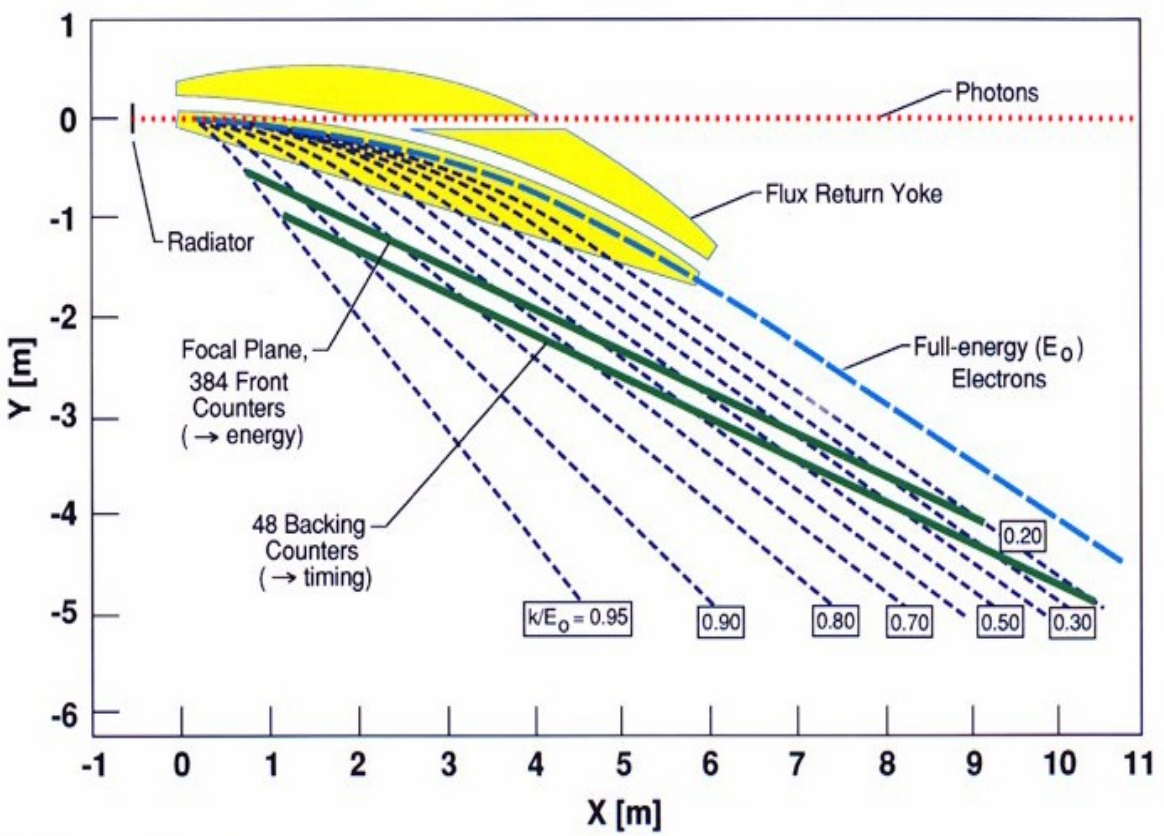
JLAB12 Collaboration Meeting
Rome, October 18-19

A Forward Photon Tagging Facility for CLAS12

M.Battaglieri,R. De Vita
Istituto Nazionale di Fisica Nucleare
Genova - Italy

The Hall-B photon tagger

- Gold and diamond radiator for In/Coherent Bremsstrahlung
- Energy coverage: 0.2-0.95 E_0
- Efficiency ~ 80%
- Energy Resolution ~ 10-3
- Timing Resolution ~100 ps



The existing dipole magnet is unable to deflect the 11 GeV primary beam on the existing beam-dump

The existing PHOTON TAGGER will be available for energies up to E_γ~6.1 GeV

Options for E_γ>6 GeV?

Why photoproduction?

Physics motivations

Meson spectroscopy

- **Standard PWA on H target**
- **Spectroscopy on He4 and other gas targets**

Hadron spectroscopy

- **Heavy mass baryon resonances (Cascades)**
  - **double-strangeness sets a higher mass**
  - **small width helps to detect and study excited states**

Compton scattering

Meson polarizabilities

J/Ψ production close threshold and on nuclear targets

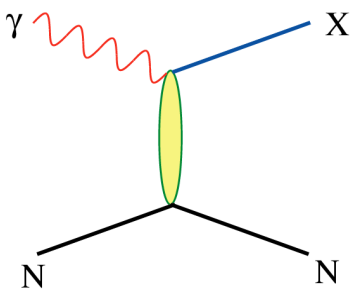
Large $-t$ physics

.....

Photoproduction experiments at JLab-12GeV

The photon beam

- With a 11-12 GeV electron beam only few choices:
  - 1) Bremsstrahlung
  - 2) Quasi-real electro-production
- Tagger (initial photon energy) is required to add 'production' information to decay
- Linear polarization is useful to simplify the PWA and essential to isolate the nature of the t-channel exchange

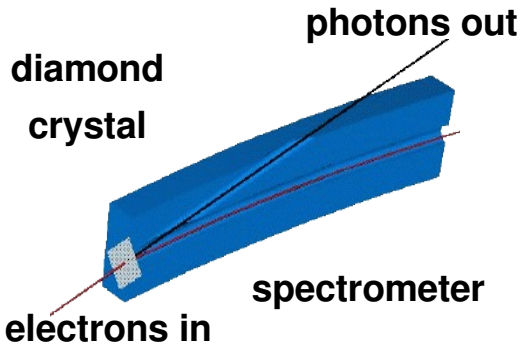


- Essential to isolate production mechanisms (M)
- Polarization acts as a J^{PC} filter if M is known
- Linear polarization separates natural and unnatural parity exchange

Hall-D and Hall-B will host real photon beam!

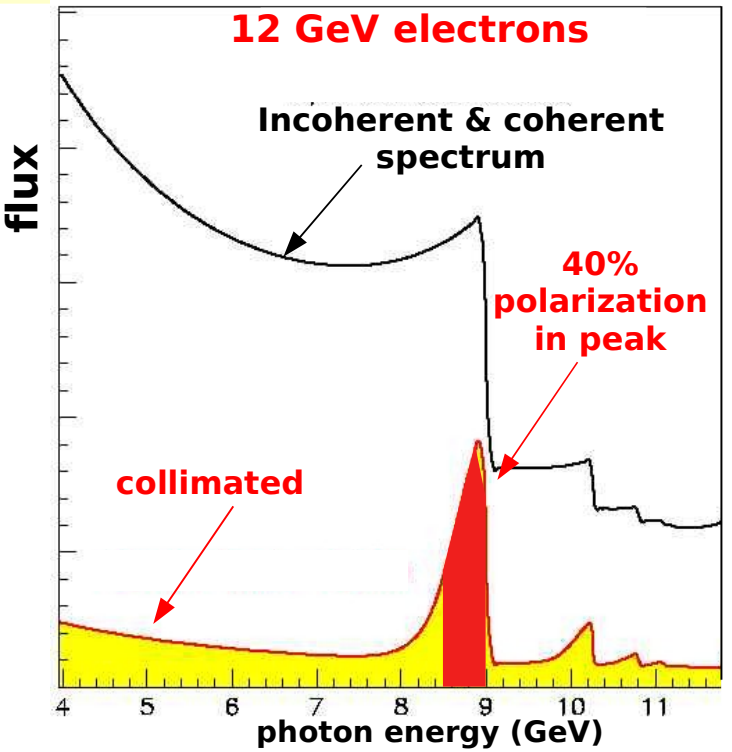
Meson spectroscopy with photons at JLab-12GeV

Coherent tagged Bremsstrahlung
Hall-D



Performance

- (.5-.95) E_{beam} → 6<E_γ<11 GeV (10MeV resolution)
- Photon Flux ~ 10^7 - 10^8 γ/s
- 30cm LH target → L ~ 10^{31} $cm^{-2}s^{-1}$
- Linear polarization ~ 50% -15% (collective)



Quasi-real electroproduction at very Low Q^2
Hall-B

$E_{scattered}$	1 - 4 GeV
θ	0.5^o - 1.2^o
ϕ	0^o - 360^o
ν	7 - 10 GeV
Q^2	0.003 - 0.029 GeV^2
W	3.9 - 4.6 GeV
x_{Bj}	0.0001 - 0.002

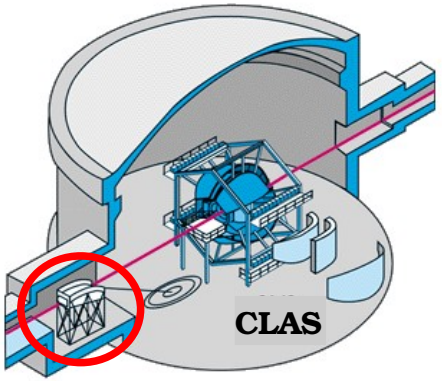
Performance

- 7 < E_γ < 10 GeV
- 5cm LH target → L ~10^{34} $cm^{-2}s^{-1}$
- Linear polarization ~ 65% - 20% (individual)
- Capability of forward tagging (electron detection)

Real and quasi-real photon beams at JLab-12GeV

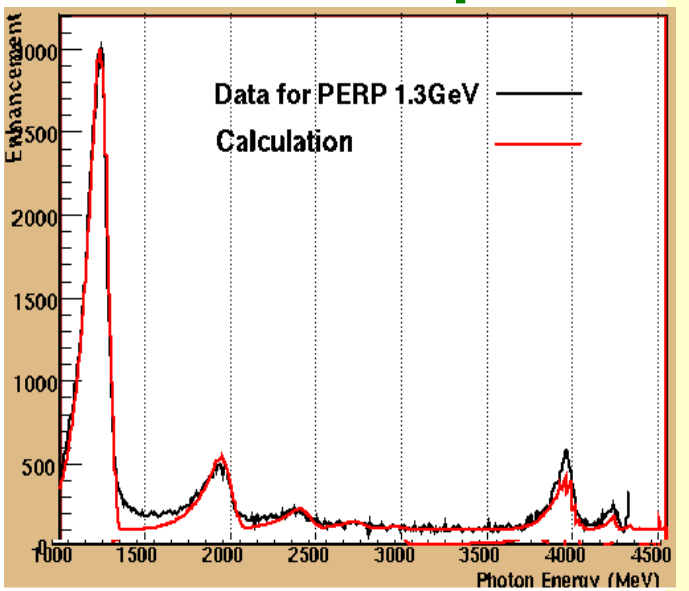
Coherent tagged Bremsstrahlung:well established technique

Hall-B real Bremsstrahlung Photon Tagger



Performance

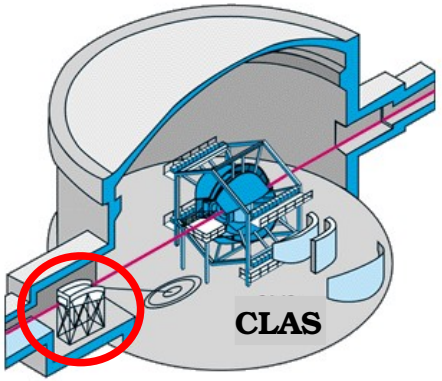
- E_γ =0.8-5.4 GeV (20% - 95% E_{beam})
- $\Delta E_\gamma/E_\gamma \sim 10^{-3}$ $\Delta t \sim 200$ps
- Linearly polarized photons (coherent Bremsstrahlung)



Real and quasi-real photon beams at JLab-12GeV

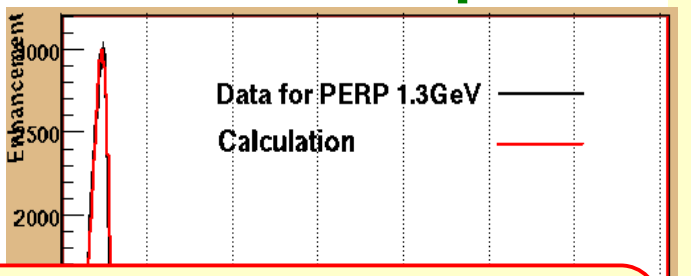
Coherent tagged Bremsstrahlung:well established technique

- Hall-B real Bremsstrahlung Photon Tagger



Performance

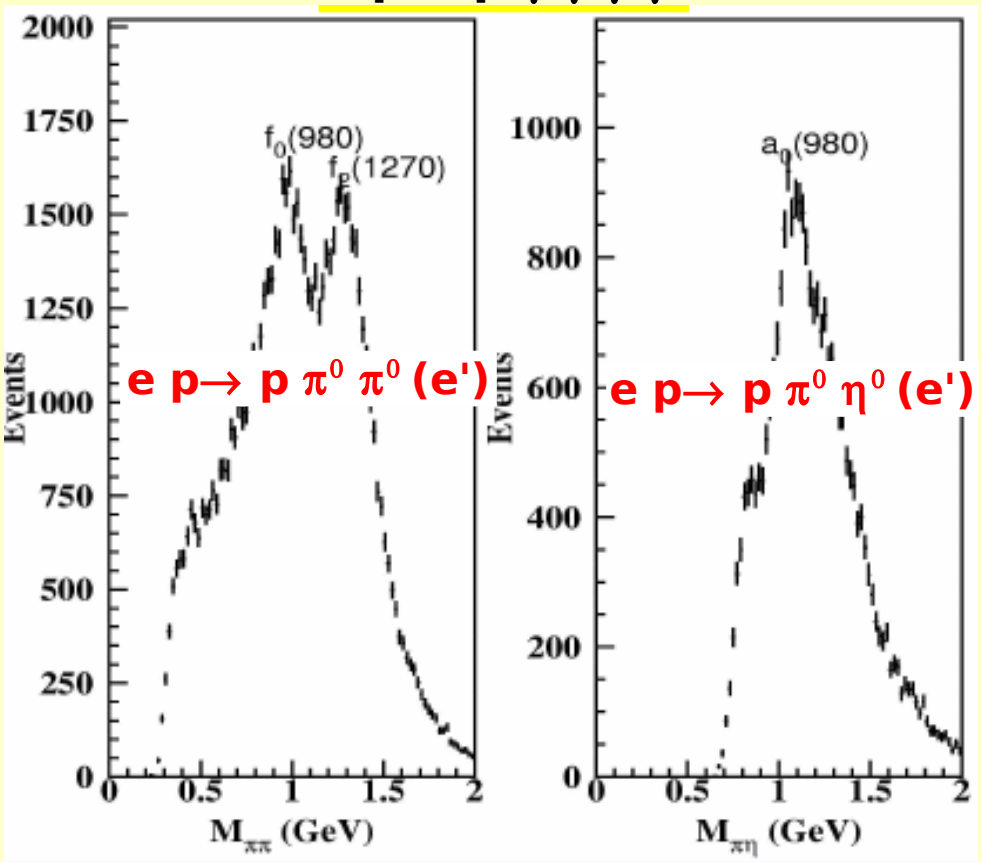
- E_γ =0.8-5.4 GeV (20% - 95% E_{beam})
- $\Delta E_\gamma/E_\gamma \sim 10^{-3}$ $\Delta t \sim$
- Linearly polarize
  (coherent Brems



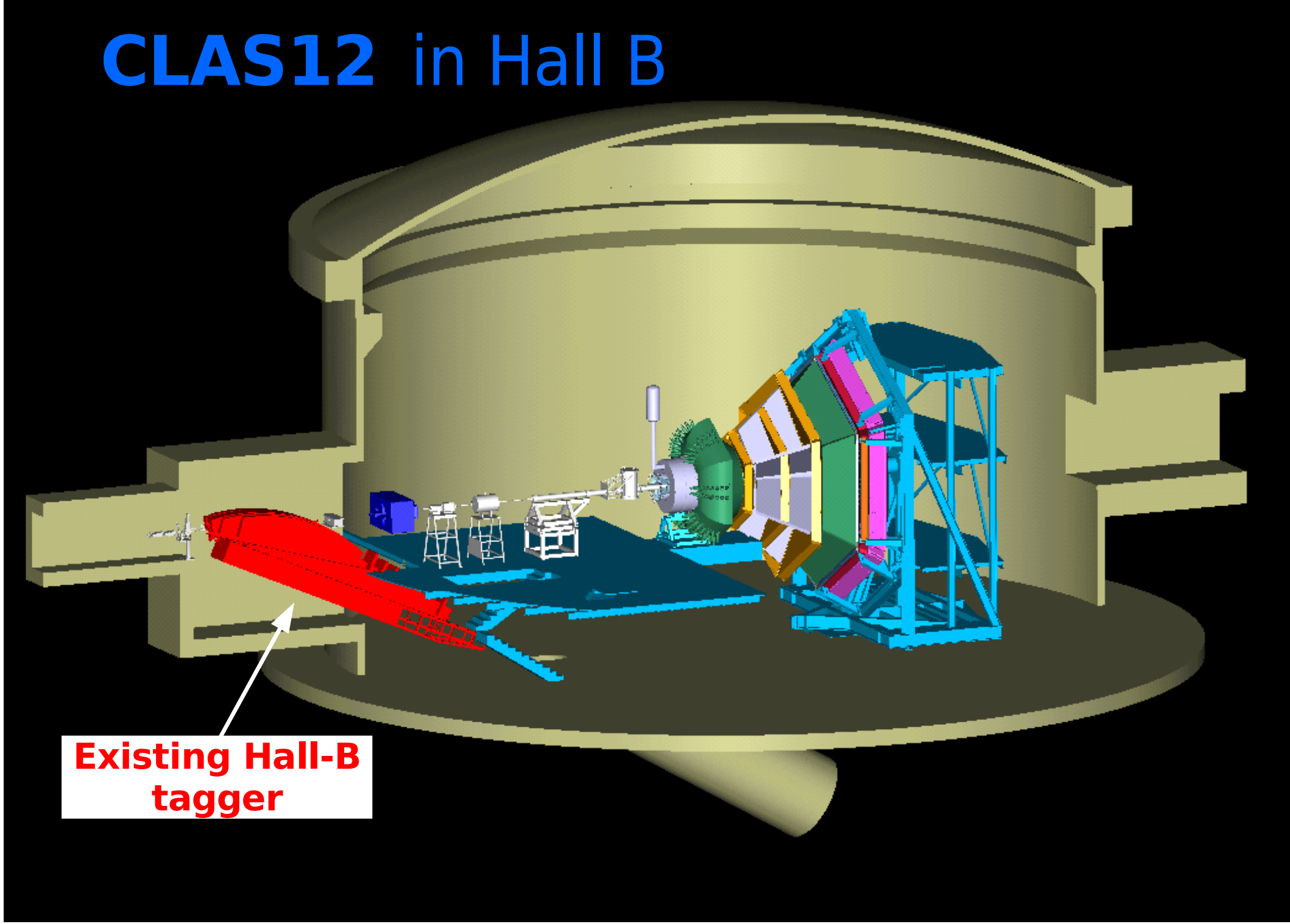
Quasi-real electroproduction at very Low Q^2

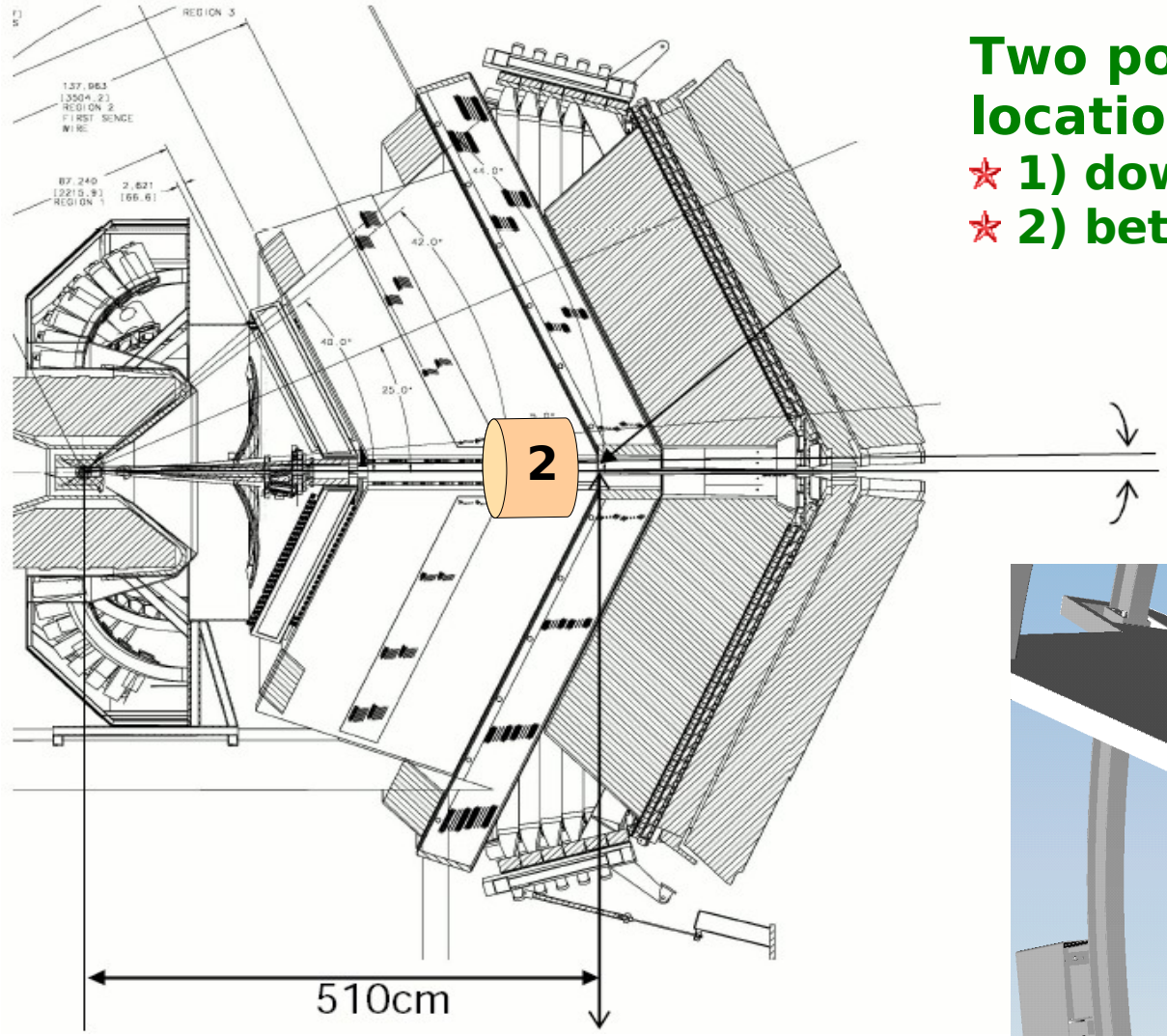
- Test level
- Fake "0^0" electroproduction (no electron in the trigger) from huge collected statistic

Bright meson peaks show up
The technique works!



CLAS12 in Hall B



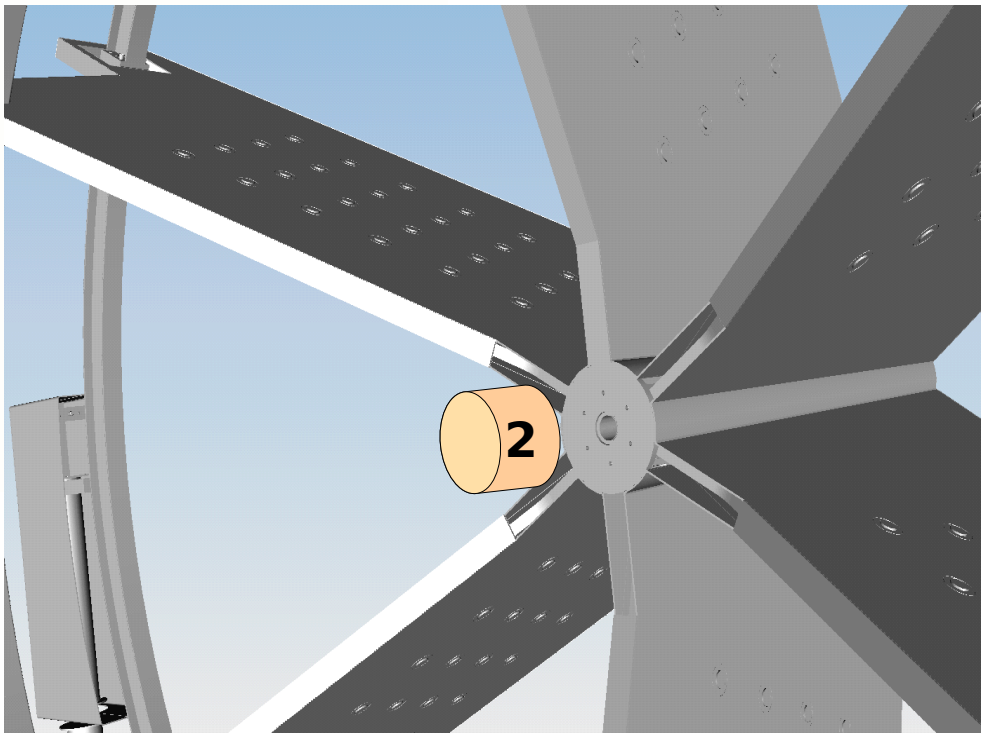


Two possible options for tagger location:

- 1) downstream
- 2) between target and torus support

θ_{max}~0.5º

1 **Forward tagger**



Maximum electron angle: 0.5º

The tagger has to be placed upstream to torus supports (option 2)

This strongly limits the possible hardware options

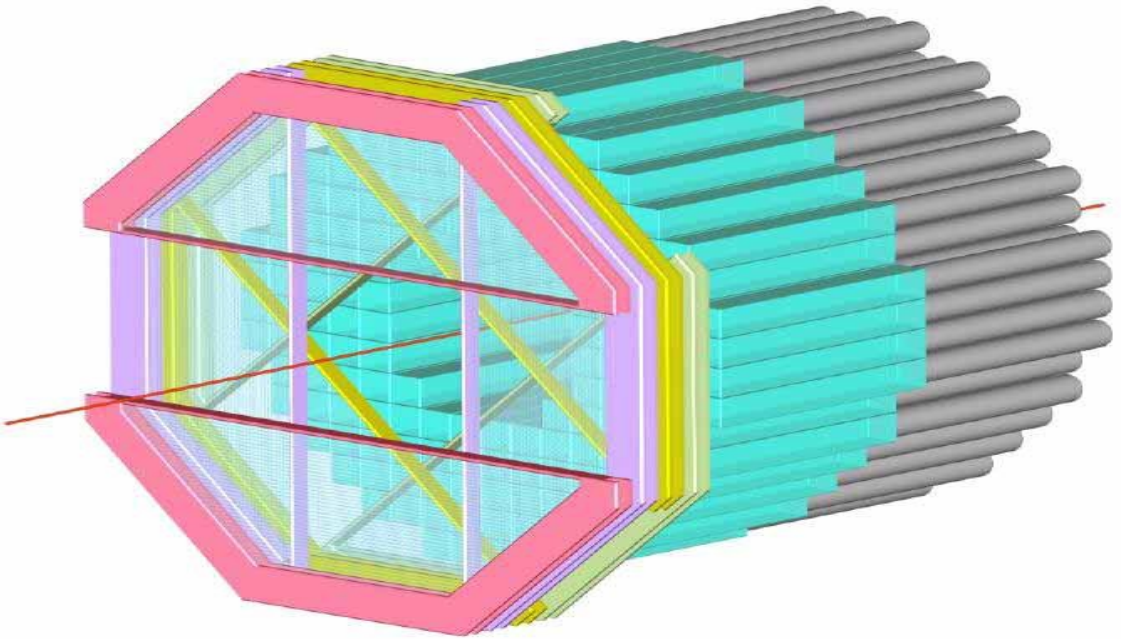
Forward Tagger

Calorimeter + tracking device

Electron Energy/momentum

- Photon energy (ν=E-E')
- Polarization $\varepsilon^{-1} \sim 1 + \nu^2/2EE'$

  - PbWO4 crystals
  - $R_M \sim 2.2$ cm
  - $\rho \sim 8.3$ g/cm^3
  - $X_0 \sim 0.9$ cm
  - Low light yield (~1% NaI(Tl))



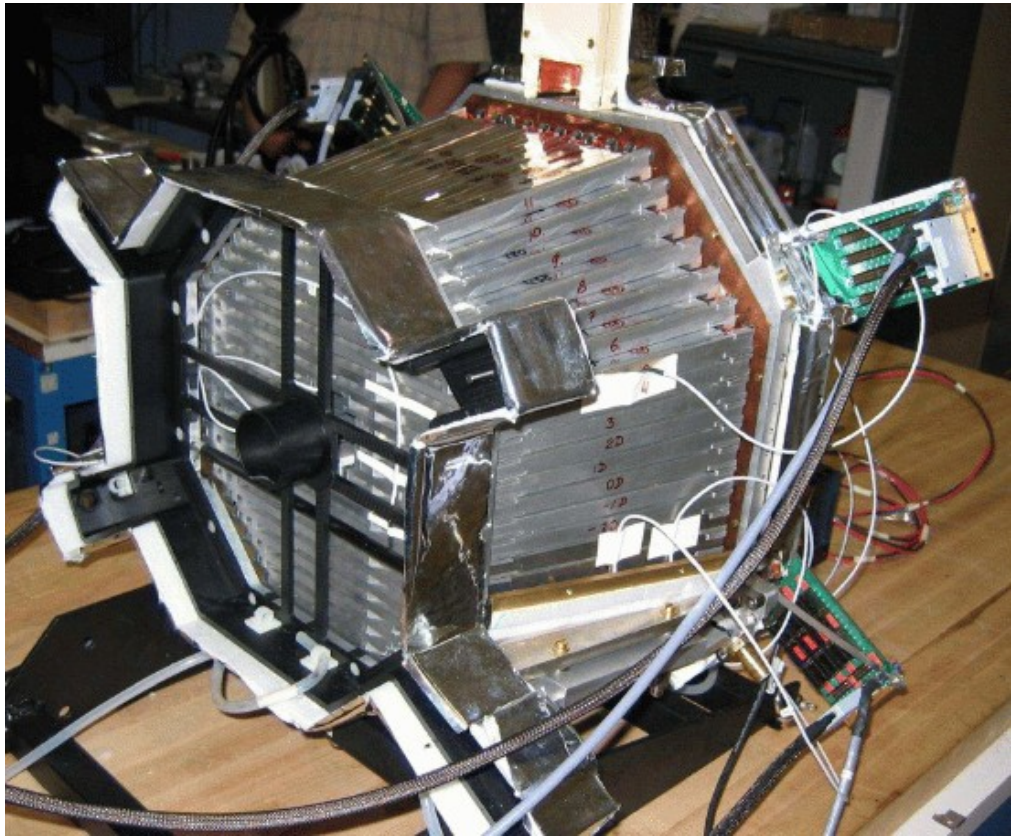
Electron angles

- $Q^2 = 4\ E\ E'\ \sin^2 \vartheta/2$
- φ polarization plane
- Veto for photons

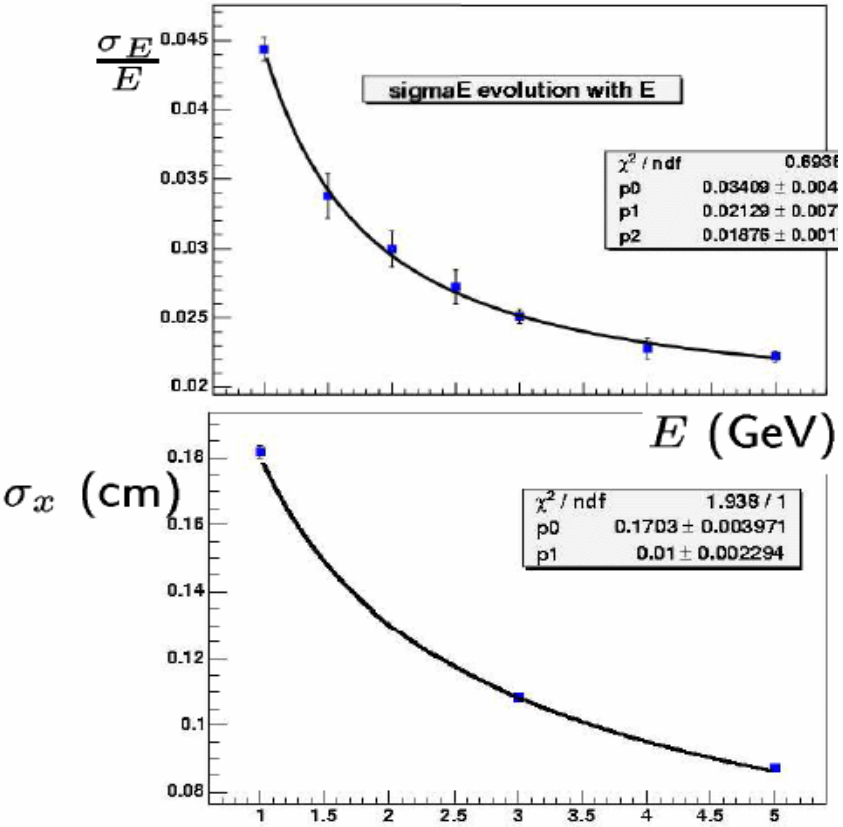
  - GEM
  - Micromegas
  - SCI-FI hodoscope

Need to estimate resolutions

CLAS Inner Calorimeter



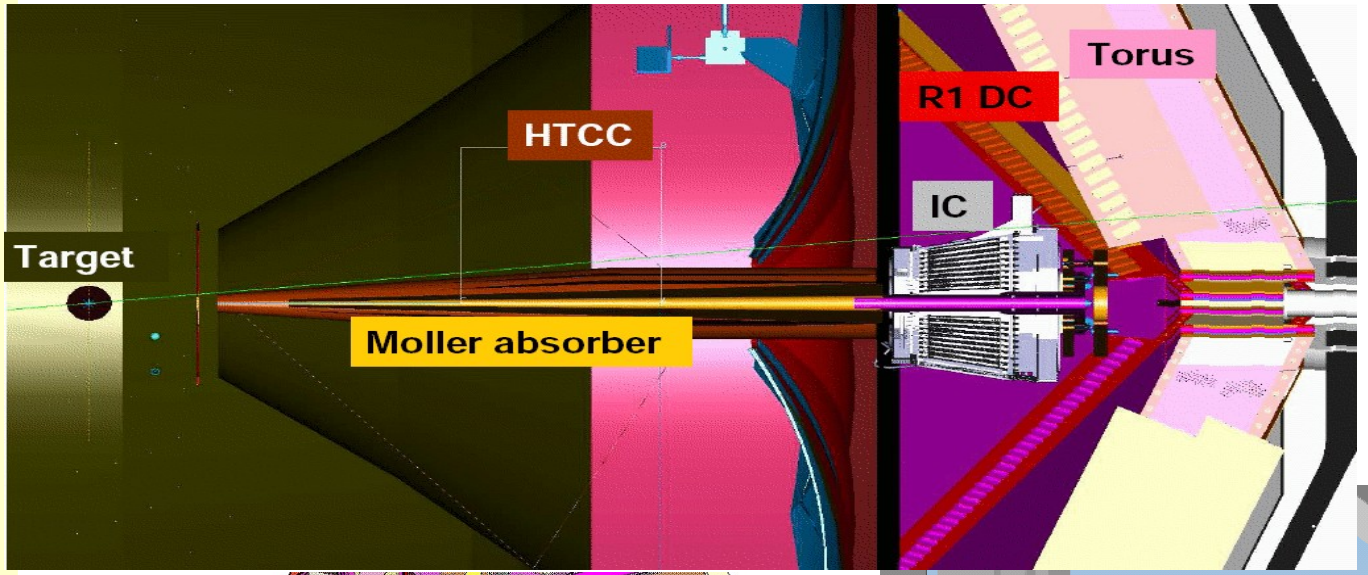
424 PbWO4 crystals
L = 16 cm = 17 X_0
Front size 1.3x1.3 cm^2
Back size 1.6x1.6 cm^2
Controlled Temperature (0.1 ^{0}C)
APD readout



$$\frac{\sigma_E}{E} = \frac{0.02}{E} \oplus \frac{0.03}{\sqrt{E}} \oplus 0.024$$

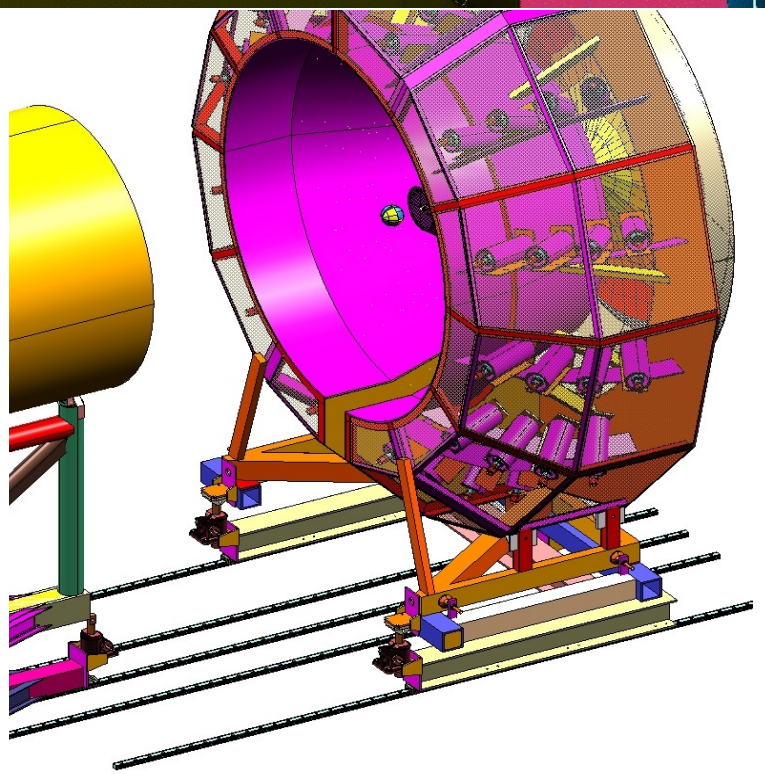
$$\sigma_x = \frac{0.2}{\sqrt{E}} \text{ (cm)}$$

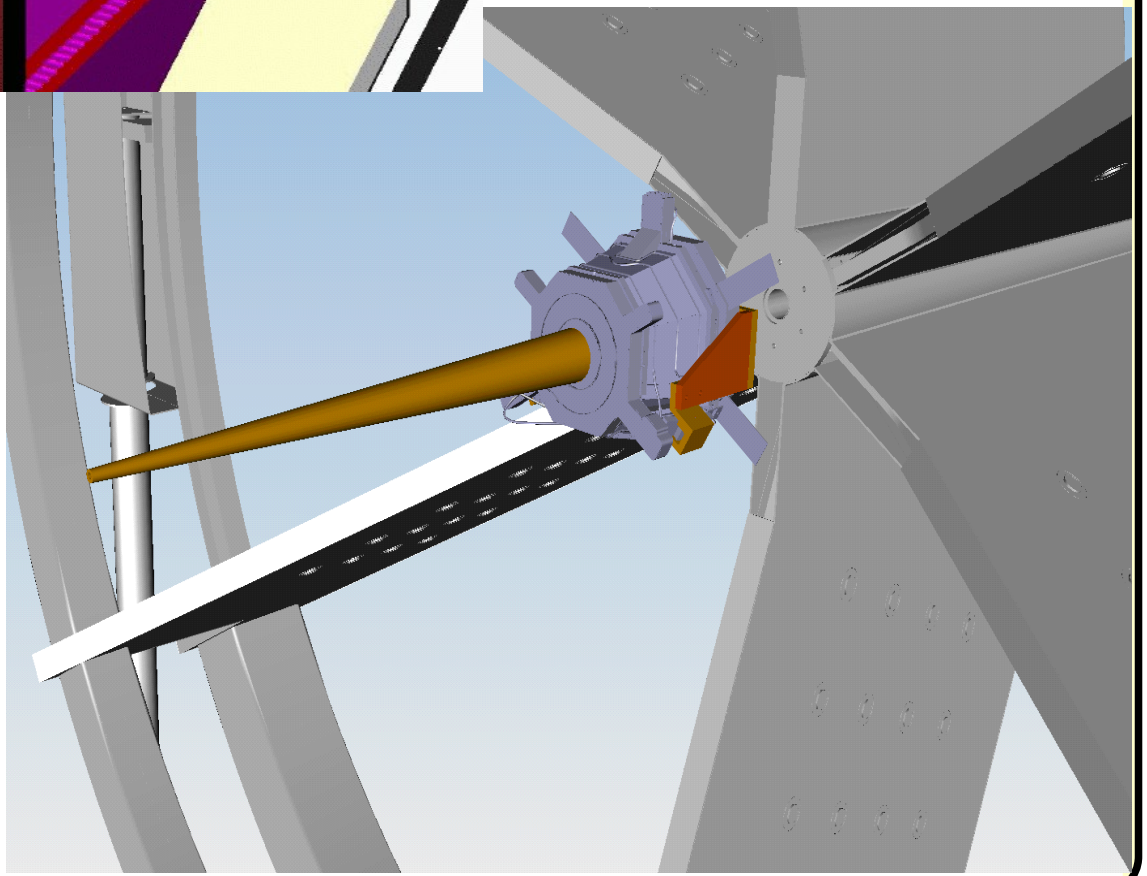
Forward Tagger within CLAS12



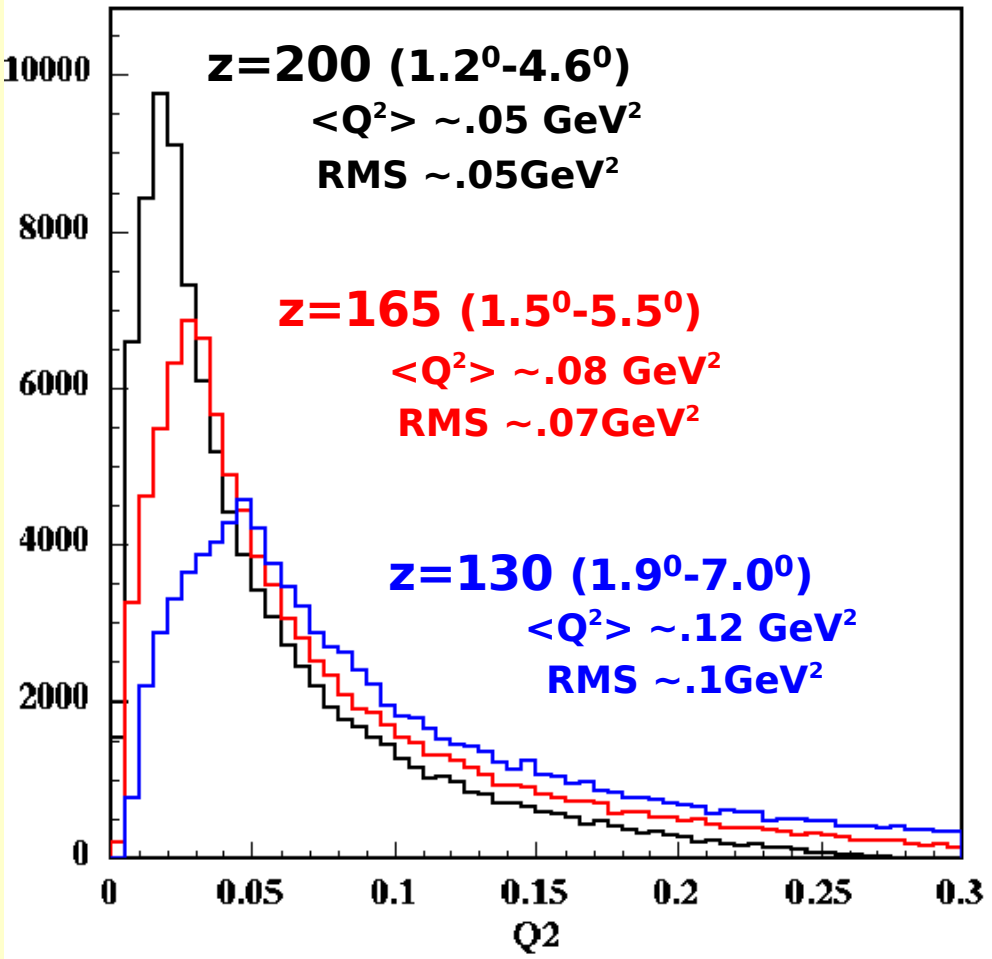
Compatibility with HTCC clearance

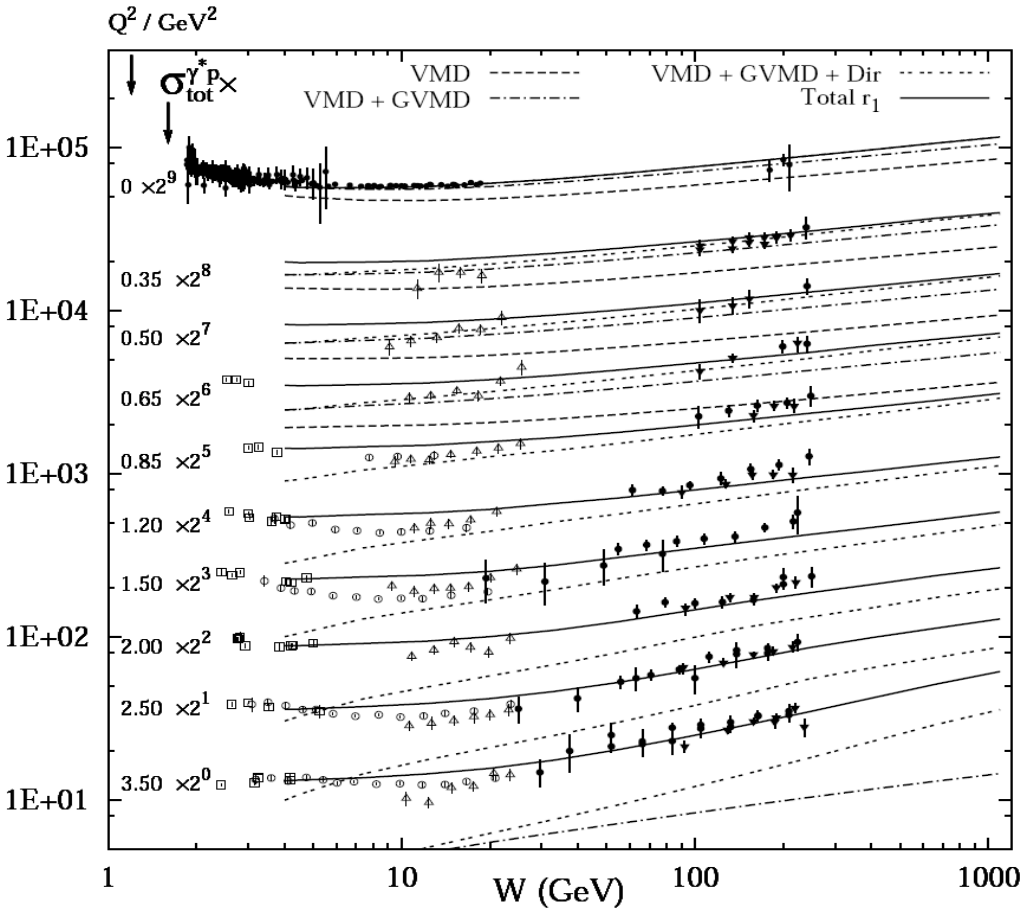
- remove HTCC
  no need electron Id
- move HTCC and solenoid upstream (~50cm)
  run parasitically!





Q^2 dependence of the Xsec





Studies at large W (~100GeV) show a smooth transition between $Q^2=0$ and $Q^2\neq 0$

Existing forward taggers

$Q^2 < W^2$

COMPASS: <1 GeV² <Q^2> ~ 10^{-1} GeV²
ZEUS: 10^{-7} – 0.02 GeV² <Q^2> ~5 10^{-5} GeV²
H1: <2 GeV²

Rates in the forward tagger

Inelastic electro-production

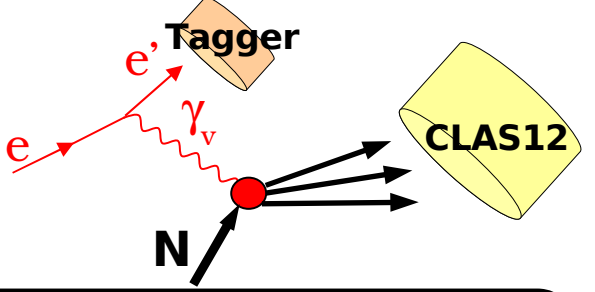
Elastic radiative tail

Moeller scattering

Signal

Background

Rates in the forward tagger



Inelastic electro-production

ϑ φ — Scattered electron angles in the Lab

$\nu = E_{beam} - E_{e'}$ — Quasi-real photon energy

$Q^2 = 4\,E\,E'\sin^2\vartheta/2$ — Virtuality

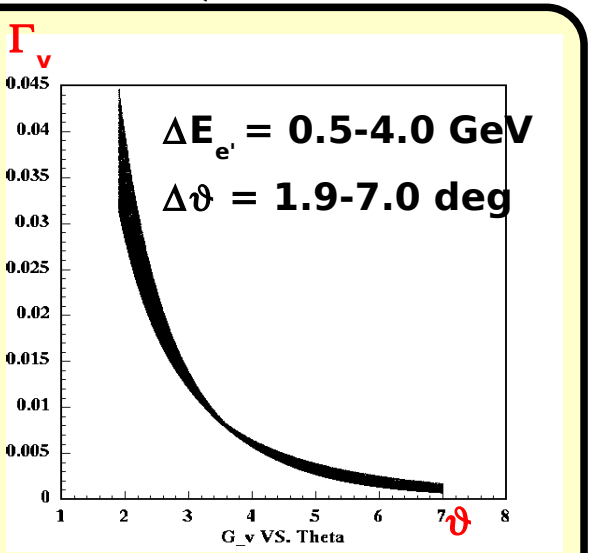
$\varepsilon^{-1} \sim 1 + \nu^2/2E_{e'}E_{beam}$ — Quasi-real photon linear polarization

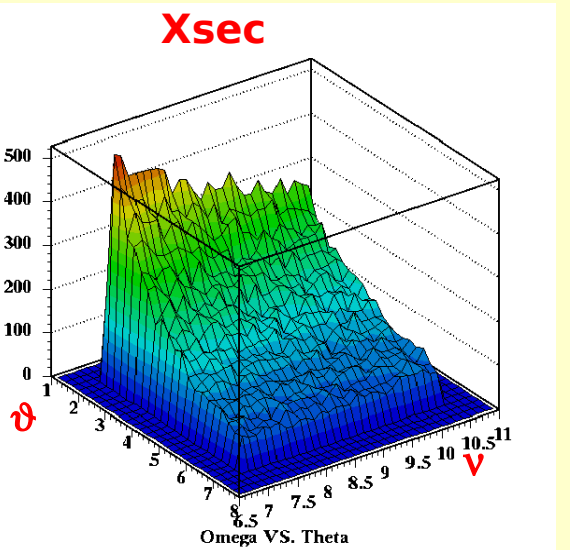
$$Xsec = \frac{\Gamma_v}{(1+Q^2/.7^2)^2}\,\sigma_{\gamma p}$$

$$\Gamma_v = \frac{1}{137}\,\frac{1}{2\pi^2}\,\frac{E_{e'}}{E_{beam}}\,\frac{W^2-M_p^2}{2M_p^2}\,\frac{1}{Q^2}\,\frac{1}{(1-\varepsilon)}$$

e' in the forward tagger
hadrons in CLAS12 (N_h>=1)

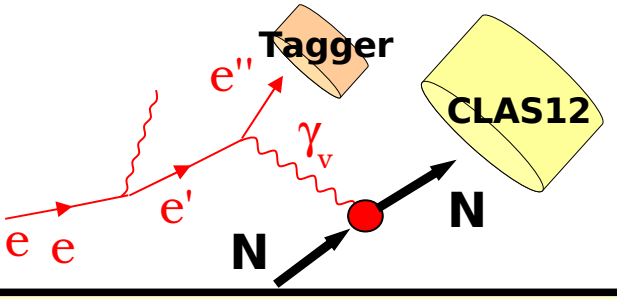
Rates are limited to ~10kHz





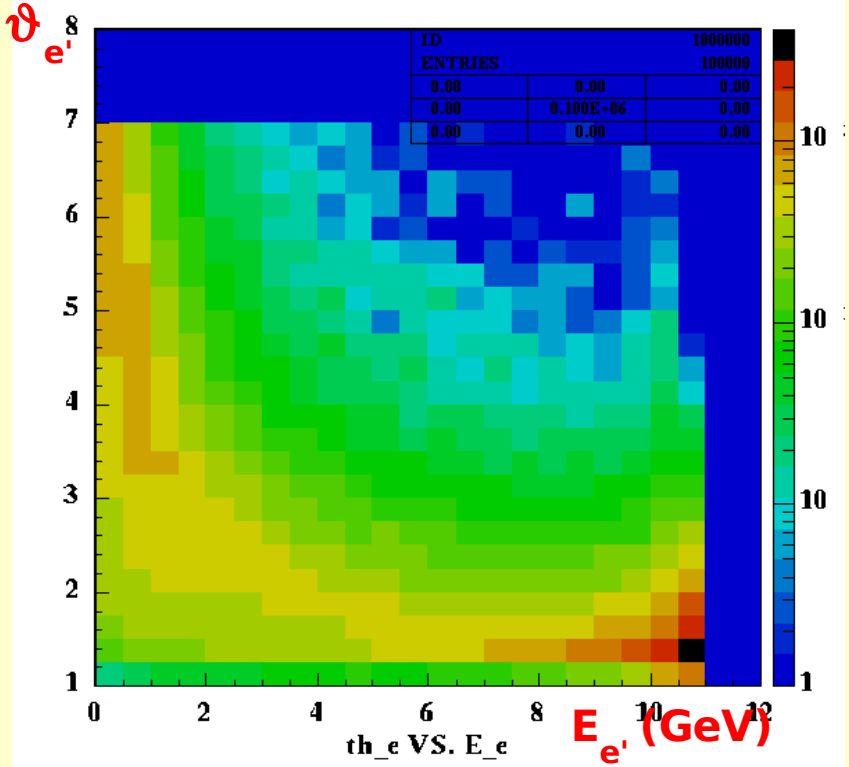
Rates in the forward tagger

Elastic radiative tail

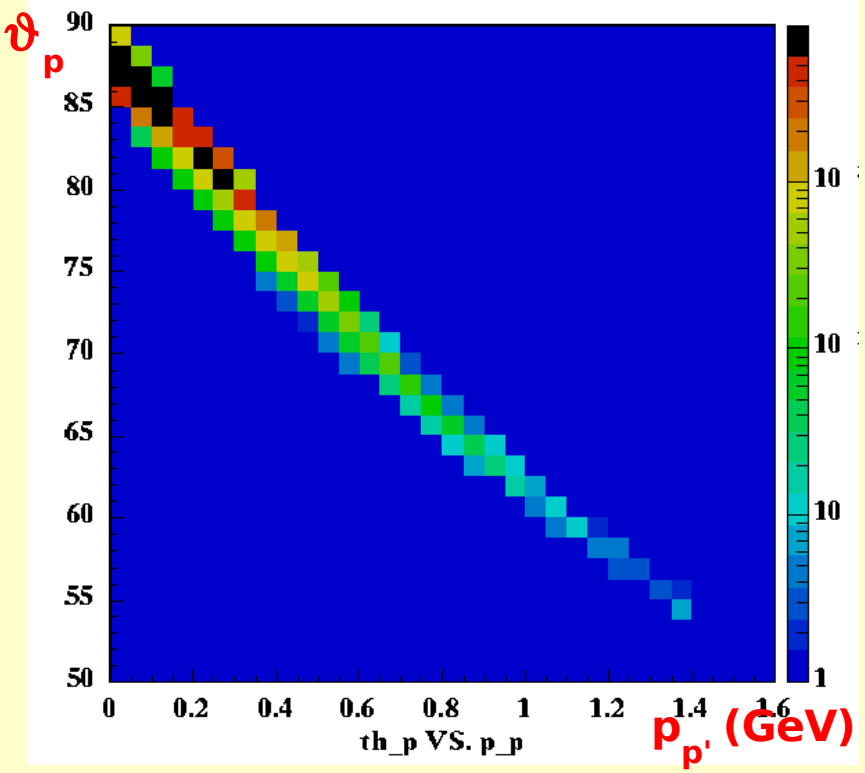


Elastic radiative tail

Electron kinematic



Proton kinematic



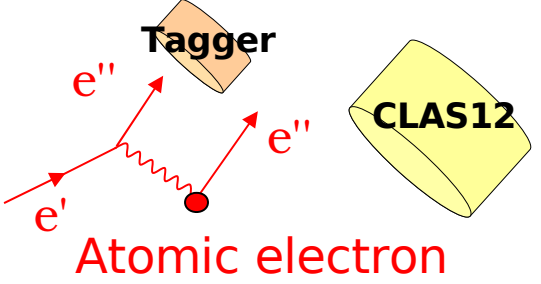
e' in the forward tagger

Elastic proton outside CLAS (N_h=0 or 1)

Electron rate in the forward tagger is high (~1 MHz)

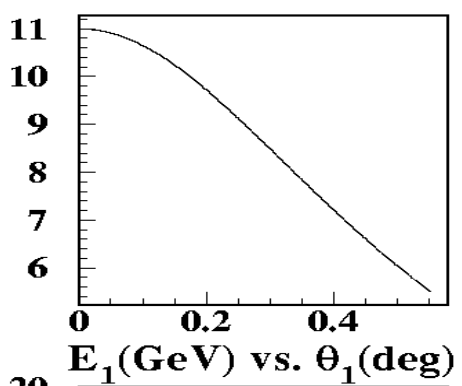
Rates in the forward tagger

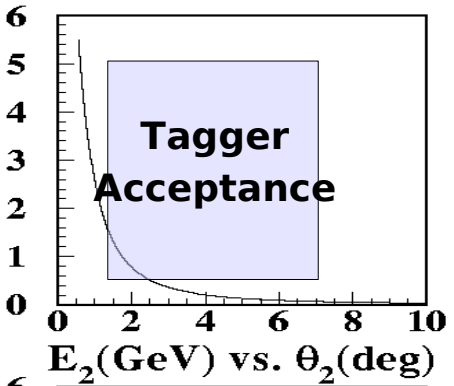
Moeller scattering

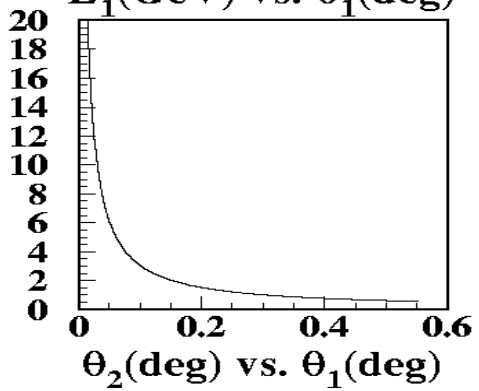


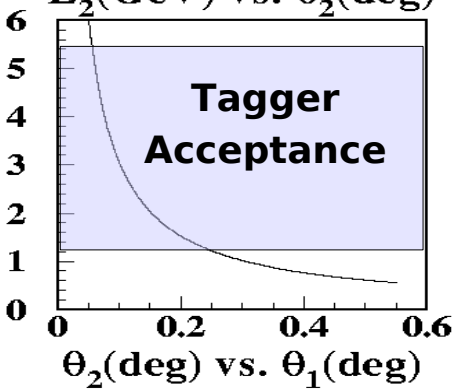
Moeller scattering

kinematics

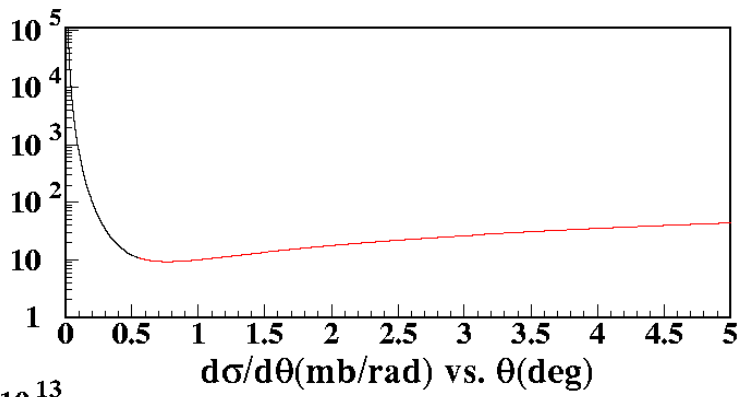


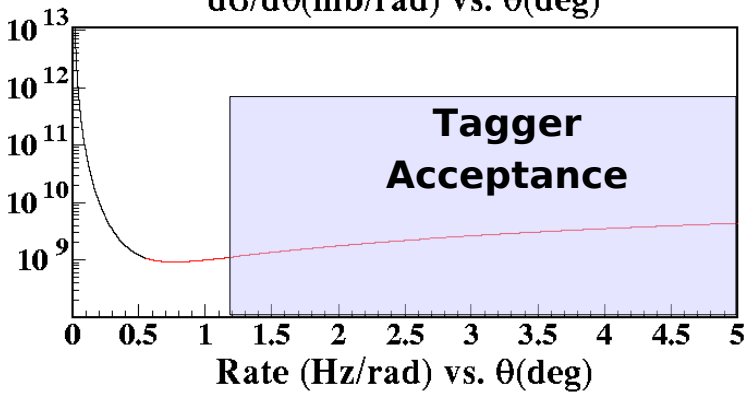






Rate

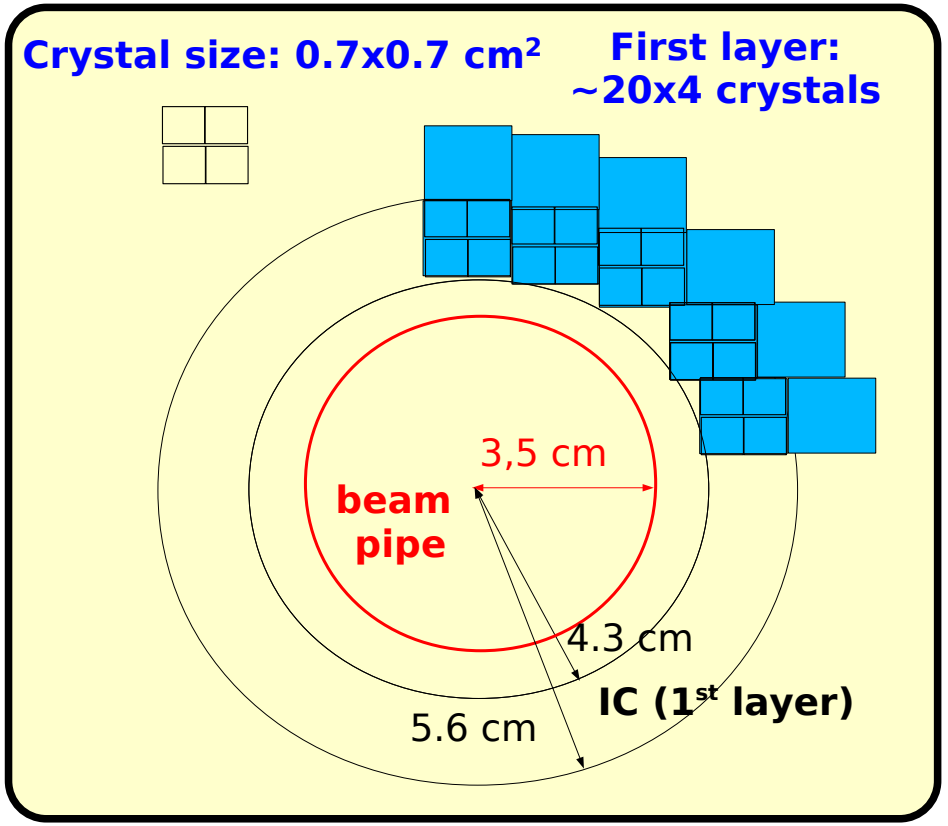




Only 1 electron in the forward tagger

No hits in CLAS (N_h=0)

Electron rate in the forward tagger is very high (~50 MHz)



Hadroproduction kinematic

Crystal size = 1.3x1.3 cm

Whole

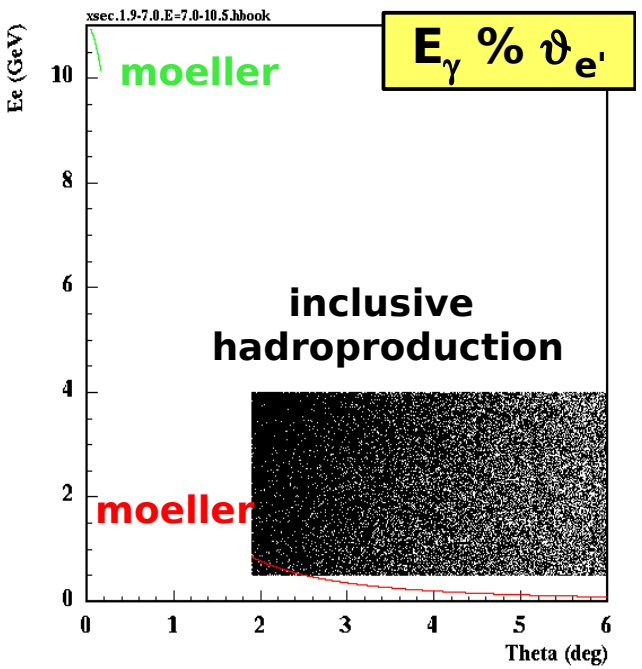
- $N_{crystal}$ = 424
- $\Delta\vartheta = 1.9^0 - 7.0^0$
- ΔE = 7.0 - 10.5 GeV
- Hadro production — $R_e \sim$ 9.7kHz
- Eq. photon flux — $R_\gamma \sim 0.44\ 10^8\ \gamma/s$

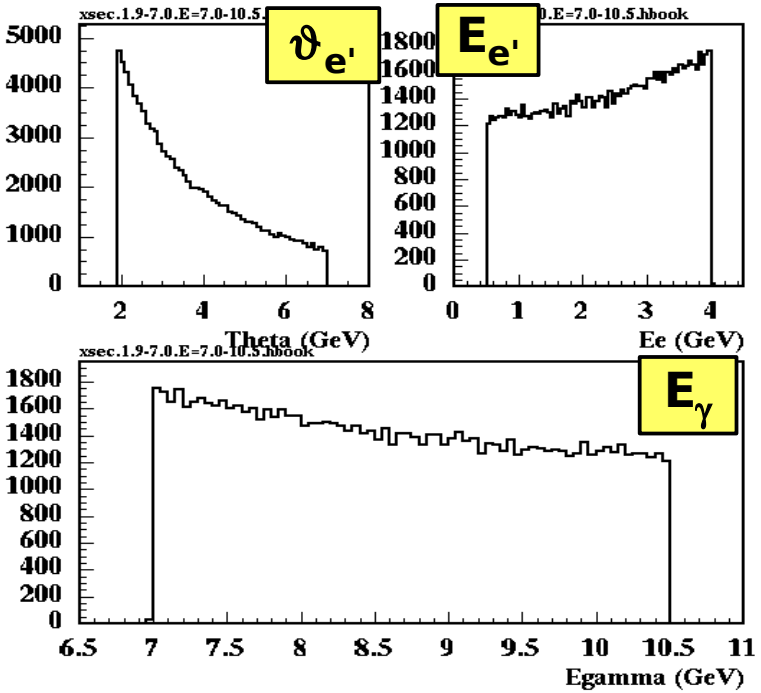
First layer

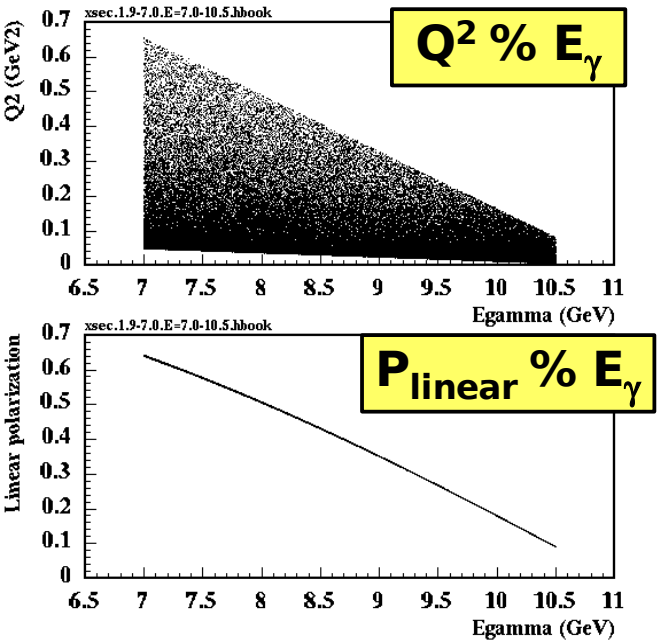
- $N_{crystal}$ = 20
- $\Delta\vartheta(1) = 1.9^0 - 2.5^0$
- Hadroproduction — $R_e \sim$ 2.1 kHz
- Rad tail (ΔE = 0.3 -10.9 GeV) — $R_e \sim$ 1.3 MHz
- Moeller — $R_e \sim$ 20 MHz

$L=130$, $\Delta\vartheta=1.9^0 - 7.0^0$

$L_e \sim 10^{35}\ cm^{-2}\ s^{-1}$







Work plan

Software activities

- Implement digitalization in GEMC
- implement the cluster recognition algorithms
- Realistic rate evaluation
- IC-DVCS used in 6 GeV runs data as benchmark
- Event generator for CLAS12 kinematic (benchmark reactions)
- CLAS12 Fast-MC reconstruction to derive ΔE and $\Delta\vartheta$ specifications
- Geometry optimization
- Active material optimization

Hardware activities

- Crystal scintillation properties
  - PbWO
  - LSO/LYSO
  - PbF2
  - light yield
  - light transmission
  - timing
  - temperature dependence
  - Magnetic field effects
- Light read-out
  - APD
  - SiPM (single)
  - SiPM (matrix)
  - FE electronics
  - readout electronics
  - cooling
- Mechanical design

Time schedule

- GEMC simulations — 2009/10
- EVGen and fastmc (D.Glazier) — 2009/10
- Final project — 2010/11
- Test facility in Genova (daq, black-box) — 2009
- Single crystal tests — 2010
- PbW powder+ SciFi — 2011
- FTC Prototype — 2011
- Test at BTF (LNF) — 2011

Conclusions

Photoproduction experiments at CLAS12

Started project and test phase

- a forward tagger for CLAS12 is feasible
- meson spectroscopy is a strong physic case
- many other physics topics addressable

Workplan for 2010 and 2011 defined

- define the project
- test components

Letter of Intents (LOI) at PAC35 (Jan 2010)

- Instrumentation: forward tagger for real quasi-real photon experiments
- Meson spectroscopy (H2 and He4 targets)
- Other LOI's with different physics topics