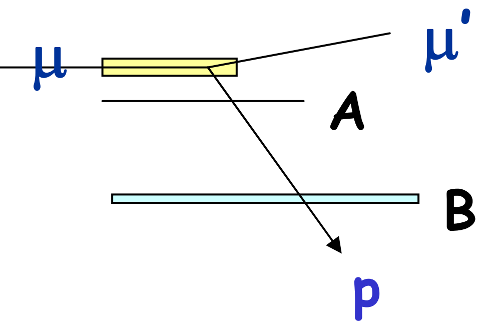
A L=280cm t=4mm

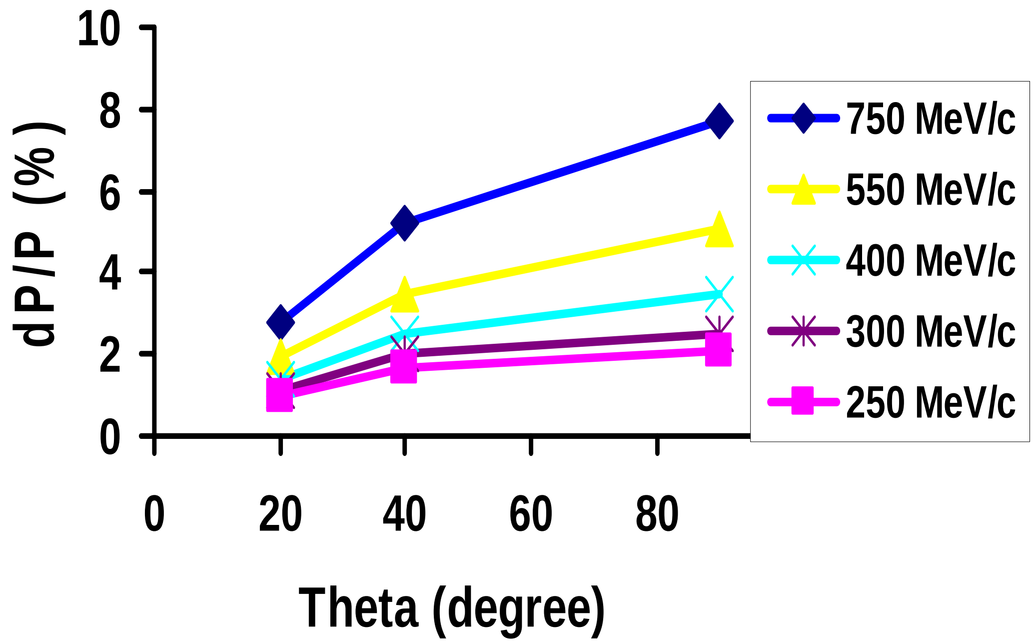
H2 target ∅ = 3cm

Relation between ToF resolution and dP/P

If ToF resolution = 200ps

dt/t ~2 dP/P





$$\frac{dP}{P} = \frac{1}{1-\beta^2}\frac{\sin\theta}{R_B - R_A}\sqrt{\cos^2\theta(dz_B^2 + dz_A^2) + \beta^2 c^2 dt_{AB}^2}$$

challenges for the JRA

Tests in 2001	→	Goal of the prototype
$L_A=40, L_B=70cm$		$L_A=280, L_B=400cm$
$\Delta\Phi=2\pi/48$		$\Delta\Phi=2\pi/24$

$\sigma(ToF)=300ps$ → 200ps

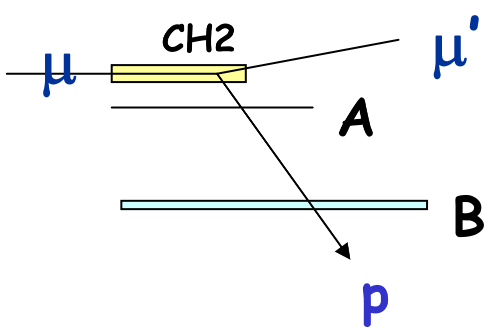
$\sigma T_{A(t=4mm)}=290\pm30ps$  → 140ps!

$\sigma T_{B(t=5cm)}=180\pm30ps$ → 140ps

$v_A=13cm/ns \rightarrow dz_A=1.9cm$ → 1.0cm

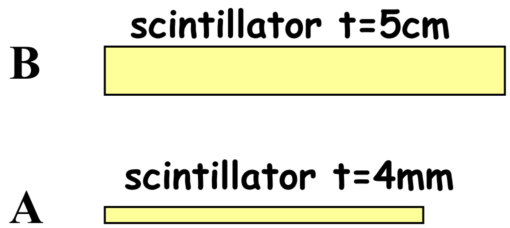
$v_B=19cm/ns \rightarrow dz_B=1.7cm$ → 1.3cm

Limitation obtained with CLAS: 190-250ps
L= 3 to 4 m, t=5cm

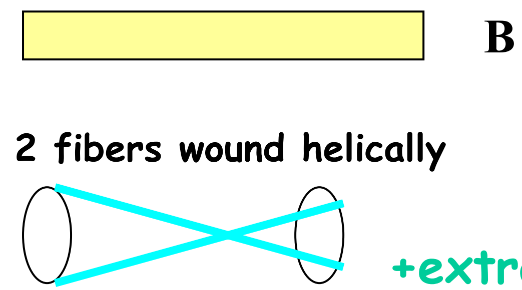


with 2.10^8 μ/spills
$N_A=$ 1MHz (δrays)
$N_B=0.2MHz$

2 solutions to study:



or



+extra start

Limitations in time resolution:

- number of photo-electrons
- dispersion of photon tracks
- dispersion in time of the PM

→ Simulation + tests

Limitations pour l'acquisition de l'information:

- high counting rates

→ Définition of the geometry and the electronics

1) Analyse of the pulse shape with an Analogue Ring Sampler (ARS)
2) Use of look-up table (extension of the COMPASS coincidence matrix)

A lot of work remain to be done …

Improvement of the limits of the experiment

large Q2 range

tmin and tmax, good resolution in t

Investigation of all the channels: DVCS,HEMP,DDVCS…

Simulation

Fast Monte Carlo

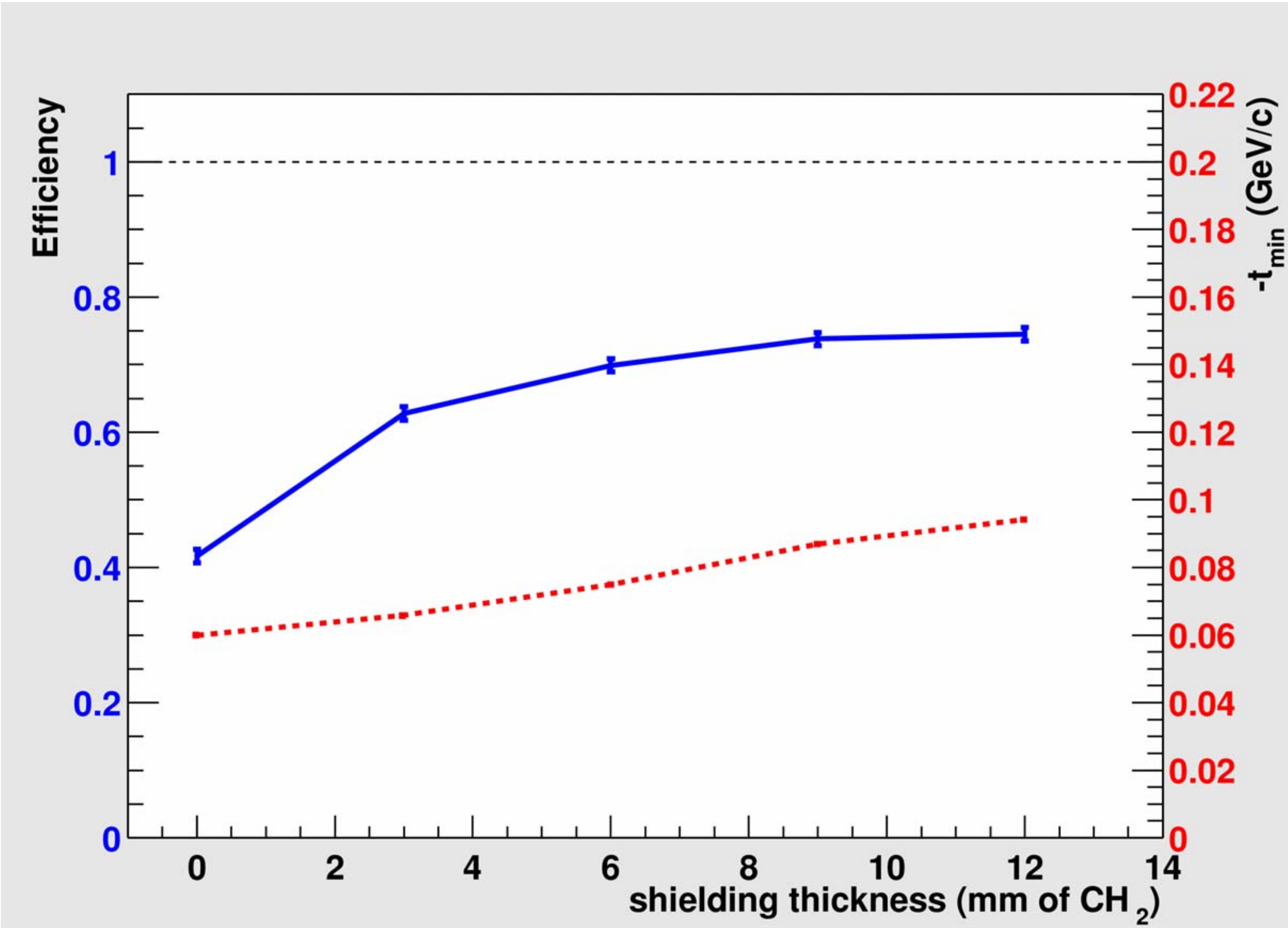
Complete GEANT + all backgrounds

→ efficiency determination

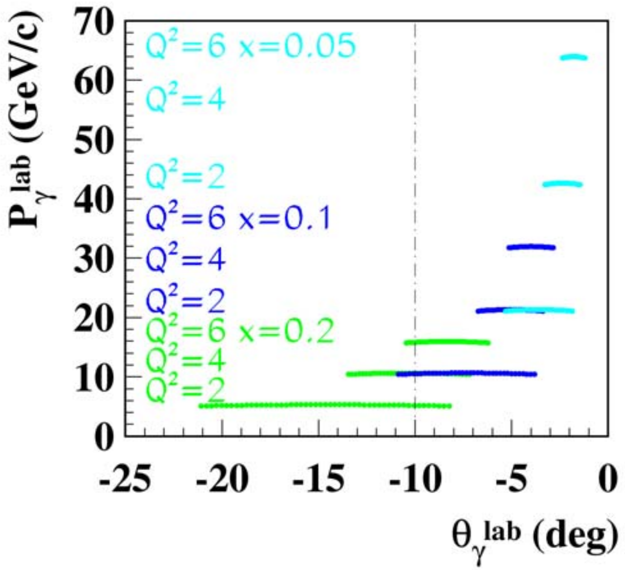
…

First draft for « Outline for GPDs measurement using COMPASS at CERN »

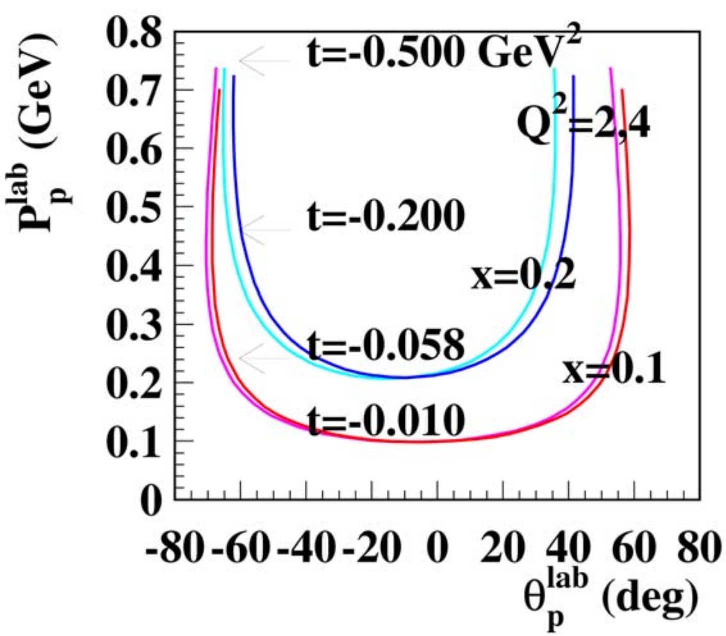
to be found in dhose/public/villars_020704.ps



Efficiency
1
0.8
0.6
0.4
0.2
0
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
$-t_{min}$ (GeV/c)
0
2
4
6
8
10
12
14
shielding thickness (mm of CH_2)



$Q^2=6$ $x=0.05$
$Q^2=4$
$Q^2=2$
$Q^2=6$ $x=0.1$
$Q^2=4$
$Q^2=2$
$Q^2=6$ $x=0.2$
$Q^2=4$
$Q^2=2$
P_γ^{lab} (GeV/c)
θ_γ^{lab} (deg)



t=-0.500 GeV^2
Q^2=2,4
t=-0.200
x=0.2
t=-0.058
x=0.1
t=-0.010
P_p^{lab} (GeV)
θ_p^{lab} (deg)