Large Acceptance Proton Form Factor Ratio Measurement at 13 and 15 GeV^2 using Recoil Polarization Method

Update on E12-07-109

B.Wojtsekhowski, Jefferson Lab
for the GEP/SBS collaboration

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May 2019

Challenges in this experiment

$$\text{Form factor} \propto Q^{-4}$$

$$\text{Cross section} \propto E^2/Q^4 \times Q^{-8}$$

$$\text{Figure-of-Merit } \epsilon A_Y^2 \times \sigma \times \Omega$$

$$\propto E^2/Q^{16}$$

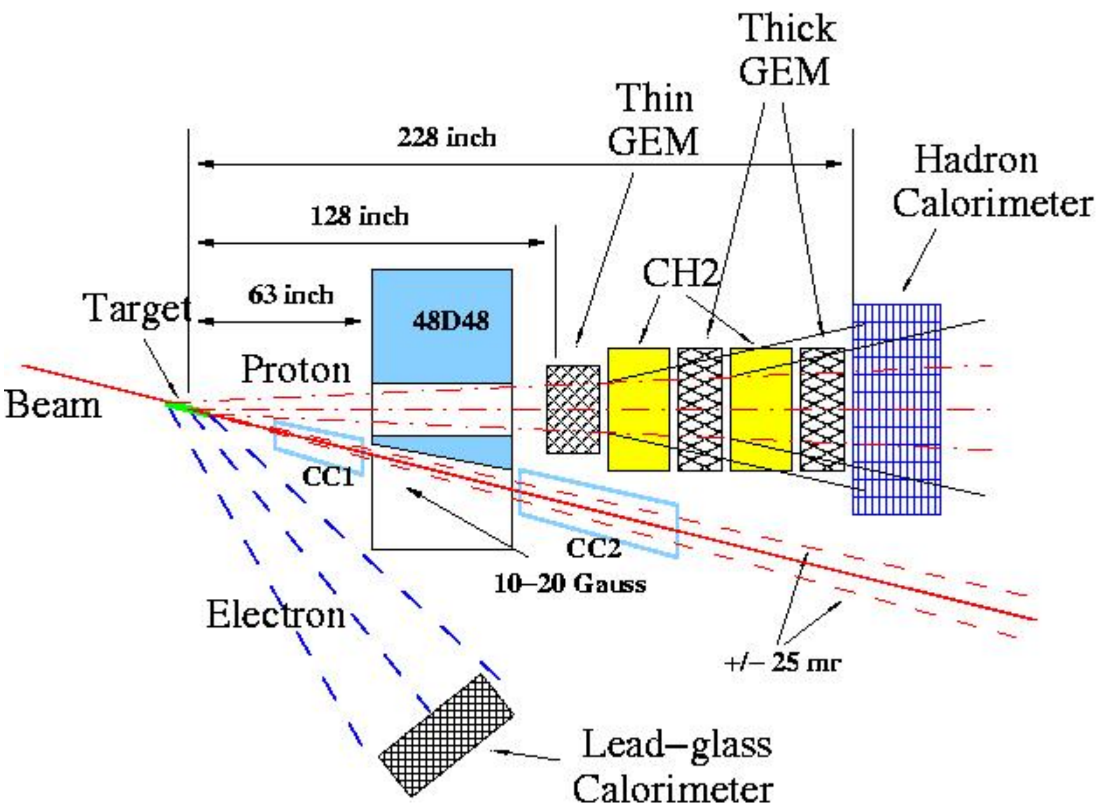
Need large statistics, max luminosity and solid angle

Max luminosity -> large background
Large solid angle -> small bend -> huge background

Solution is a modern tracking detector based on
Gas Electron Multiplier (Fabio Sauli, 1997)

Experiment: Layout and Parameters

$H(\vec{e}, e'\vec{p})$



Beam: 75 μA, 85% polarization
Target: 40 cm liquid H_2
Electron arm at 37^o, covers Q^2 range from 12.5 to 16 GeV^2
Proton arm at angle 14^o,
Ω = 35 msr ,
Spin precession angle is ~ 90^o
(it is optimum)

Event rate is 15 times higher than with standard spectrometer

From 58 days of production time resulting accuracy is

$$\Delta(\mu G_E^p / G_M^p) = \pm 0.10$$

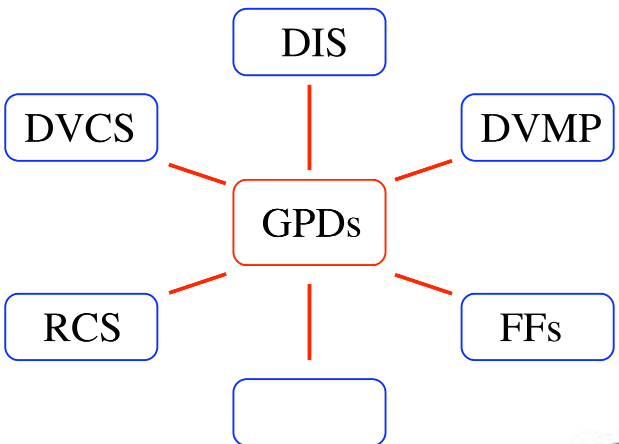
PAC32 August 7, 2007 Slide 5 GEP-15 Bogdan Wojtsekhowski, JLab

Large Acceptance Proton Form Factor Ratio

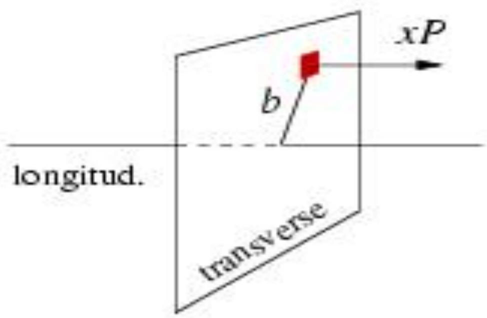
$H(\vec{e}, e'\vec{p})$

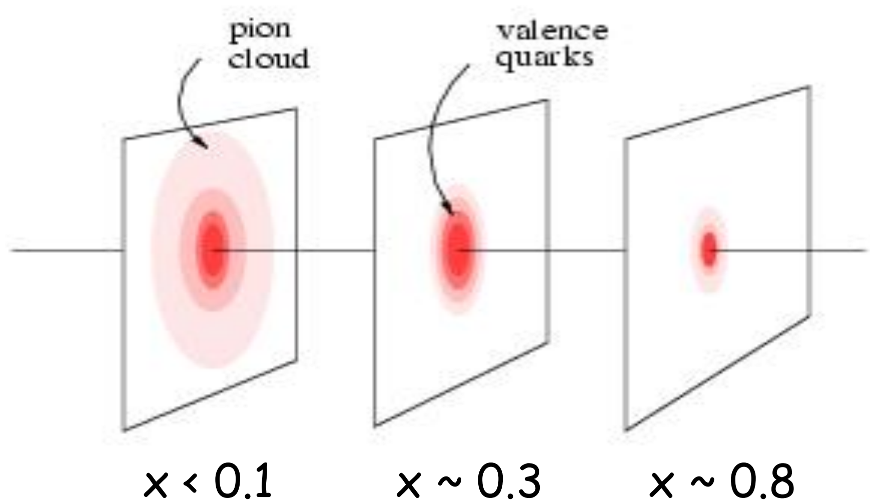
$$d\sigma = d\sigma_{NS}\left\{\varepsilon(\tilde{G}_E + \frac{s-u}{4M^2}\tilde{F}_3)^2 + \tau(\tilde{G}_M + \varepsilon\frac{s-u}{4M^2}\tilde{F}_3)^2\right\}$$

two-photon effect



$$\frac{G_E^p}{G_M^p}\Big|_{1-\gamma} = -\frac{P_x}{P_z}\frac{E_e + E_{e'}}{2M_p}\tan(\theta_e/2)$$

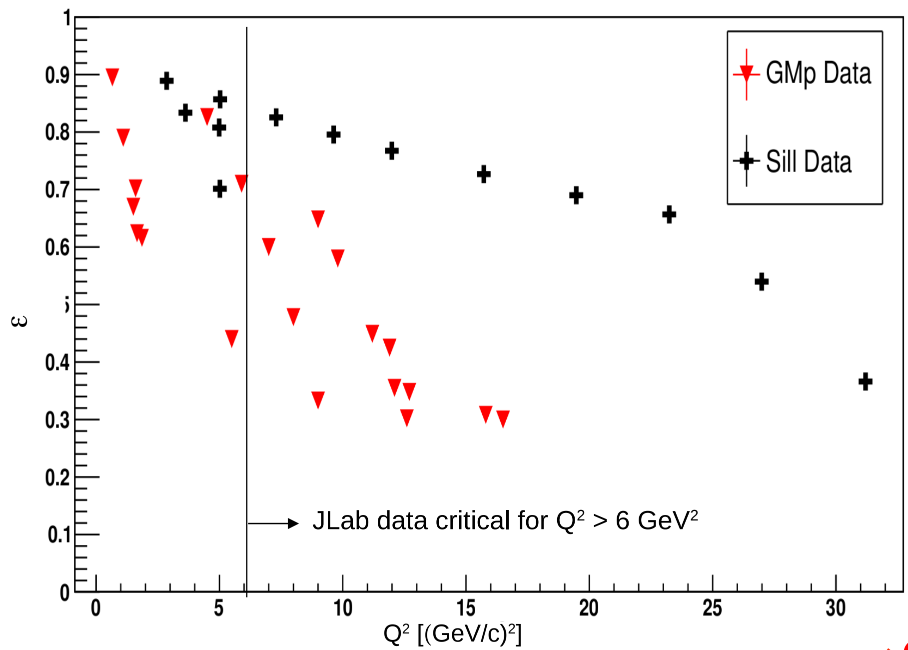


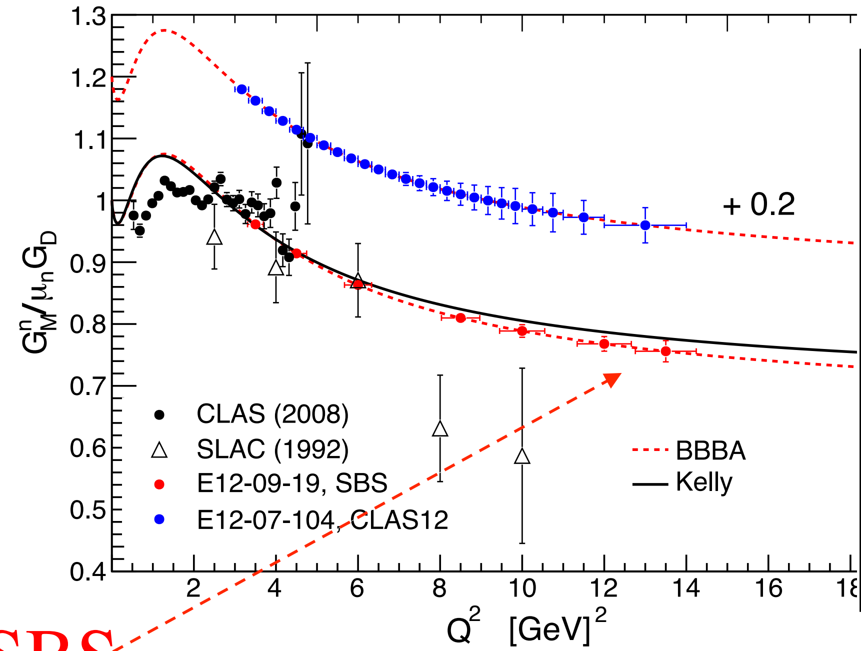


$\rho(\vec{b})$ $\rho(\vec{b}, x)$

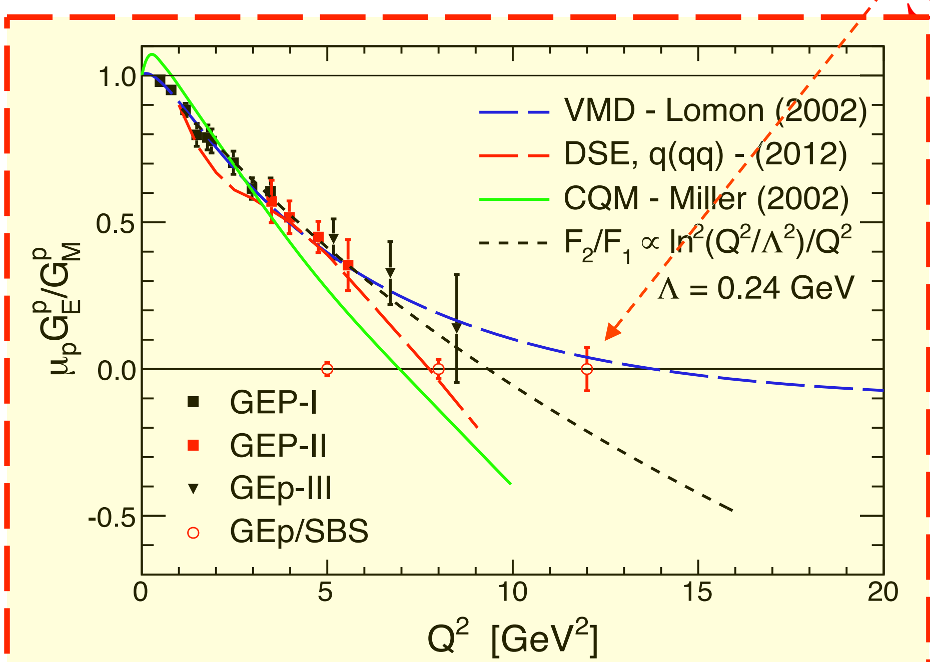
Scientific case

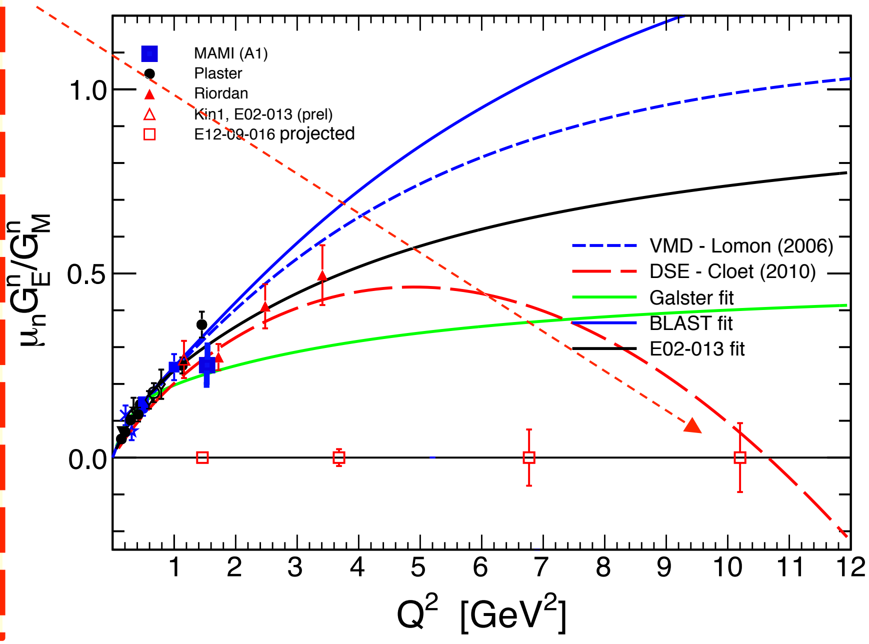
The nucleon FFs



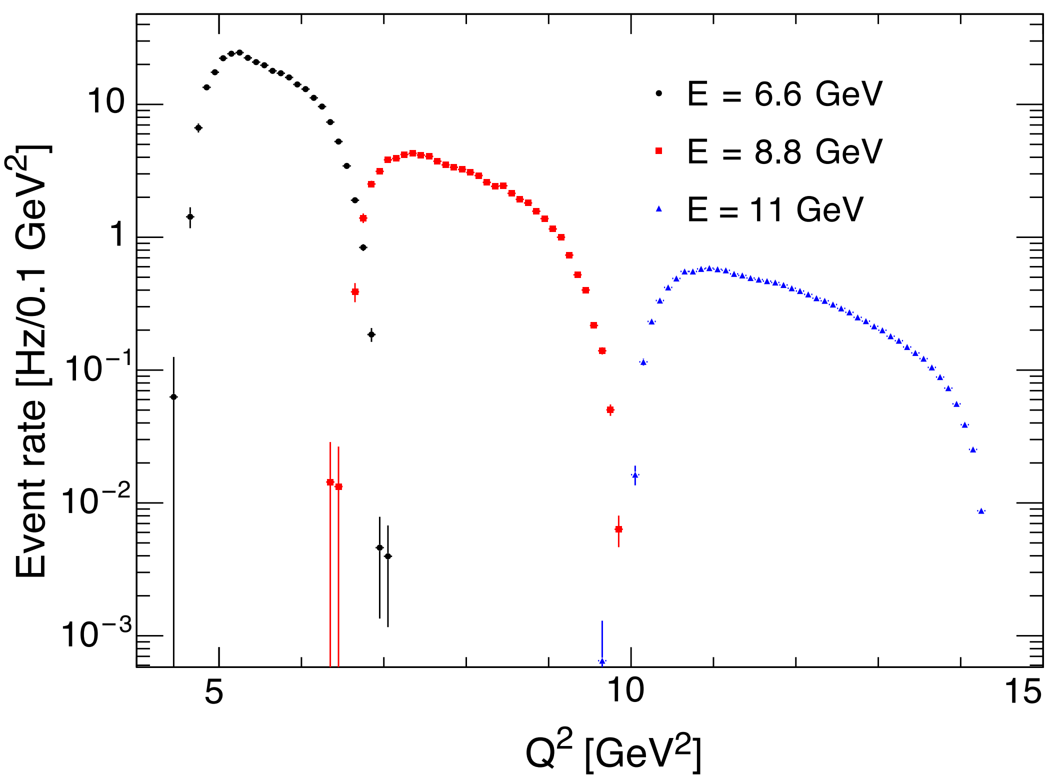


SBS



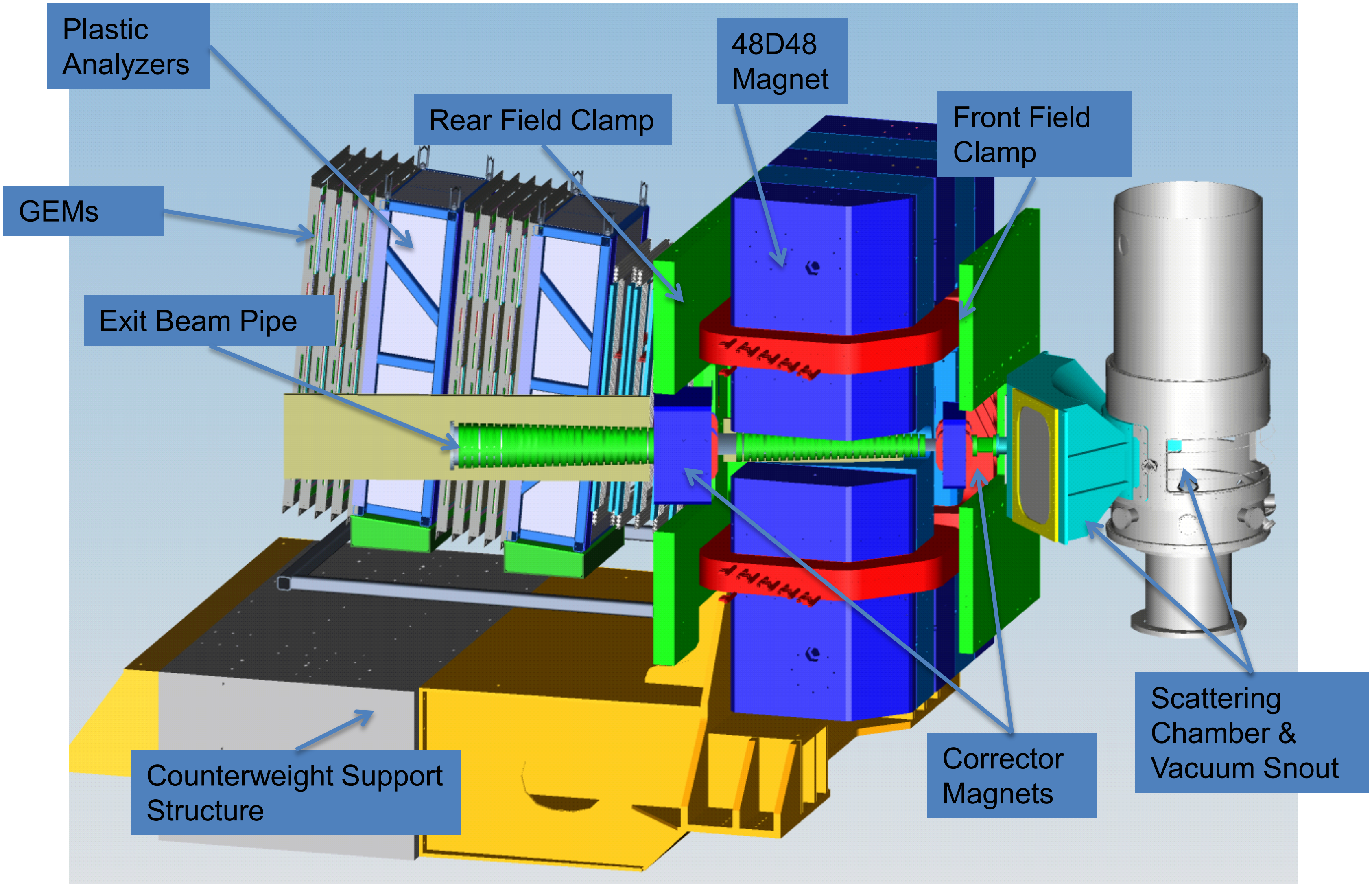


GEP/SBS Q^2 acceptance and projected accuracy

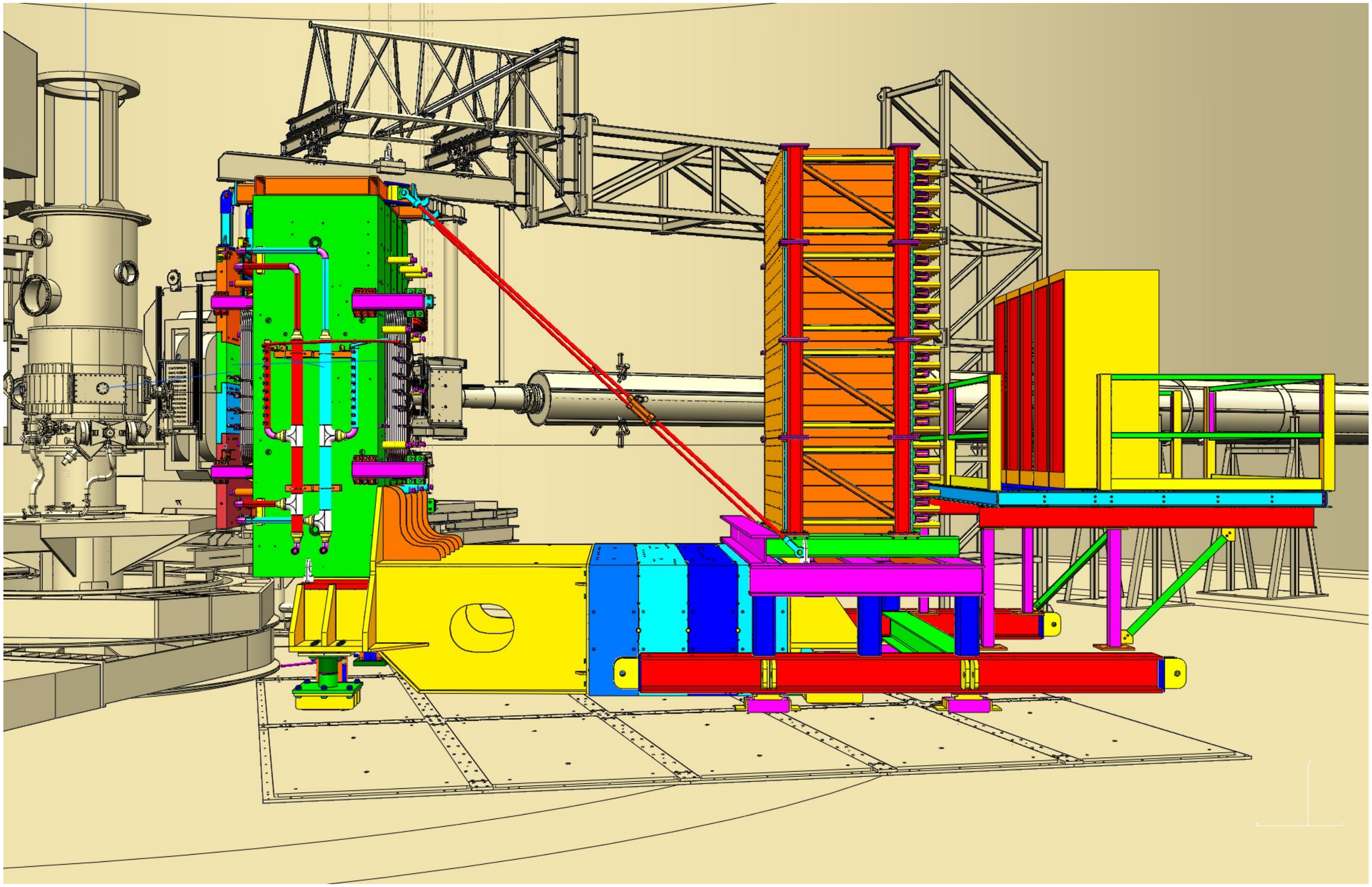


E_{beam}, GeV	Q^2 range, GeV^2	$\langle Q^2 \rangle$ GeV^2	θ_{ECAL} degrees	$\langle E'_e \rangle$, GeV	θ_{SBS} degrees	$\langle P_p \rangle$ GeV	$\langle \sin\chi \rangle$ degrees	Event rate Hz	Days	$\Delta\,(\mu G_E/G_M)$
6.6	4.5-7.0	5.5	29.0	3.66	25.7	3.77	0.72	291	2	0.029
8.8	6.5-10.0	7.8	26.7	4.64	22.1	5.01	0.84	72	11	0.038
11.0	10.0-14.5	11.7	29.0	4.79	16.9	7.08	0.99	13	32	0.081

Proton arm in the CAD model



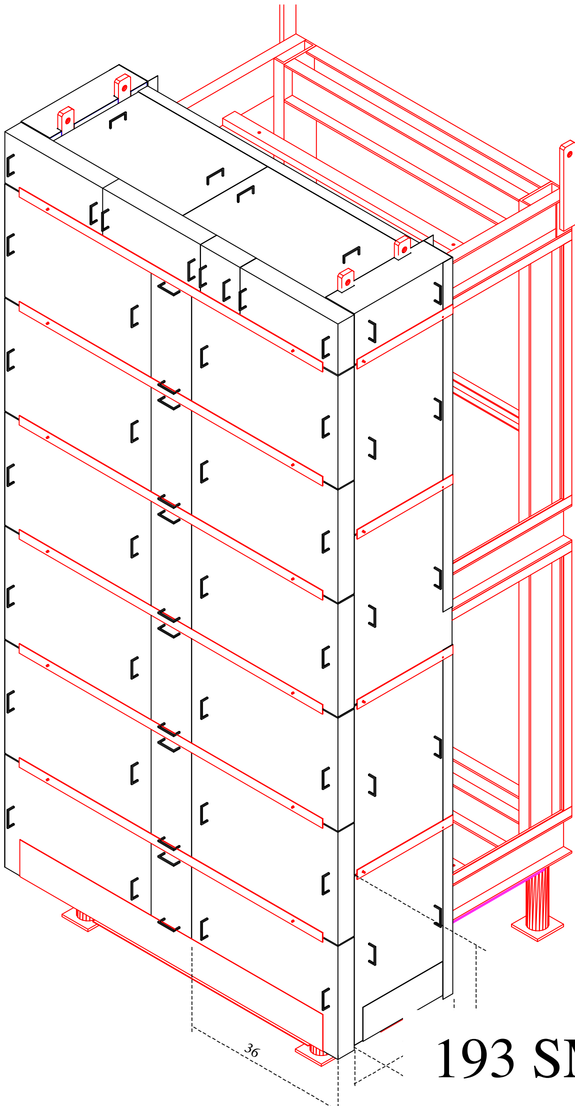
Proton arm calorimeter in the CAD model

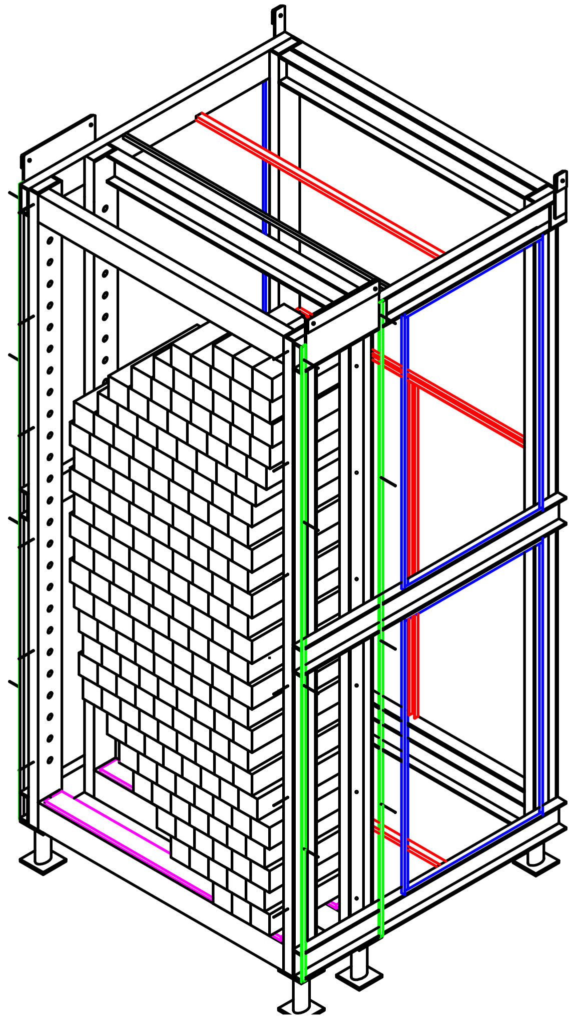


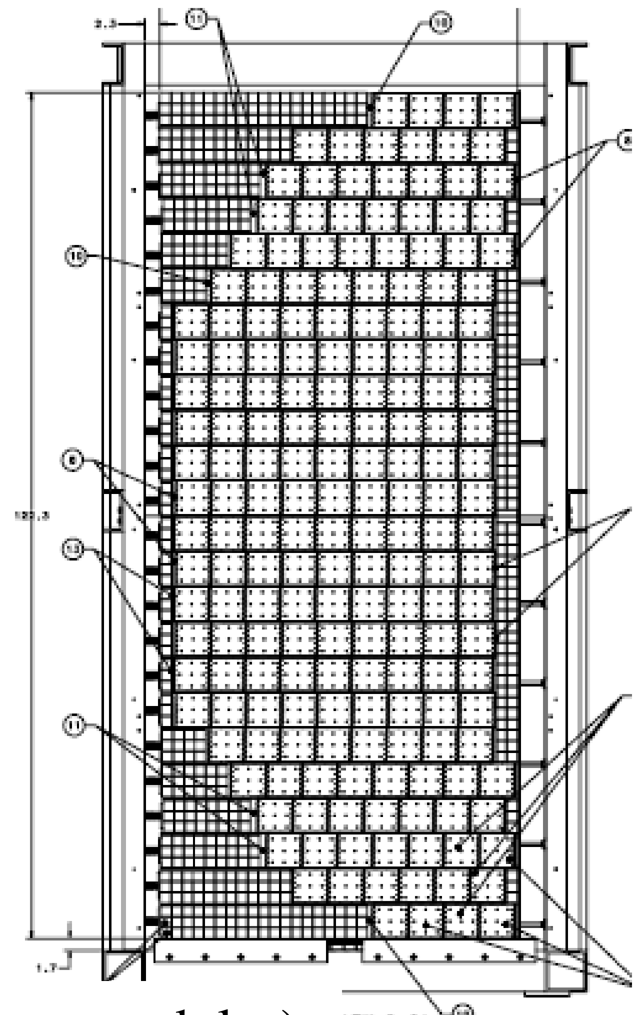
energy resolution $60\%/\sqrt{E[GeV]}$

time resolution ~ 0.5 ns

Electron arm calorimeter in the CAD model

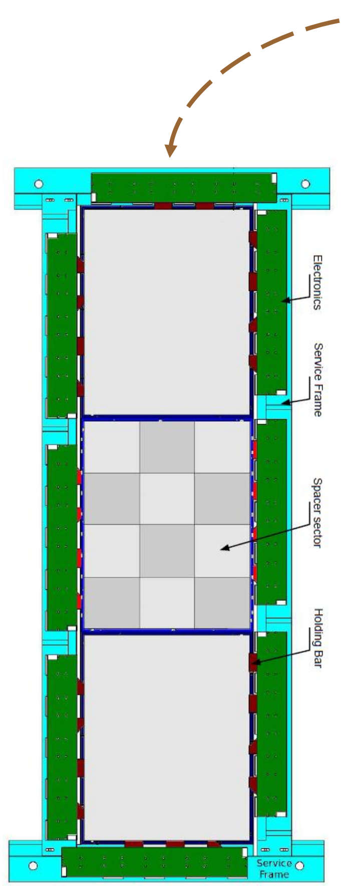


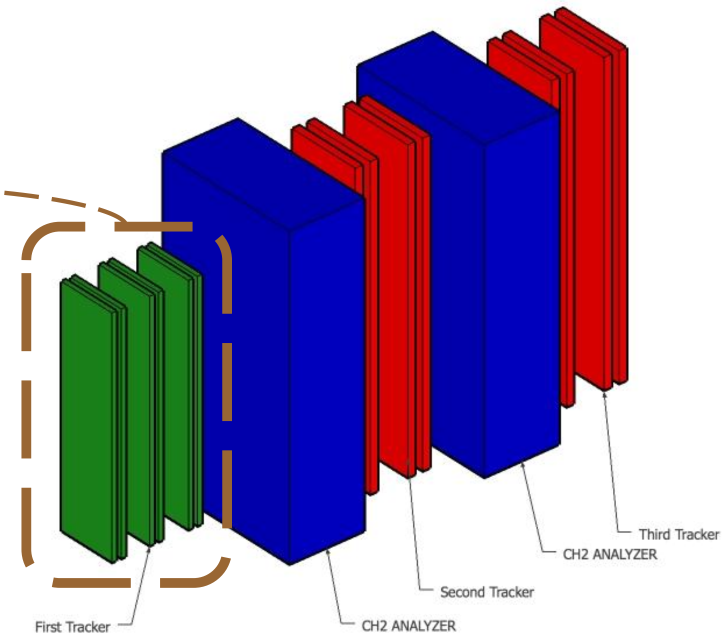




193 SMs (each is a 3x3 group of lead-glass modules),
Elevated temperature of the glass (225-185 C)
provides continuous annealing of radiation damage

SBS trackers/polarimeters:
Front tracker: INFN/UVa





Hit spatial resolution ~ 70 μm

Stand large background (γ ~ 250 MHz/cm^2, e/π 160 kHz/cm^2)

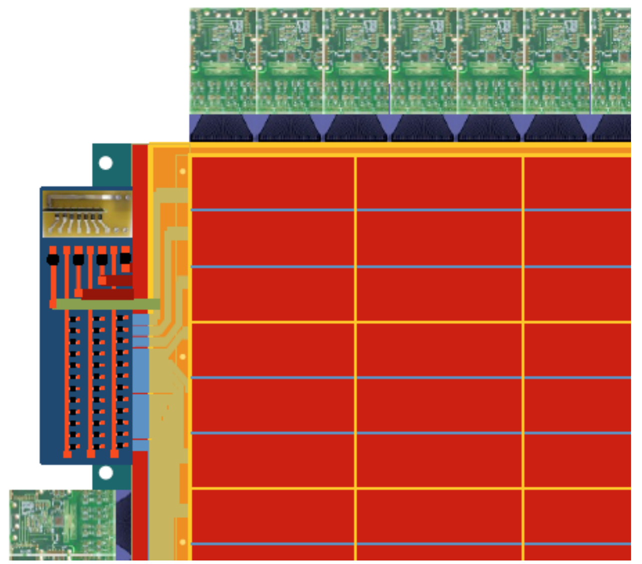
Transverse area at least 40x120 cm^2

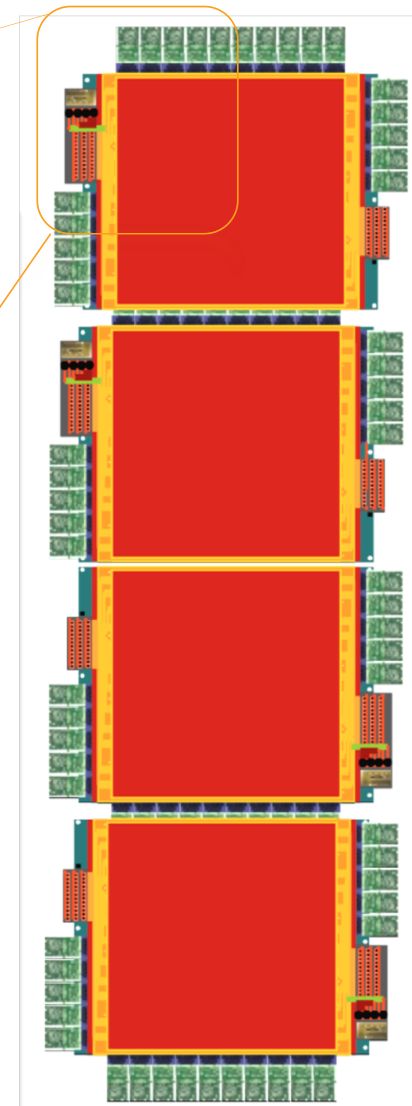
Event rate at the level of 20 kevents/s

Reuse in different configurations (SBS/GEp, BigBite/GEn …)

SBS trackers/polarimeters:

Rear tracker: UVa/INFN





- Protection resistors are outside the chamber: reliable, easy access.
- Large alignment pins, away from the active area
- Wide frames on the two sides not in active area: better mechanical rigidity and more room for gas inlets, HV traces etc.
- Electronics arranged to minimize the material within active area.

Summary

- After 12 years of development the GEP experiment is on track to be ready for installation in 2022.

- Nucleon elastic form factors are important ingredients in the GPD models in the high-t region.

Backup slides

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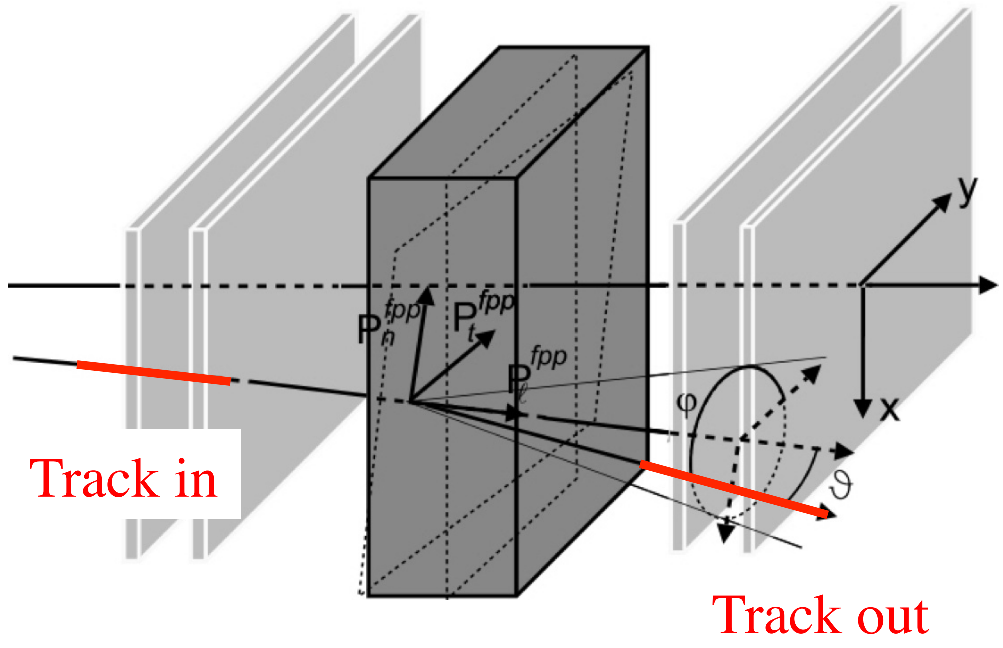
C.Perdrisat, L.Pentchev, E.Cisbani,
V.Punjabi, B.Wojtsekhowski

August 2007

Method: Focal Plane Polarimeter

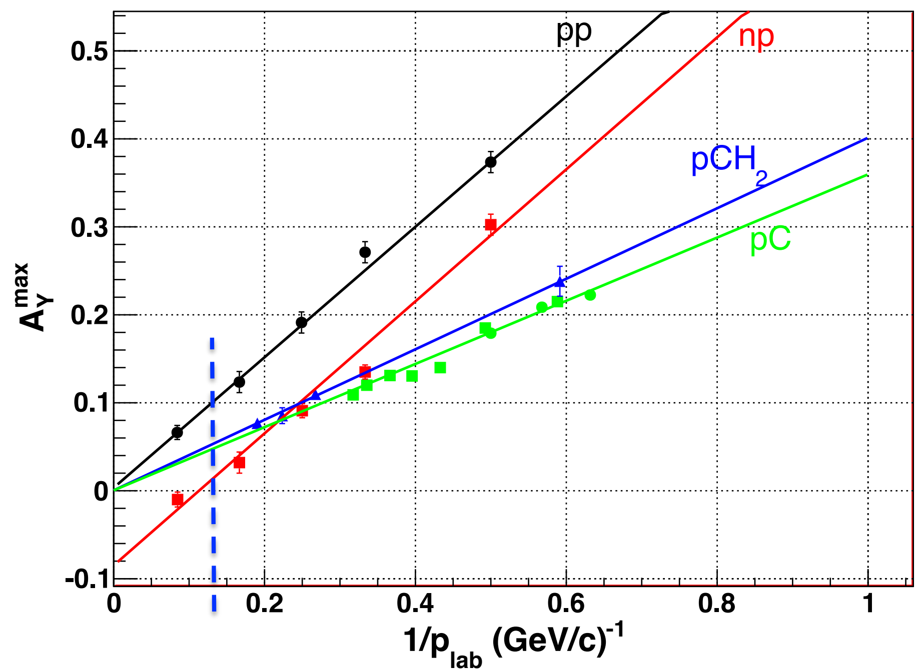


$$f^{\pm}(\vartheta,\varphi) = \frac{\epsilon(\vartheta,\varphi)}{2\pi}\left[1 \pm A_y(P_x^{fpp}\sin\varphi - P_y^{fpp}\cos\varphi)\right]$$

where $\pm$ refers to electron beam helicity

$$A = \frac{f^+ - f^-}{f^+ + f^-} = A_y\left(P_x^{fpp}\sin\varphi - P_y^{fpp}\cos\varphi\right)$$

A_Y analyzing power vs. inverse proton momentum

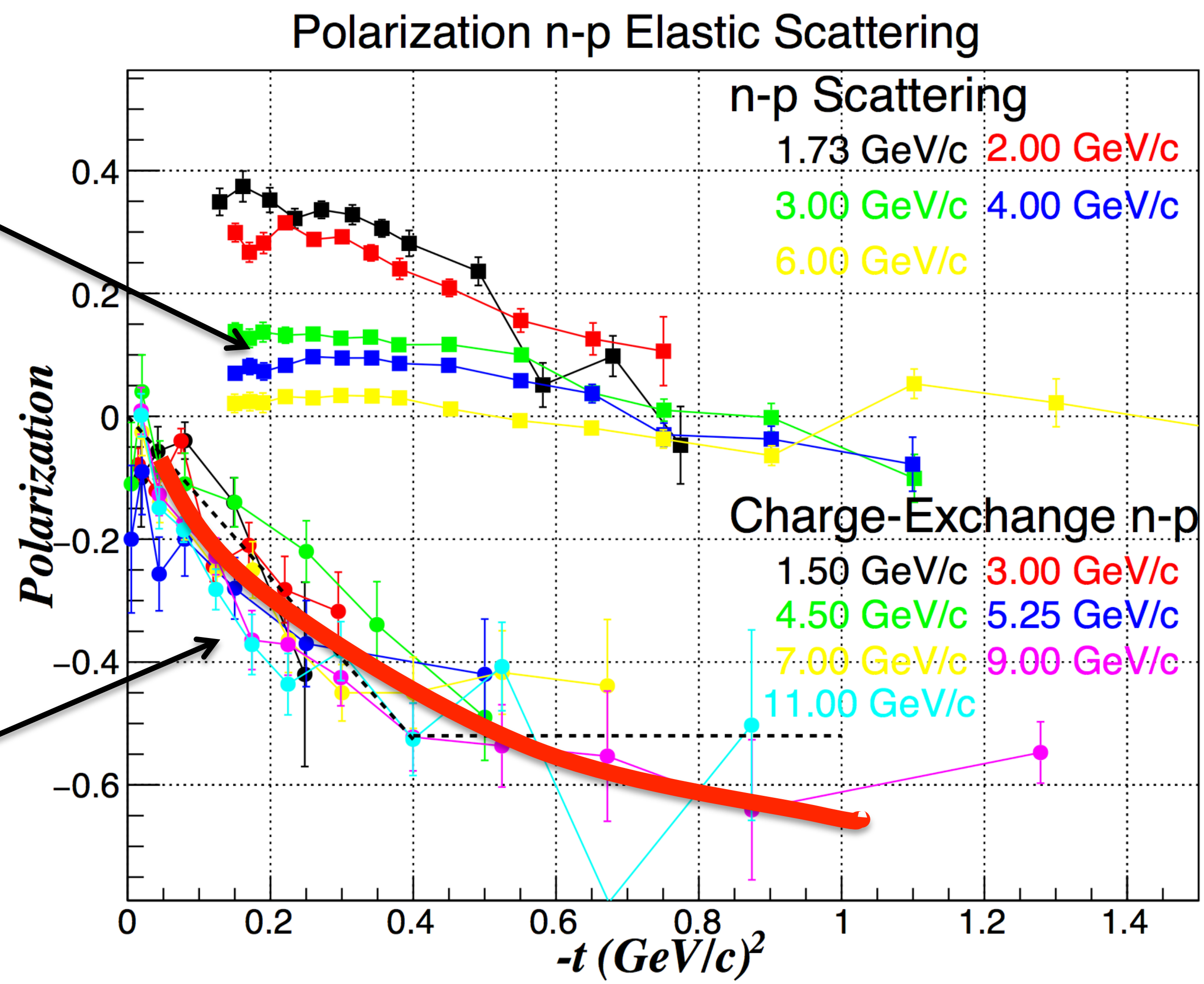


p will be ~ 8.5 GeV/c

$$\mu_p\frac{G_E^p}{G_M^p} = -\mu_p\frac{E_e + E_e'}{2M_p}\tan\frac{\theta_e}{2}\left(\frac{P_x^{fpp}}{P_y^{fpp}}\sin\chi_\theta + \gamma_p(\mu_p - 1)\Delta\phi\right)$$

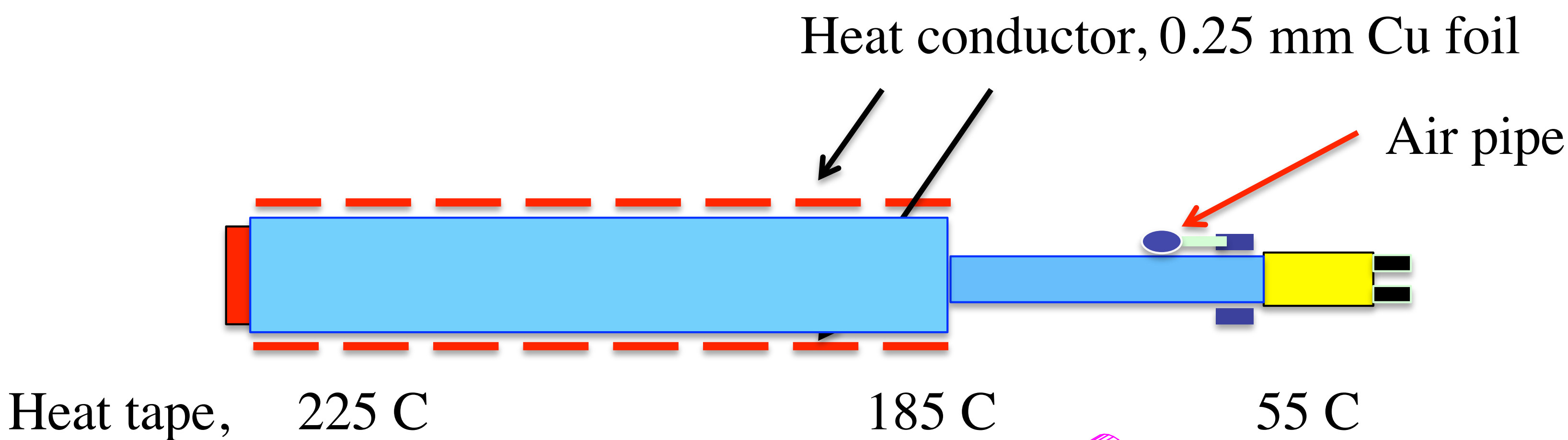
Forward proton vs. charge-exchange p-n

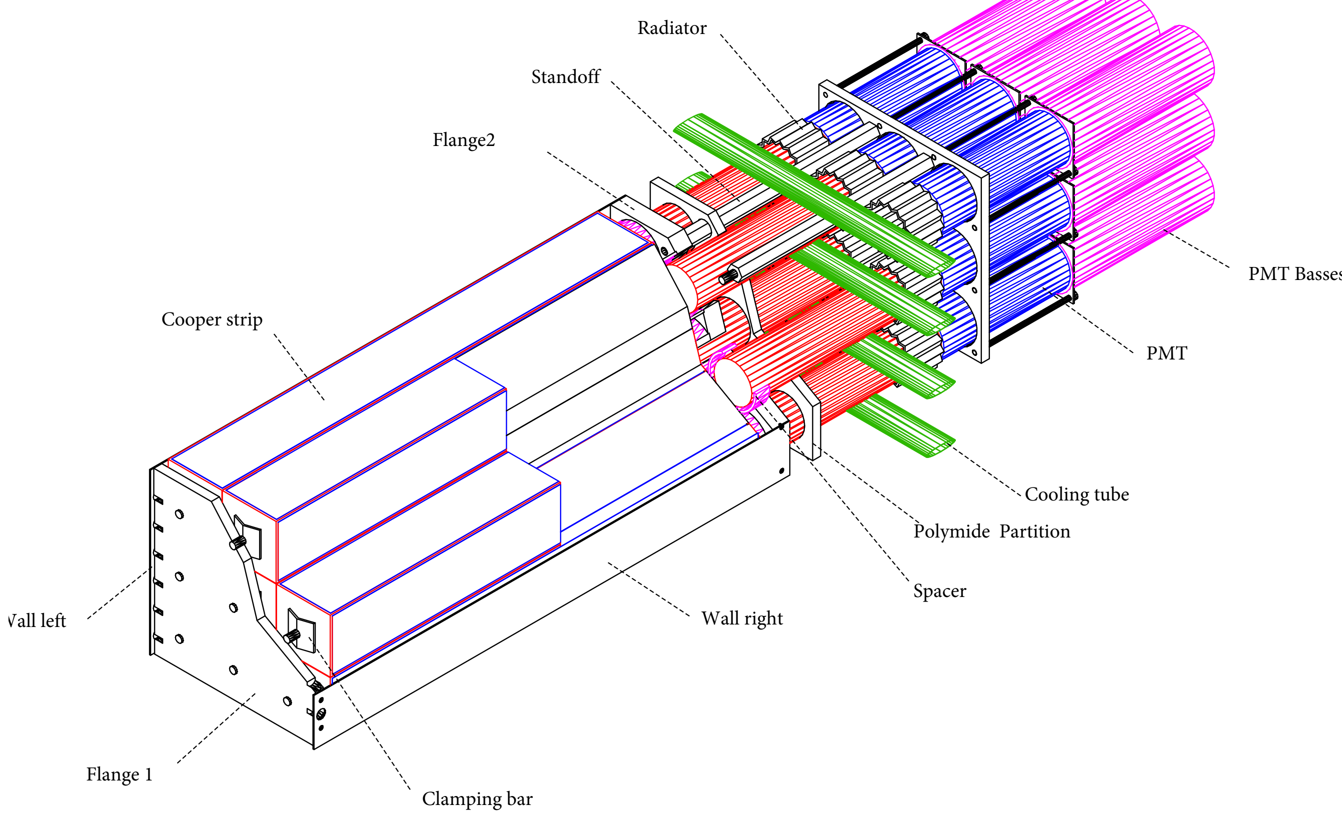
Drops fast with the incident nucleon energy!



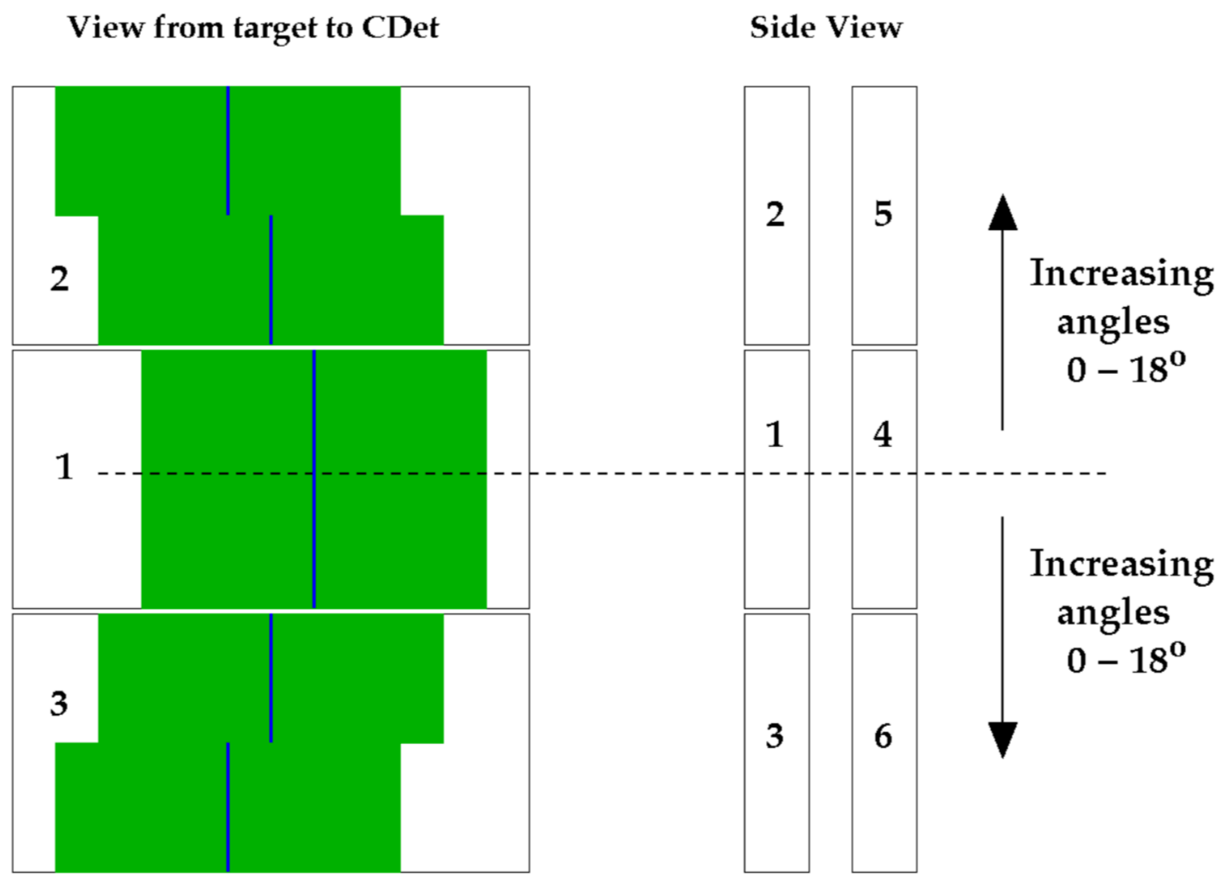
Independent of the incident nucleon energy!

Electron arm: Calorimeter's temperature, 3x3 group





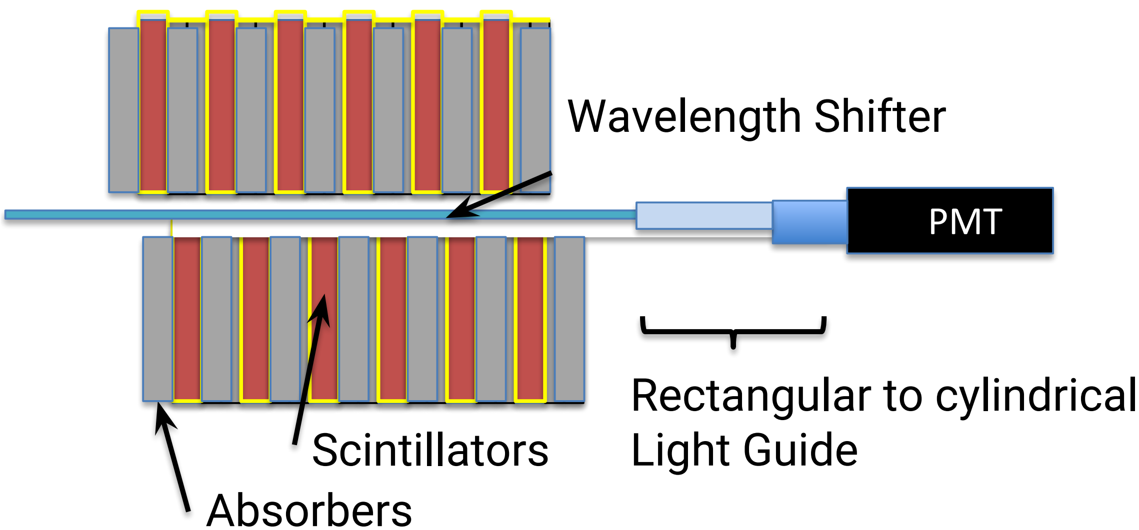
Electron arm: Coordinate detector

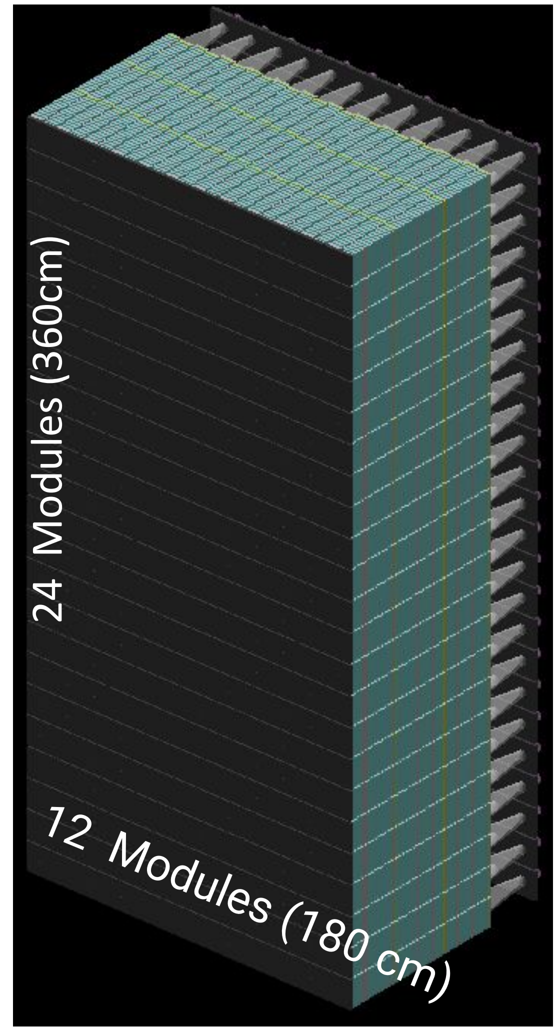


Two layers: 6 modules (each has 16 x 14 x 2 counters)

Proton arm: Calorimeter counter structure

- Each module is 15 cm x 15 cm x ~1 m
  - Plus light guide and PMT at end
- 40 layers scintillators + iron per module
  - Staggered to increase light output





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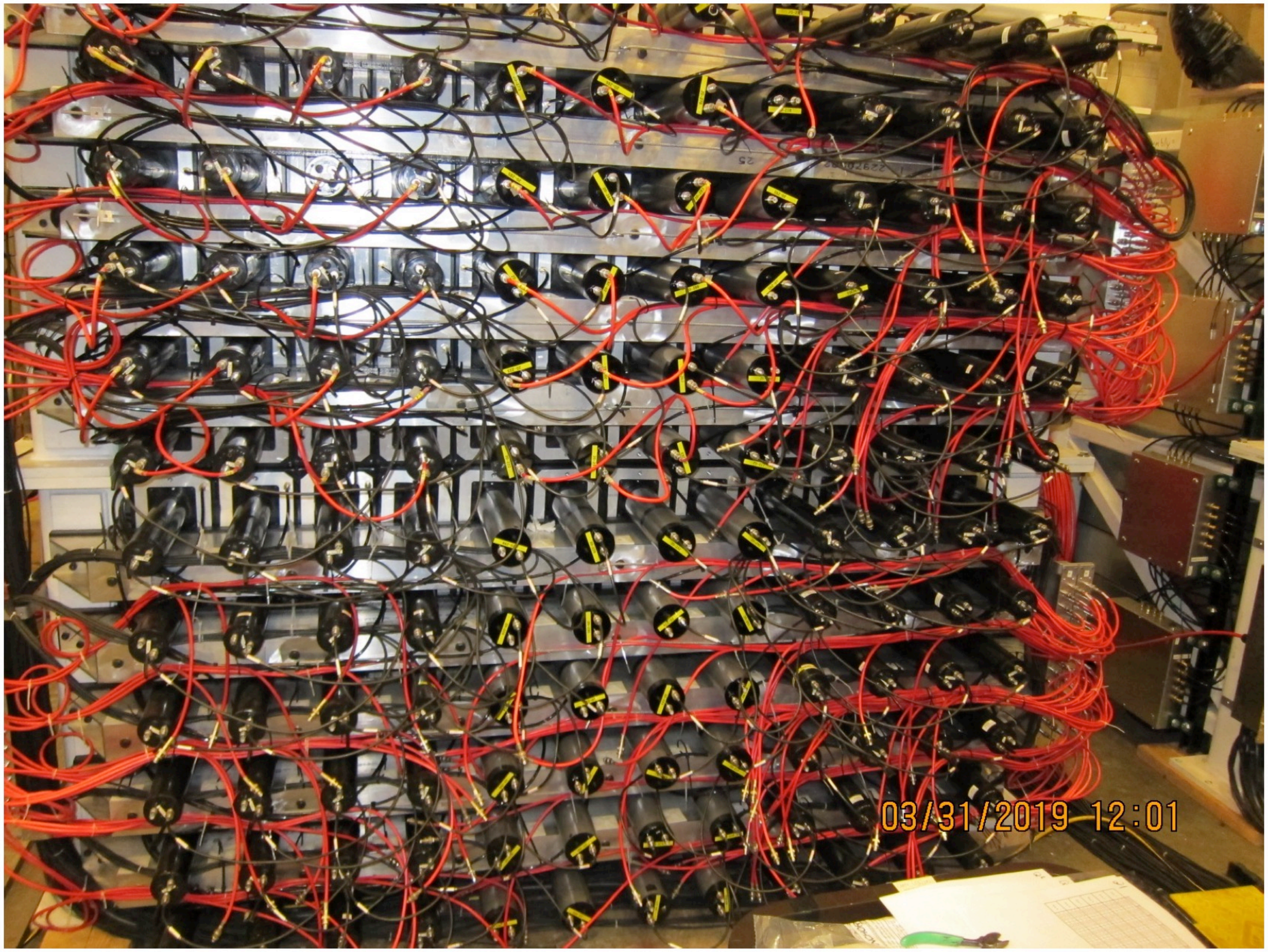
Proton arm: Calorimeter commissioning



288 counters (in 12 x 24 array)