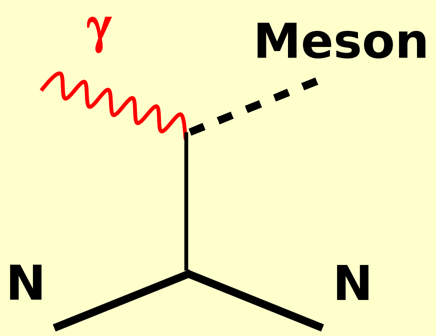
Proposal to PAC37
January 10-14 2011

Meson spectroscopy with low Q^2 electron scattering in CLAS12

M.Battaglieri, *R.De Vita, D.Glazier, C.Salgado,*
S.Stepanyan, D.Weygand
and the CLAS Collaboration

- Physics motivation
- Low Q^2 electron scattering
- Experimental setup: Forward Tagger
- Simulation studies
- Beam time request and expected results

We propose to study the light meson spectrum in a photoproduction experiment using CLAS12



- $q\bar{q}$ system $\rightarrow$ easier to study
- information on interquark potential
- access to strong interaction dynamics
- access to gluonic degrees of freedom
- towards a quantitative understanding of quark and gluon confinement

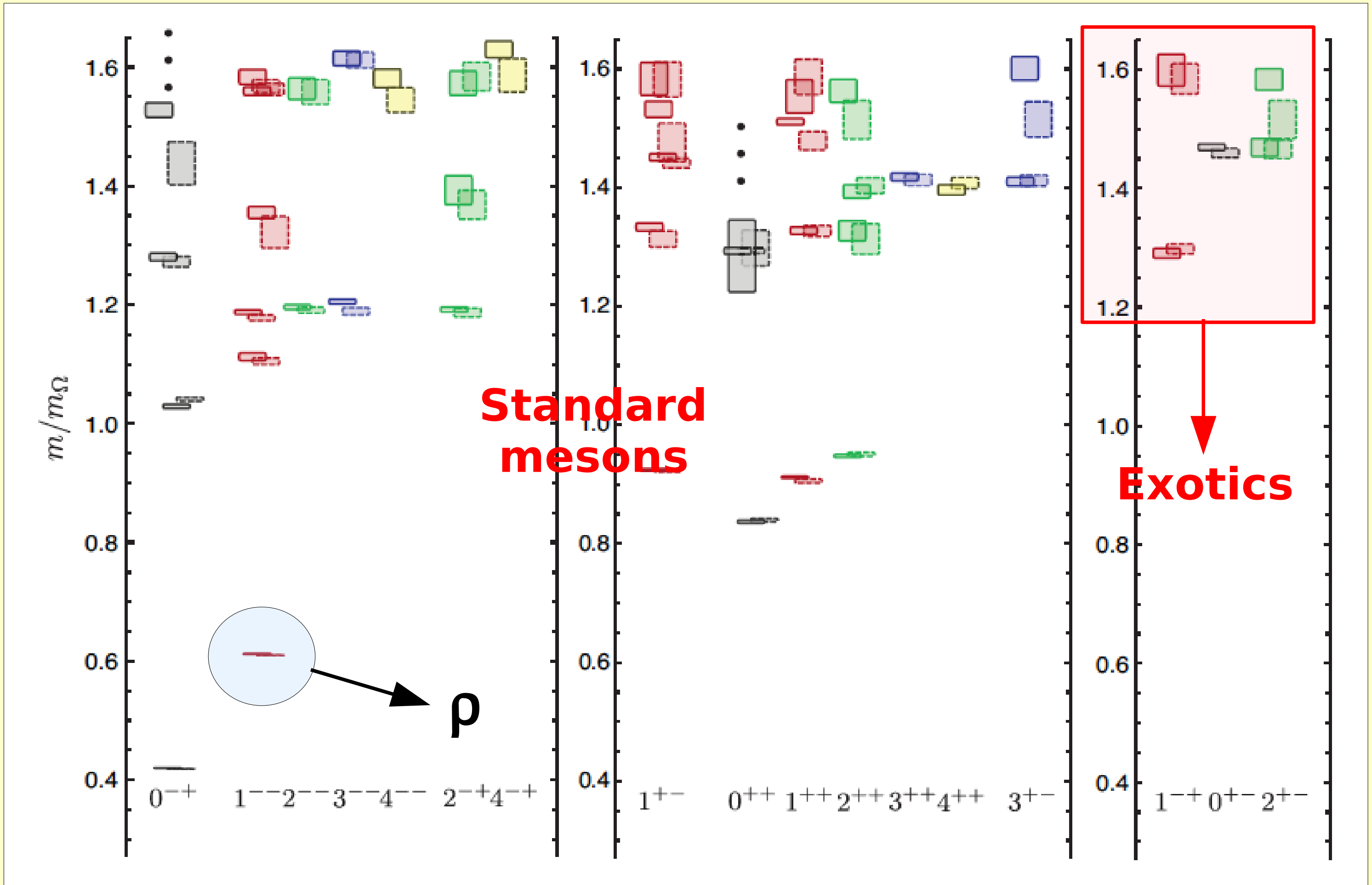
Detailed study of the meson spectrum and search for *exotic* configurations

Why photoproduction?

- Complementary to hadro-production
- Hybrid mesons with exotic quantum numbers are more likely produced by S=1 probe
- Linear polarization acts like a filter to disentangle the production mechanisms and suppress backgrounds

Requires high intensity tagged photon beam and large acceptance detector

QCD Lattice calculations



J.Dudek et al Phys.Rev.D82 (2010) 034508

Lattice-QCD predictions for the lowest hybrid states

0^{+-} 1.9 GeV
1^{-+} 1.6 GeV

Hybrid mesons and glueballs mass range:

1.4 GeV - 3.0 GeV

This mass range is accessible in photoproduction experiments with a beam energy in the range 5 GeV < E_γ <12 GeV

Perfectly matched to JLab12 energy!

Meson spectroscopy program in CLAS12

Study the meson spectrum in the 1-3 GeV mass range to identify gluonic excitation of mesons (hybrids) and other quark configuration beyond the CQM

Hybrid mesons and Exotics

- Search for hybrids looking at many different final states
- Charged and neutral-rich decay modes
- $\gamma p \to p\, 3\pi$, $\gamma p \to p\, \eta\, \pi$, ...

Hybrids with hidden strangeness and *strangeonia*

- Intermediate mass of *s* quarks links long to short distance QCD potential
- Good resolution and kaon Id required
- $\gamma p \to p\, \varphi\, \pi$, $\gamma p \to p\, \varphi\, \eta$, $\gamma p \to p\, 2K\, \pi$, ...

Scalar mesons

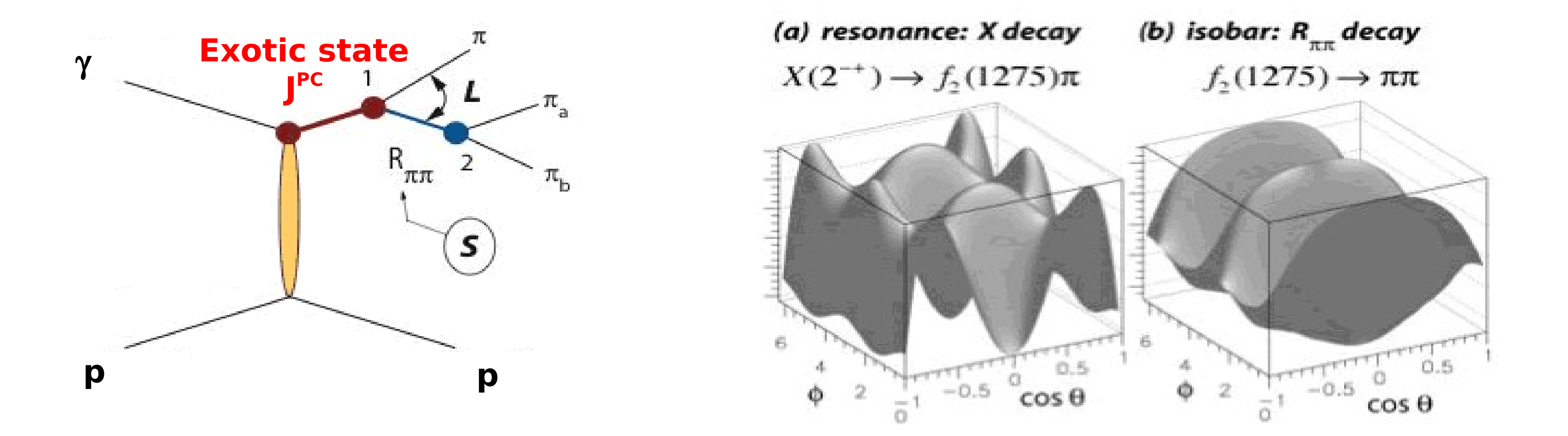
LOI-11-001

- Poorly know f_0 and a_0 mesons in the mass range 1-2 GeV
- Theoretical indications of unconventional configurations ($q\bar{q}q\bar{q}$ or *gg*)
- $\gamma p \to p\, 2\pi$, $\gamma p \to p\, 2K$, ...

One of the most important issue in hadron physics and main motivation for the JLab 12 GeV upgrade

Partial Wave Analysis

✯ **Search for mesons with 'exotic' quantum numbers (not compatible with quark-model)**



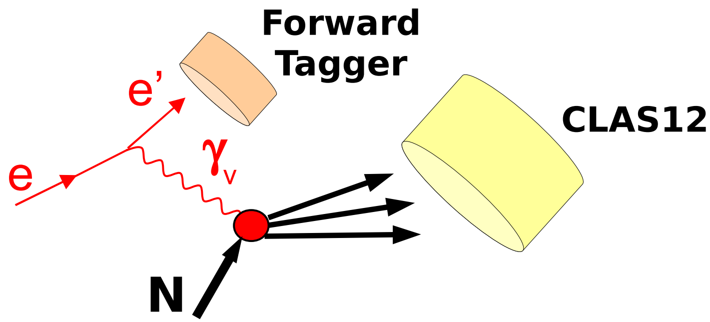
- ✯ **Parametrize the cross section in term of partial waves**
- ✯ **Fit to data to extract amplitudes**
- ✯ **A model is needed to parametrize amplitudes: Isobar Model, Dispersion Relations, ...**
- ✯ **Strong interaction between theoreticians and experimentalists to develop the best analysis framework**

PWA were successfully performed on CLAS data ($\gamma p \to p\, \pi^+\pi^-$, $\gamma p \to n\, \pi^+\pi^+\pi^-$, ...) using different models

e.g. first observation of the f_0(980) in a photoproduction experiment

M.B. et al. PRL 102 2009 102001

Quasi-real photoproduction with CLAS12
(Low Q^2 electron scattering)



$E_{scattered}$	0.5 - 4.5 GeV
θ	2.5^o - 4.5^o
ϕ	0^o - 360^o
ν	6.5 - 10.5 GeV
Q^2	0.01 - 0.3 GeV^2 ($< Q^2 >$ 0.1 GeV^2)
W	3.6 - 4.5 GeV

- **Electron scattering at "0" degrees (2.5^o - 4.5^o)**
  low Q^2 virtual photon ⇔ real photon
- **Photon tagged by detecting the scattered electron at low angles**
  High energy photons 6.5 < E_γ < 10.5 GeV
- **Quasi-real photons are linearly polarized**
  Polarization ~ 70% - 10% (measured event-by-event)
- **High Luminosity (unique opportunity to run thin gas target!)**
  Equivalent photon flux $N_\gamma \sim 5\ 10^8$ on 5cm H_2 ($L=10^{35}\ cm^{-2}s^{-1}$)
- **Multiparticle hadronic states detected in CLAS12**
  High resolution and excellent PID (kaon identification)

Complementary to Hall-D (GLUEX)

Hadron detection: CLAS12

- Determination of J^{PC} of meson states requires Partial Wave Analysis
- Decay and Production of exclusive reactions
- Good acceptance, energy resolution, particle Id (k/π separation)

Hermetic charged/neutral particles detector

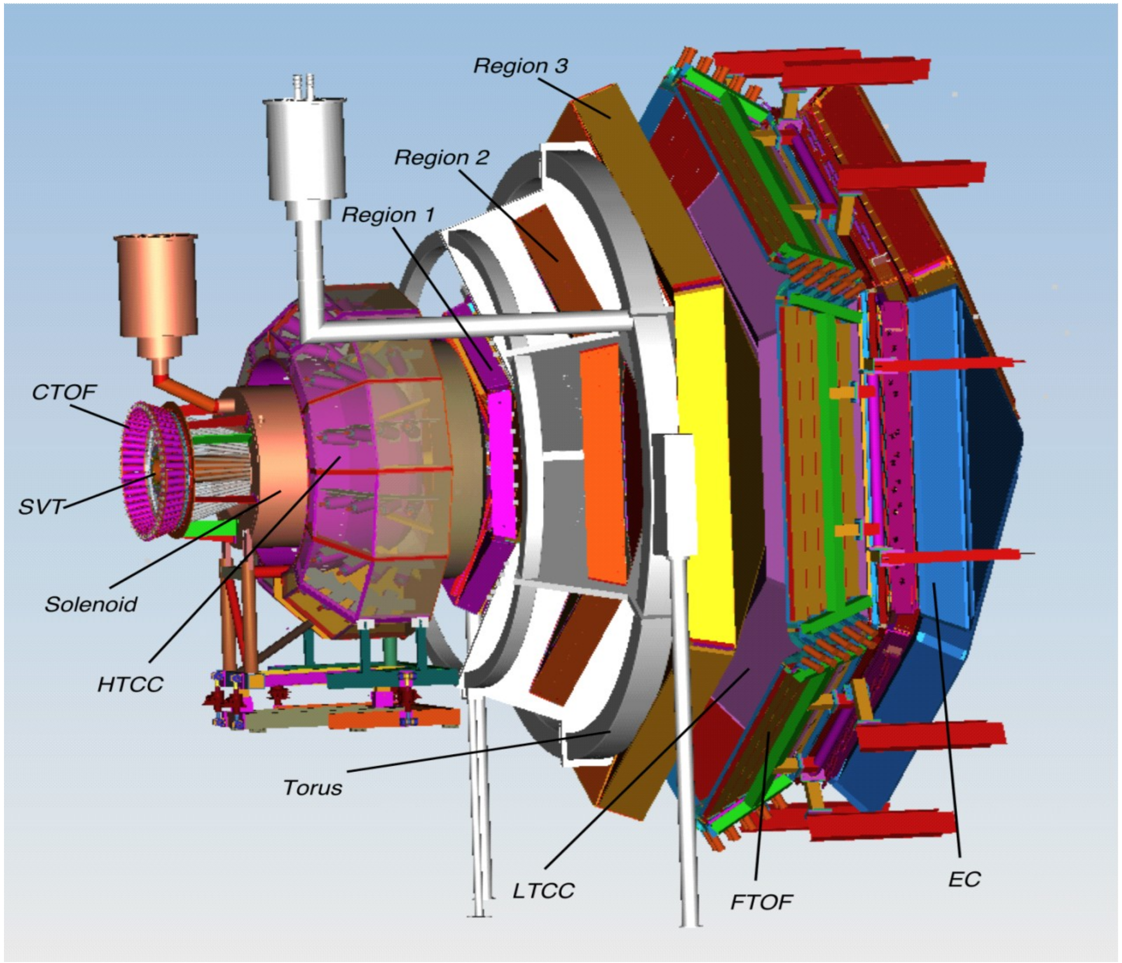
Forward Detector (FW)

- TORUS Magnet
- Forward SVT tracker
- HT Cerenkov Counter
- LT Cerenkov Counter
- Forward TOF System
- Preshower calorimeter
- E.M. Calorimeter

Central Detector

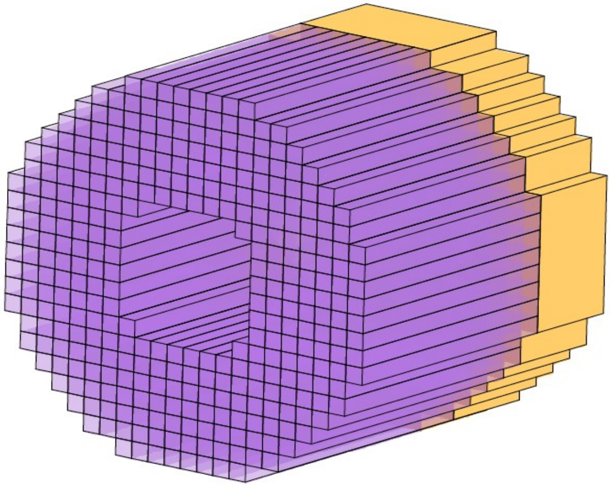
- SOLENOID magnet
- Barrel silicon tracker
- Central TOF

Proposed upgrade
Forward Tagger (FT) between Central and FW Detector



Forward Tagger

Calorimeter + hodoscope + tracker



Electron energy/momentum

Photon energy (ν=E-E')

Polarization $\varepsilon^{-1} \sim 1 + \nu^2/2EE'$

$\delta\nu / \nu = \delta E'/(E-E')$

Veto for photons

Electron angles

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

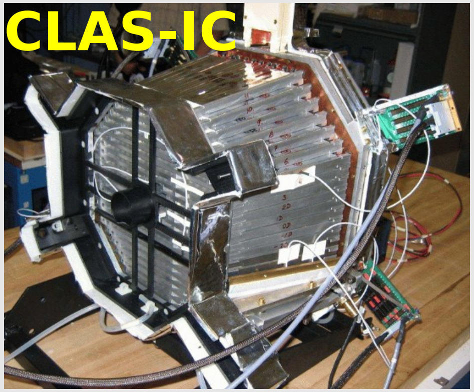
Scattering plane

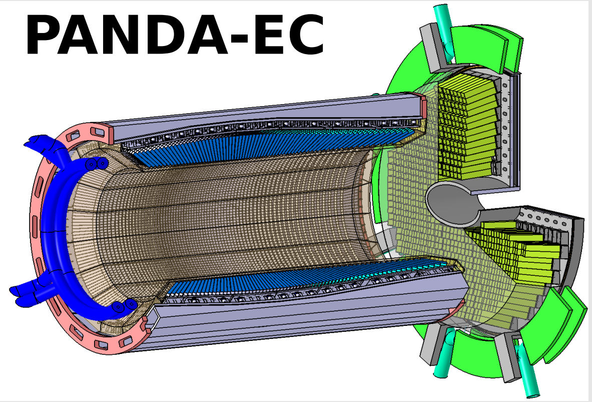
Calorimeter

Homogeneous, fast, dense, inorganic-crystals (PbWO4)

Specs

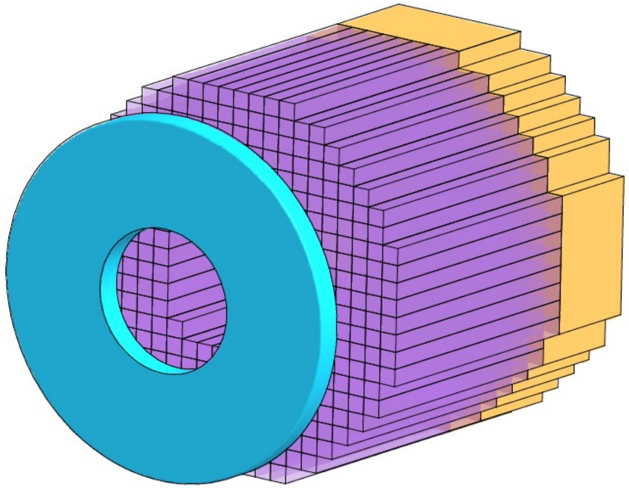
- Radiation hard
- Good light yield
- Energy resolution
- Time resolution
- Light read-out (APD/SiPM)





Forward Tagger

Calorimeter + hodoscope + tracker



Electron energy/momentum

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Veto for photons

Electron angles

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

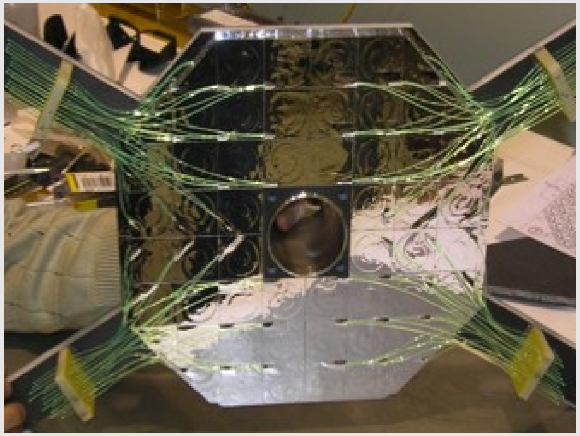
Scattering plane

Hodoscope

Specs

- Good timing (<ns) for MIPs
- High segmentation (same as the cal or higher)
- 100% efficient to charged particles

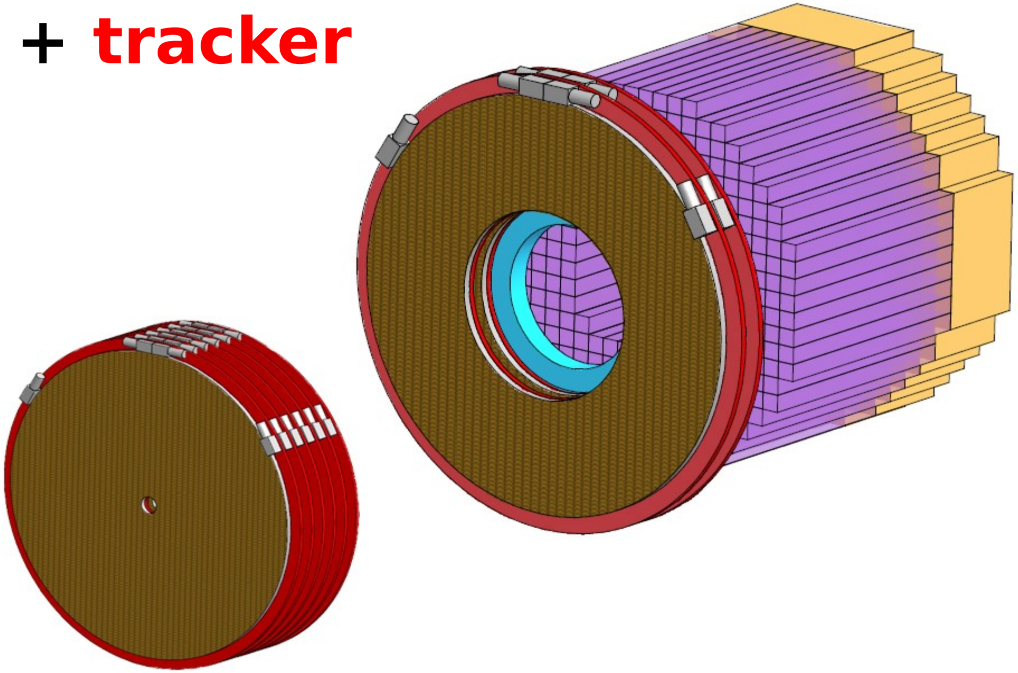
Plastic scintillator tiles with WLS fibres coupled to SiPM



CLAS-HODO

Forward Tagger

Calorimeter + hodoscope + tracker



Electron energy/momentum

Photon energy (ν=E-E')

Polarization $\varepsilon^{-1} \sim 1 + \nu^2/2EE'$

Veto for photons

Electron angles

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

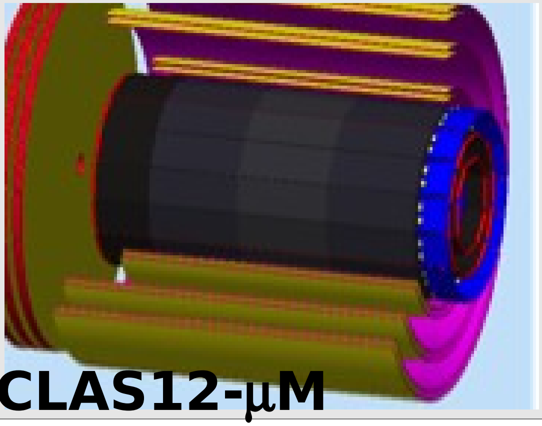
Scattering plane

Tracker

Sustain high rate, moderate resolution, low material budget (Micromegas)

Specs

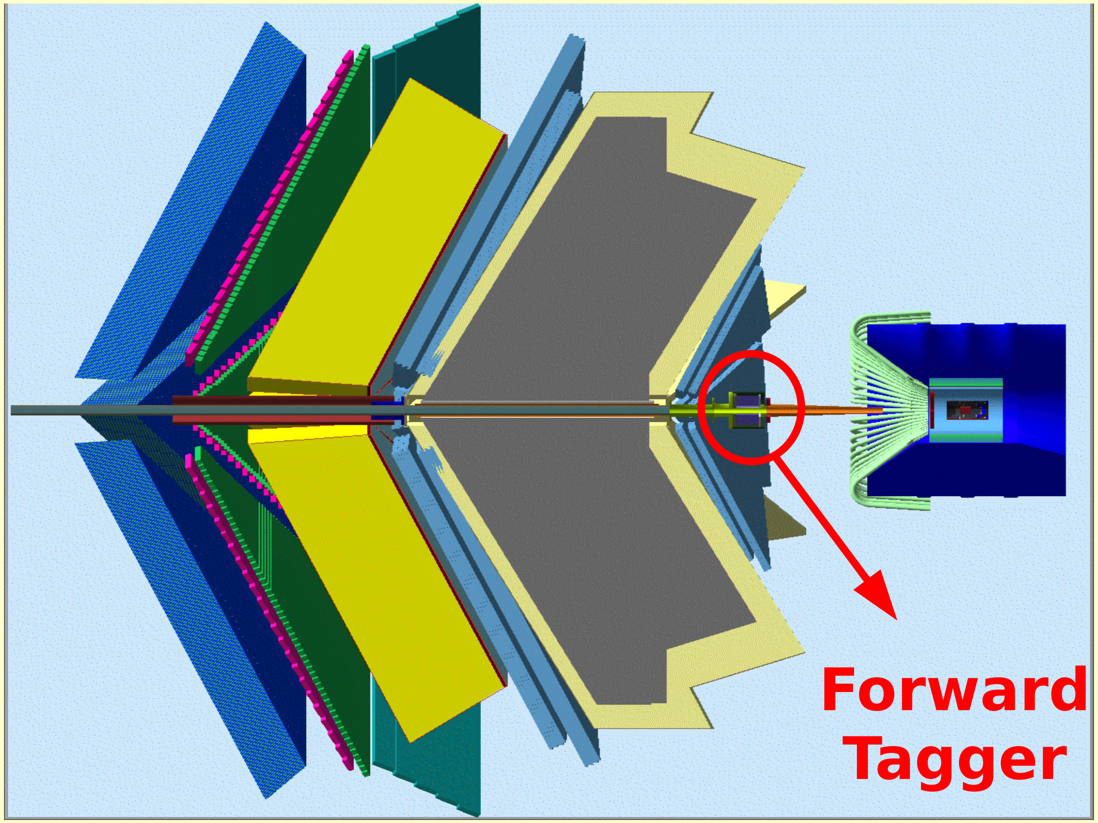
- 5T solenoidal field
- High pixel density (FW)
- 100-300 μm resolution
- Integrated in the CLAS12 base equipment

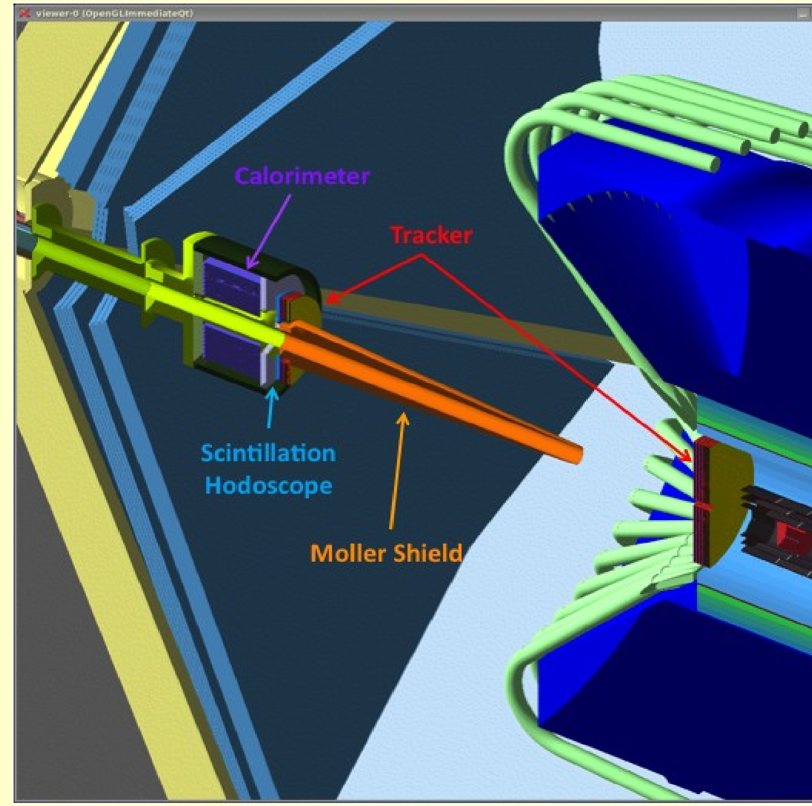


CLAS12-μM

The Forward Tagger in CLAS12

- Compatible with standard electron runs





- Photon detector for leading DVCS experiments
- Extend the CLAS12 coverage for neutrals at small angles

Photons and electrons can run in parallel!

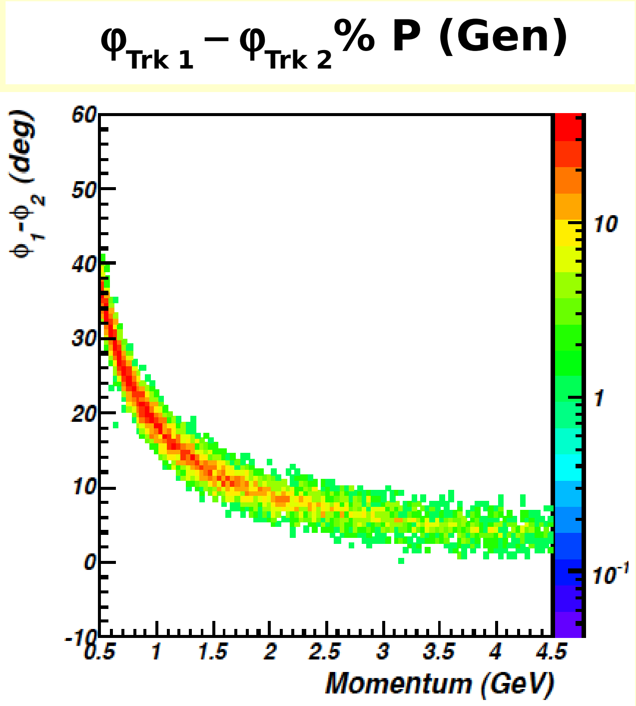
GEANT4 Simulations

FT (cal+hodo+trk) and W shield in GEMC

Tagged electrons

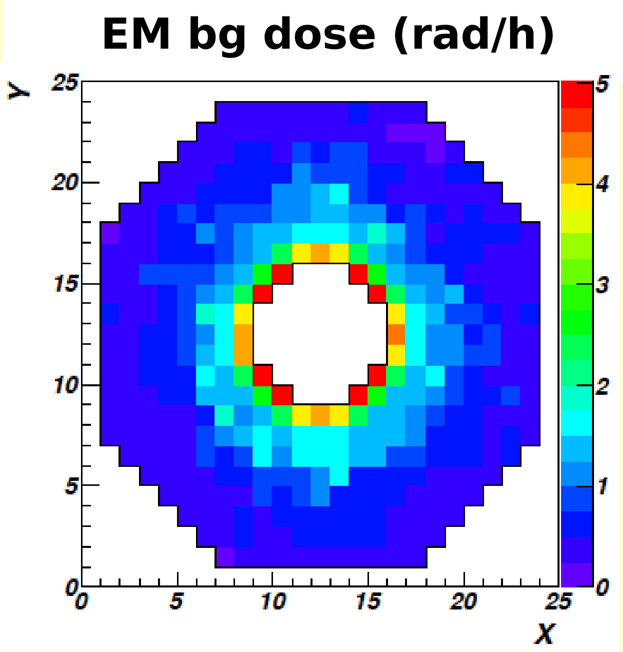
(E = 0.5 - 4.5 GeV)

- **Angular resolution ($\Delta\varphi \sim 2.8^o$, $\Delta\vartheta/\vartheta \sim 1.6\%$)**
- **Tracking and calorimeter efficiency**
- **Clusters reconstruction in calorimeter**



EM background

- **Effect on track-finding algorithm**
- **Effect on drift chamber occupancy**
- **Rates and radiation dose in the calorimeter**



Physics channel simulations

- **Evaluate CLAS12 acceptance for multiparticle final states**
- **Define resolution for exclusive channel selection (missing mass technique) and mass reconstruction**

Benchmark channels

$\gamma\, p \rightarrow n\, \pi^+\, \pi^+\, \pi^-$ $\quad$ $\gamma\, p \rightarrow p\, \eta\, \varphi$

$\gamma\, p \rightarrow n\, \eta\, \pi^+$ $\quad$ $\gamma\, p \rightarrow p\, K^+\, K^-\, \pi^0$

$\gamma\, p \rightarrow n\, Res \rightarrow\; n\, \pi^+\, \pi^+\, \pi^-$

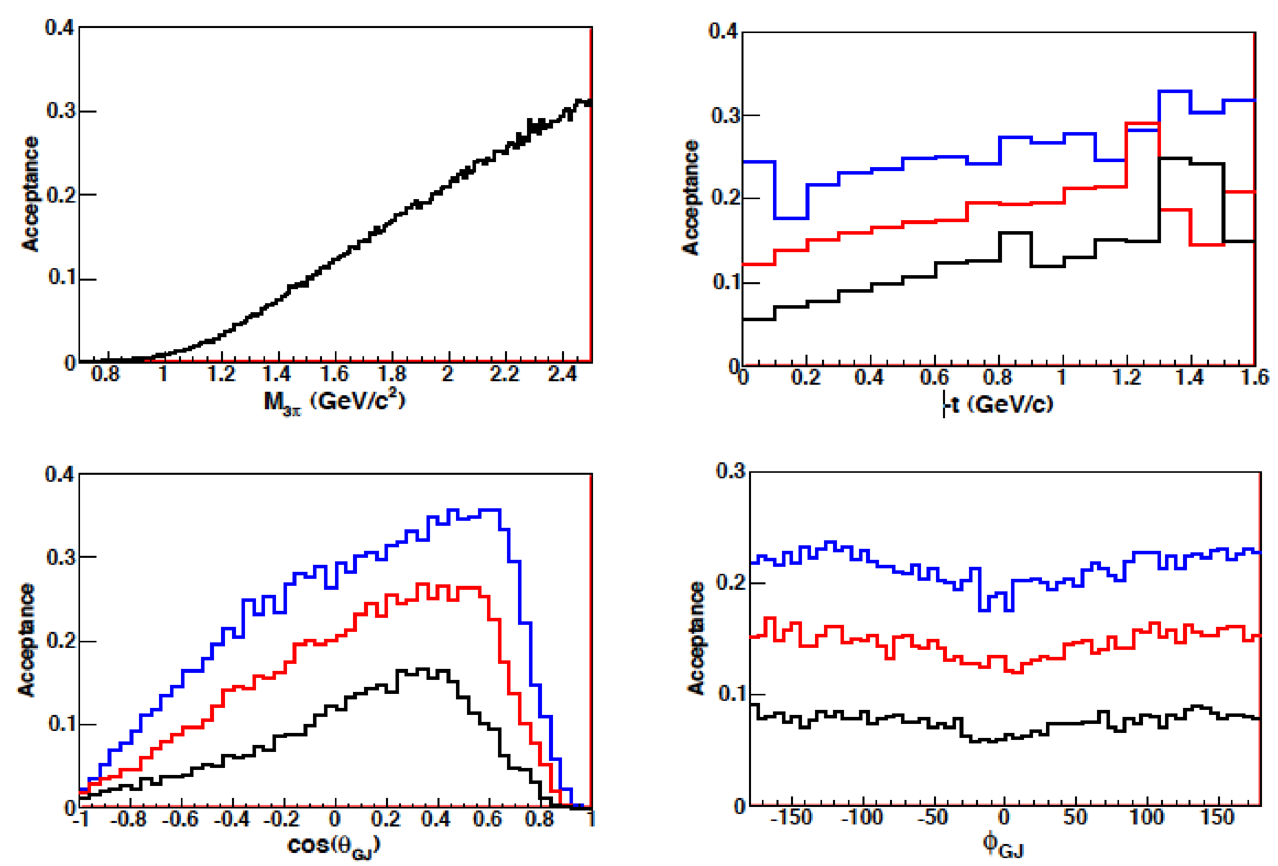
Acceptance (all 3 π det)

Resonance parameters

M=1.4 GeV, Γ=150 MeV

M=1.7 GeV, Γ=150 MeV

M=2.0 GeV, Γ=150 MeV



- **Extended kinematic coverage**
- **Flat acceptance in the meson rest frame**

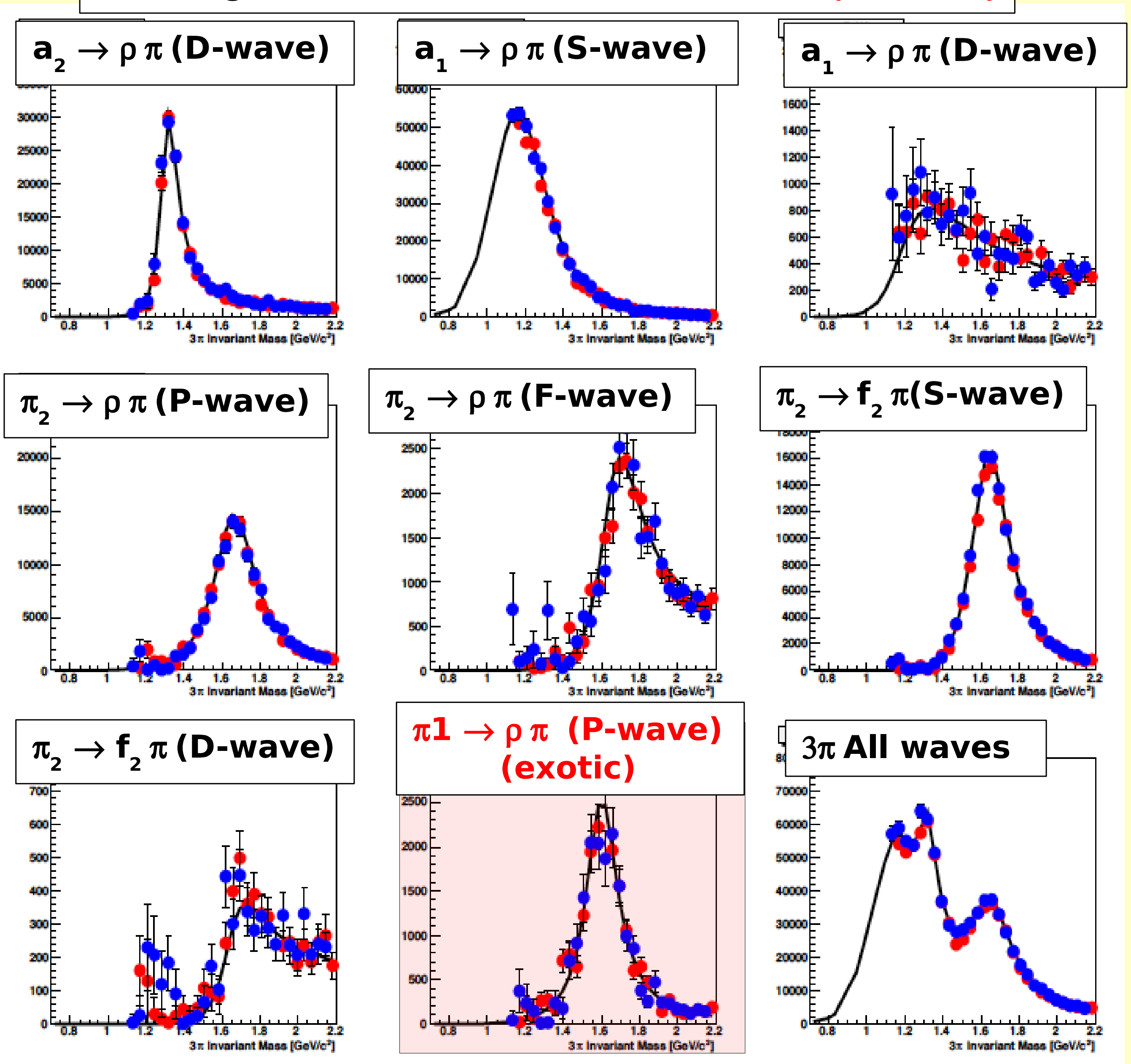
Partial Wave Analysis in CLAS12

$\gamma\, p \rightarrow n\, \pi^+ \pi^+ \pi^-$

- The process is described as sum of 8 isobar channels:
  - $a_2 \rightarrow \rho\,\pi$ (D-wave)
  - $a_1 \rightarrow \rho\,\pi$ (S-wave)
  - $a_1 \rightarrow \rho\,\pi$ (D-wave)
  - $\pi_2 \rightarrow \rho\,\pi$ (P-wave)
  - $\pi_2 \rightarrow \rho\,\pi$ (F-wave)
  - $\pi_2 \rightarrow f_2\,\pi$ (S-wave)
  - $\pi_2 \rightarrow f_2\,\pi$ (D-wave)
  - $\pi 1 \rightarrow \rho\,\pi$ (P-wave) (exotic)
- Amplitudes calculated by A.Szczepaniak and P.Guo
- CLAS12 acceptance projected and fitted
- PWA is stable against CLAS12 acceptance/ resolution distortion

PWA in CLAS12 is feasible !

Black = generated blue/red = fit t=0.2 GeV^2 (0.5 GeV^2)



Partial Wave Analysis in CLAS12

The photon linear polarization is necessary to extract production mechanisms and filter-out specific processes

$\pi 1 \rightarrow \rho\, \pi$
P-wave (exotic)

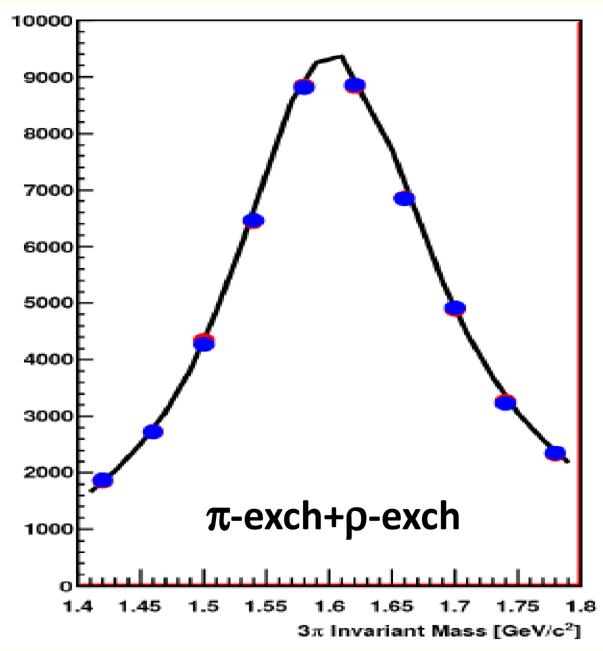
Two possible production mechanisms

π-exchange (un-natural parity)
ρ-exchange (natural parity)

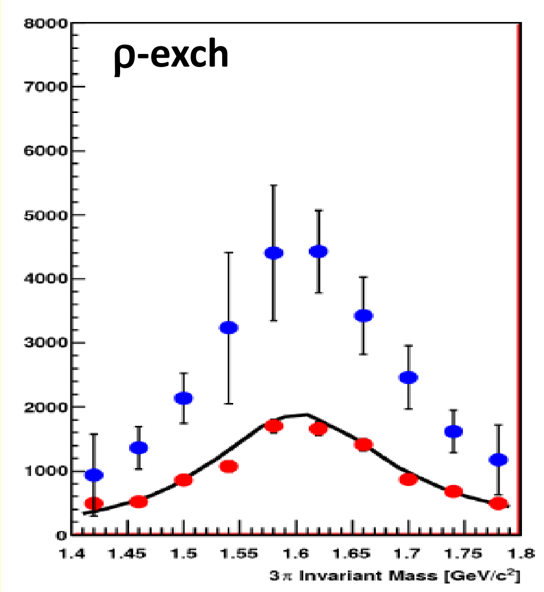
In red: fit result including the linear polarization

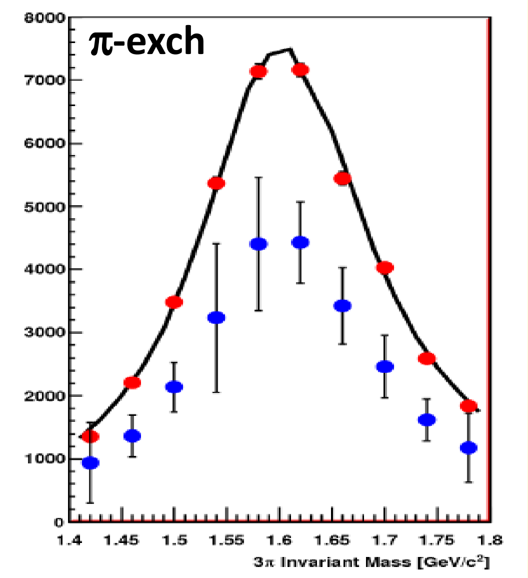
In blue: fit result ignoring the polarization

The sum of the two can be fit with or w/o polarization



Including linear polarization in the fit the two exchanges can be reliably separated





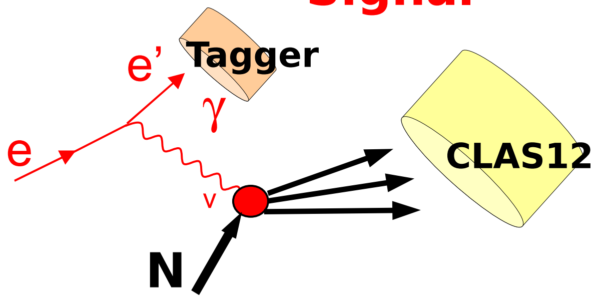
Trigger and rates

Hardware trigger:
Coincidence of an electron in FT and 3-prong event in CLAS12

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

Inelastic electro-production

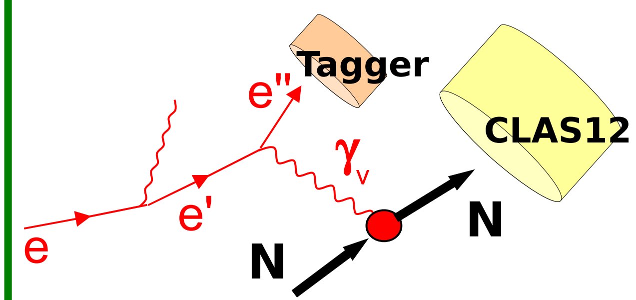
Signal

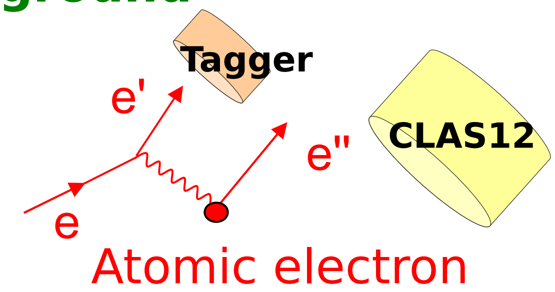


R~7 kHz

Elastic radiative tail **Moeller scattering**

Background





R~ 180kHz

	Hadronic rate		Random coincidences	
DAQ FT/CLAS12 online trigger rate	=($R \cdot \varepsilon$ (3prong in CLAS12)	+	$2\ \Delta t\ R_{FT}\ R_{CLAS12}$	) ~ 2 kHz
	~ 1.3 kHz		~ 0.9 kHz	

DAQ standard electro-production trigger rate ~ 2kHz

Low Q^2 e-production and standard e-production can run together (Max CLAS12 DAQ rate ~10 kHz)

Beam time request and expected results

Production

Cross sections

$\sigma(\gamma\, p \rightarrow p\ 3\pi)$ ~ 10 μb
$\sigma(\gamma\, p \rightarrow p\ \eta\ \pi)$ ~ .2 μb
$\sigma(\gamma\, p \rightarrow p\ K\ K\ \pi)$ ~ 10 nb
$\sigma(\gamma\, p \rightarrow p\ \varphi\ \eta)$ ~ 10 nb

Assuming exotic meson production ~1%

Yield/Mass bin to run PWA ~5000 ev

Production beam time:

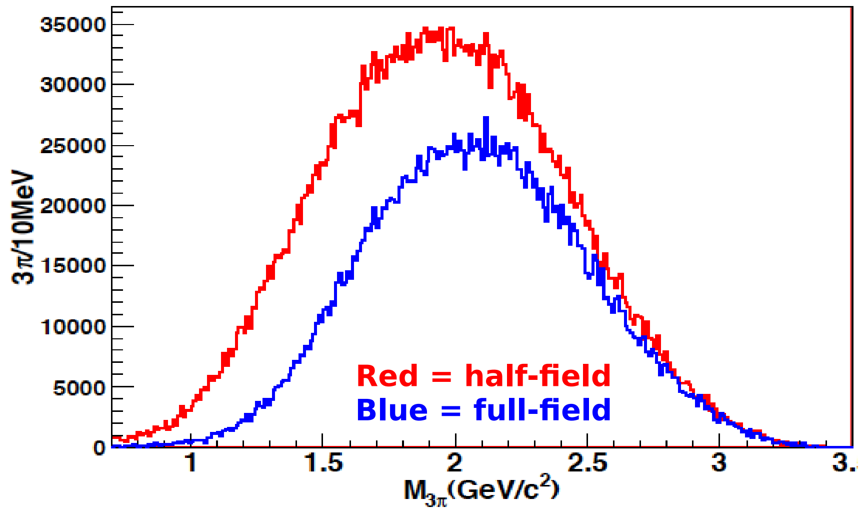
80 days

Can be scheduled in parallel to already approved electron runs

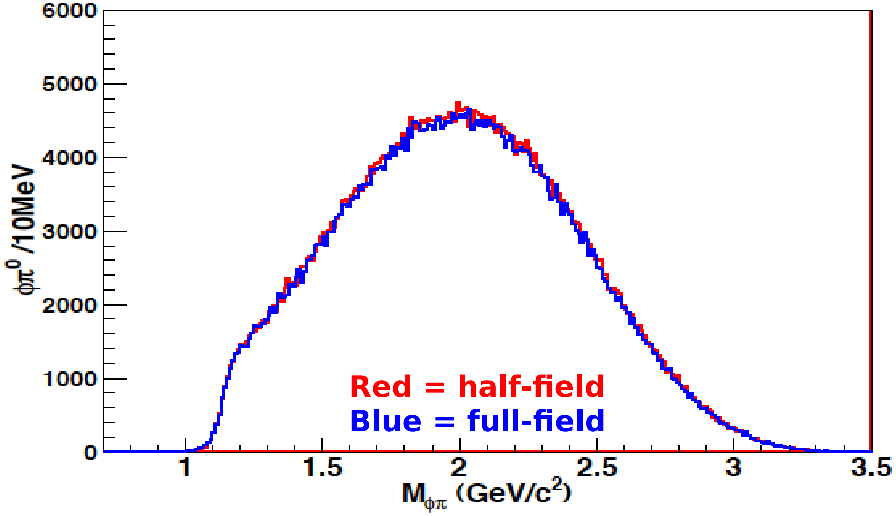
Commissioning and calibration

- **15d FT commissioning**
- **20d+4d low luminosity (L_e~5 10^{33} cm^{-2} s^{-1}) & minimum bias trigger (2-prongs)**

Expected yield 20d run
$\gamma\, p \rightarrow\ (n)\ \pi^+\ \pi^+\ \pi^-$



Expected yield 80d run
$\gamma\, p \rightarrow\ p\ (K^-)\ K^+\ \pi^0$



Meson spectroscopy with low Q^2 electron scattering in CLAS12

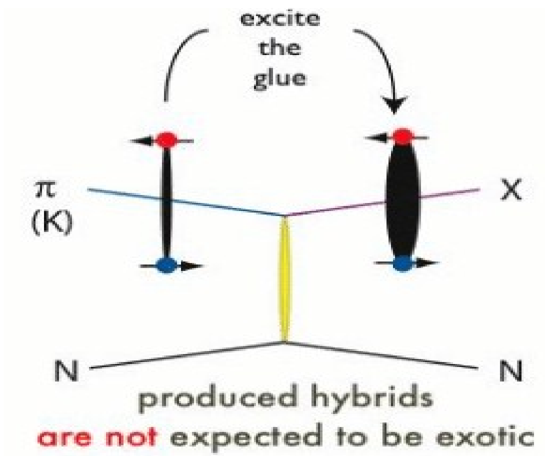
- Exotics and strangeness-rich mesons can be studied in the Hall-B with the CLAS12 detector
- Low Q^2 electron scattering is a complementary technique to the Hall-D coherent Bremsstrahlung
- New equipment: Forward Tagger (calorimeter + hodoscope +tracker) compatible with standard operation of CLAS12
- Excellent CLAS12 resolution and particle Id
- Complete PWA feasible in CLAS12
- This experiment will add further strength to JLab in hadron spectroscopy

With a beam-time of 80d (+39 commissioning) about 5000 ev/M-bin for the rarest channels are collected

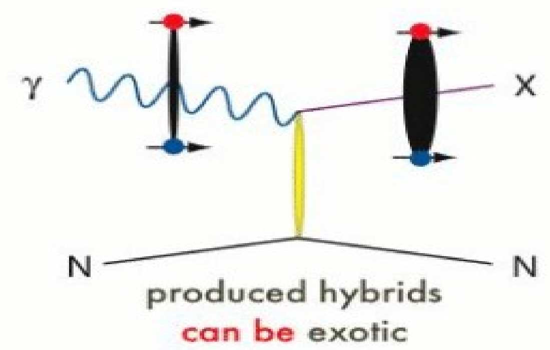
Back up slides

Why photoproduction?

- Photoproduction: exotic J^{PC} are more likely produced by S=1 probe



Need spin-flip for exotic quantum number



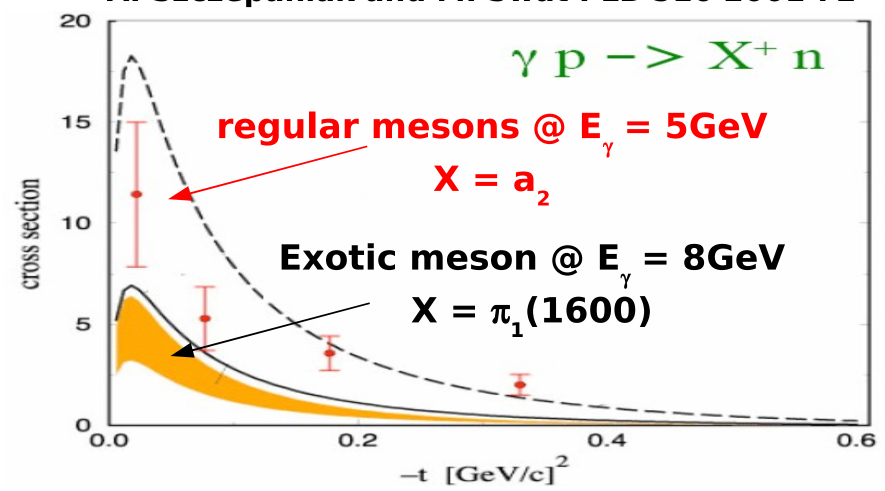
No spin-flip for exotic quantum number

- Linear polarization acts like a filter to disentangle the production mechanisms and suppress backgrounds

A. Afanasev and P. Page et al. PR A57 1998 6771
A. Szczepaniak and M. Swat PLB 516 2001 72

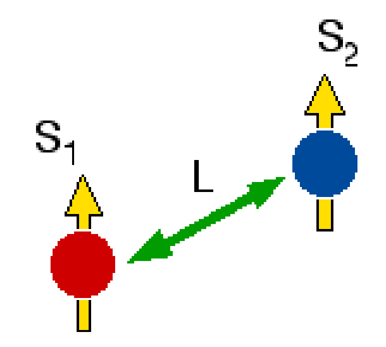
- Production rate for exotics is expected comparable as for regular mesons

Few data (so far) but expected similar production rate as regular mesons



Hybrid meson quantum numbers

★ **Search for mesons with 'exotic' quantum numbers (not compatible with quark-model)**

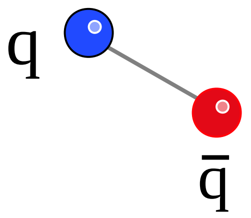


$S=S_1+S_2$ $J= L+S$ $P = (-1)^{L+1}$ $C= (-1)^{L+S}$

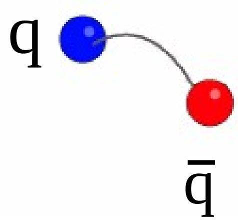
Not-allowed: $J^{PC} = 0^{--}, 0^{+-}, 1^{-+}, 2^{+-} \ldots$

Unambiguous experimental signature for the presence of gluonic degrees of freedom in the spectrum of mesonic states

Normal meson:
flux tube in ground state
m=0
$CP=(-1)^{S+1}$

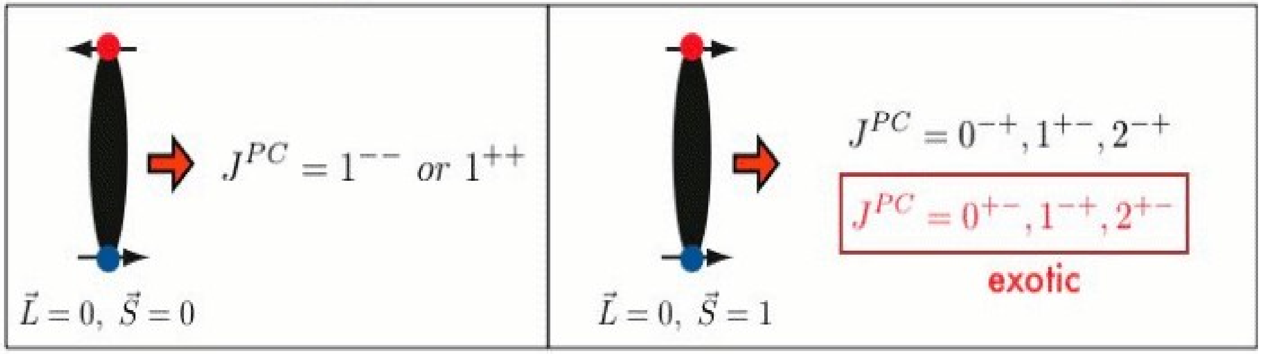


Hybrid meson:
flux tube in excited state
m=1
$CP=(-1)^{S}$



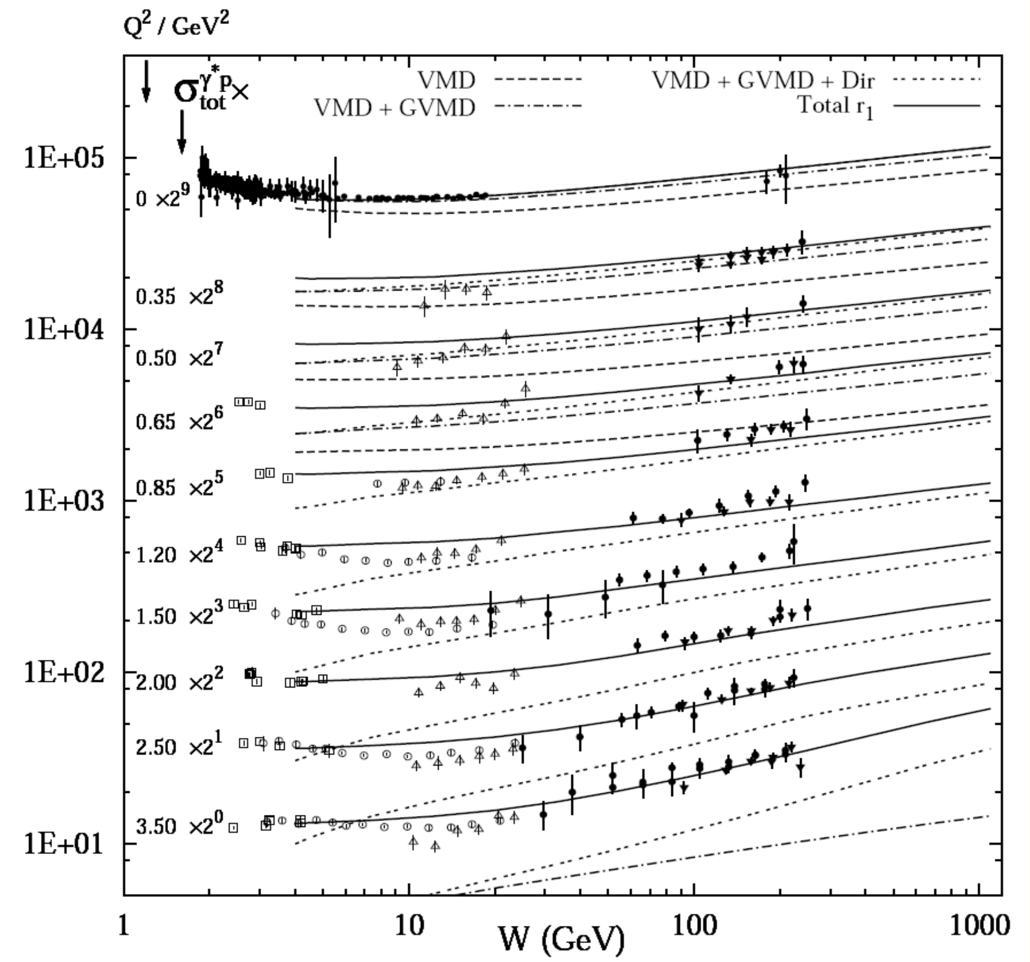
Flux tube J^{PC} 1^{-+}, 1^{+-}

Combine excited glue quantum number with those of the quarks



Q^2 dependence of the Xsec

Studies at large W (~100GeV) show a smooth transition between $Q^2=0$ and $Q^2\neq0$



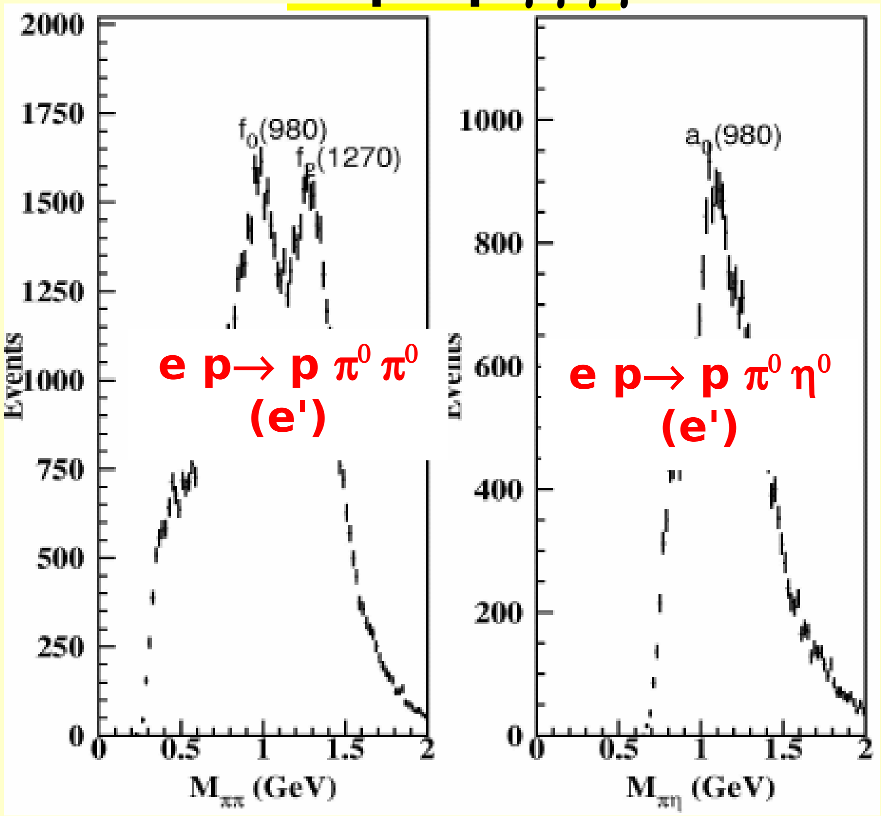
Well known technique used in hep

$Q^2 < W^2$

COMPASS	**<1 GeV^2**	**$\langle Q^2\rangle \sim 10^{-1}$ GeV^2**
ZEUS:	**~ 10^{-7} – 0.02 GeV^2**	**$\langle Q^2\rangle \sim 5\ 10^{-5}$ GeV^2**
H1:	**<2 GeV^2**	

Tested in CLAS

e p→ p γγγγ X



Bright meson peaks show up
The technique works!

Meson spectroscopy with photons at JLab-12GeV

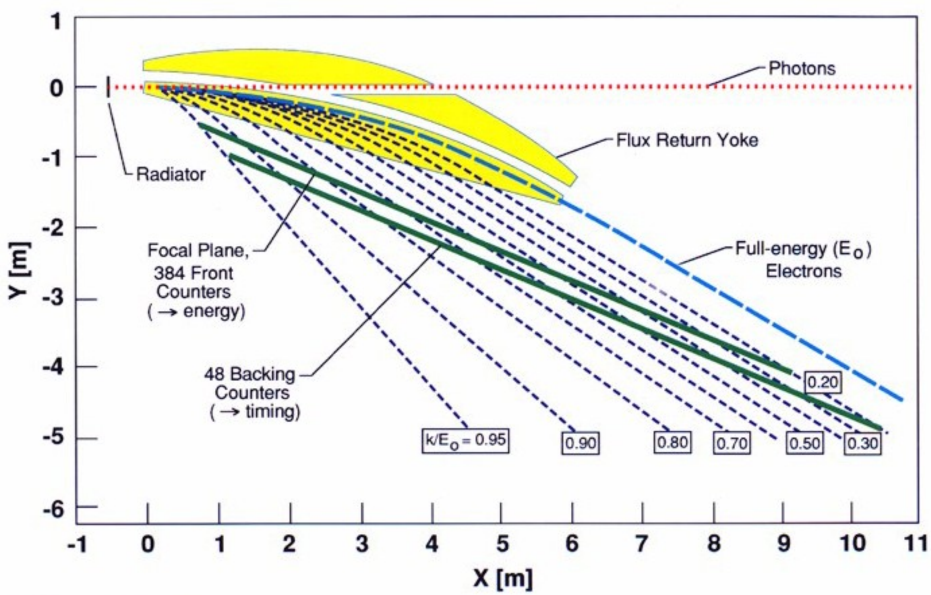
Photon beam requirement

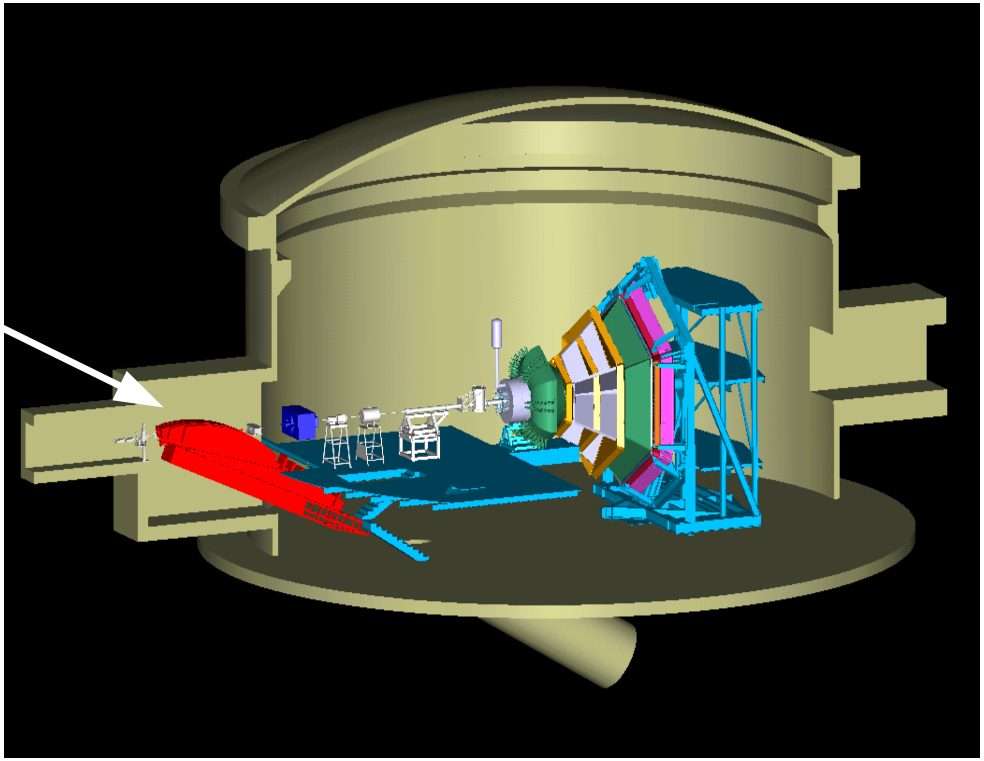
- High luminosity
- Tagger
- Linear polarization

With a 12 GeV electron beam only few choices

1) Bremsstrahlung
2) Low Q^2 electroprod

The Hall-B real photon tagger





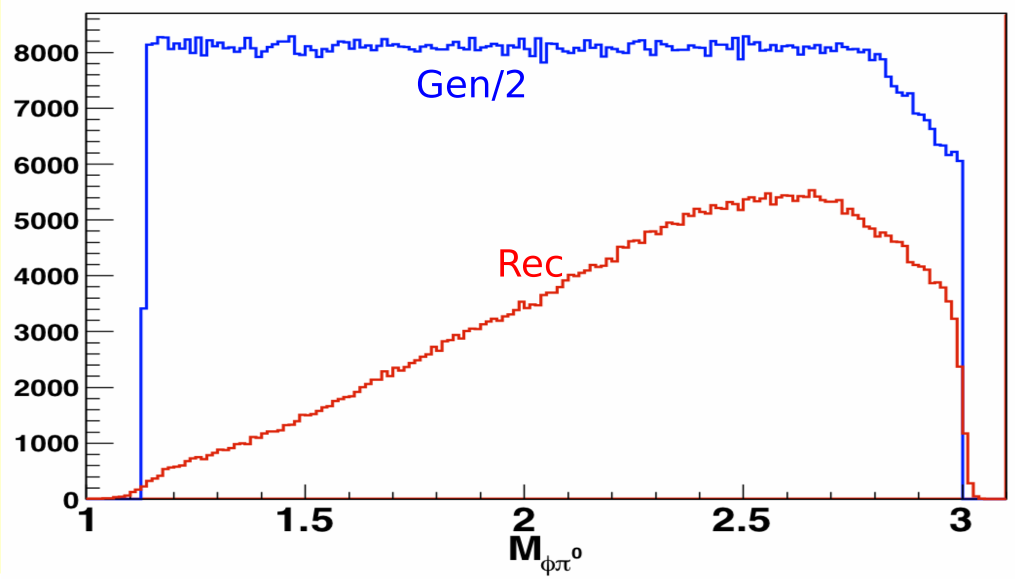
The Hall-B existing dipole magnet is unable to deflect the 11 GeV primary beam on the existing beam-dump

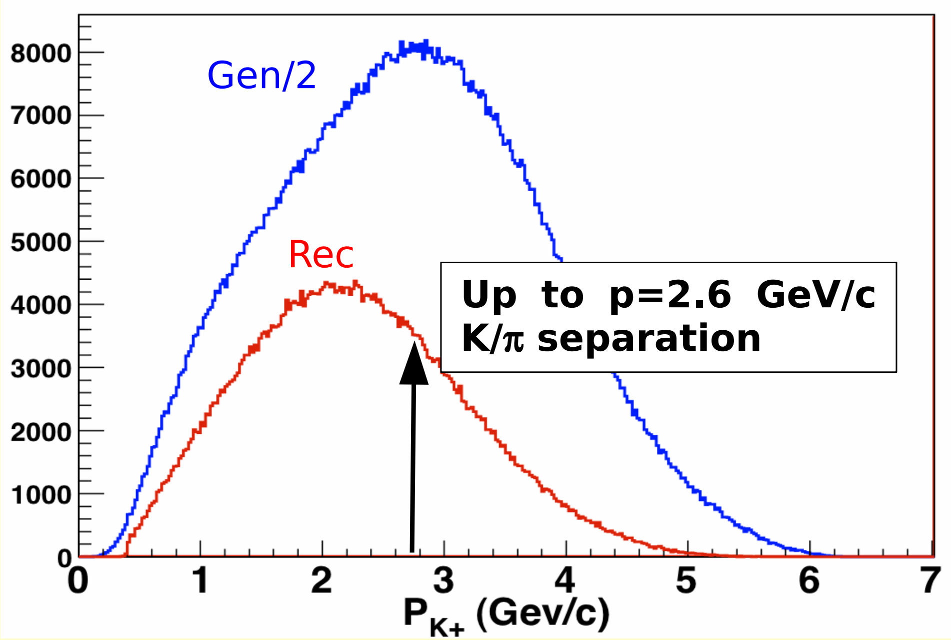
Search for strangeonia in CLAS12

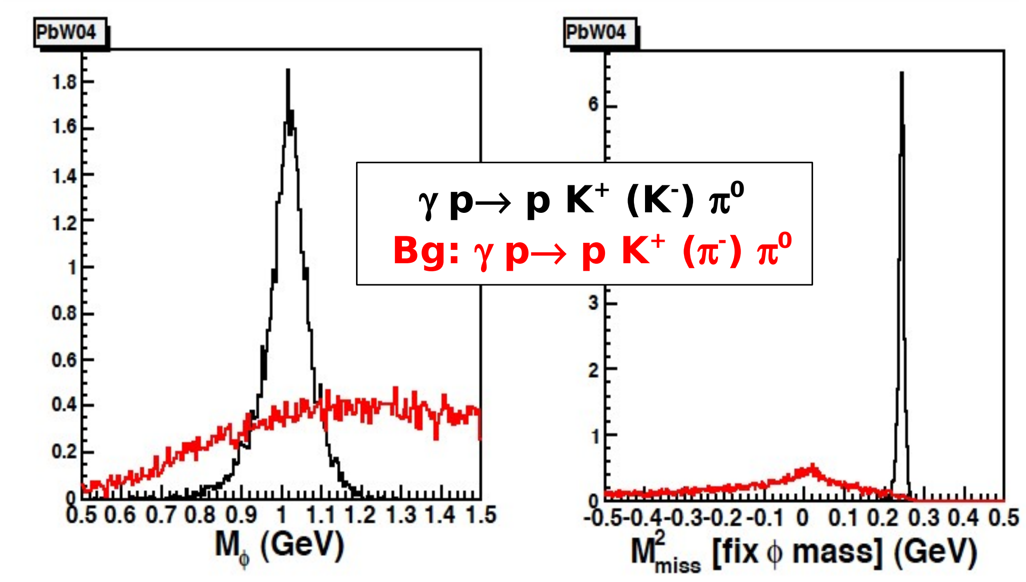
CLAS12 simulations

$\gamma\, p \rightarrow p\ C(M=1480,\ \Gamma=130\ \mathrm{MeV}) \ \rightarrow\ p\ \varphi\, \pi^0 \rightarrow\ p\ K^+(K^-)\ \gamma\gamma$

- Unusual BR in $\varphi\pi$ (OZI suppressed)
- $J^{PC}=1^{--}$ $\sigma \sim 10$nb
- Tetra-quarks or hybrid
- CLAS12 acceptance ~ 10%
- High-p K id relies on kin-fit
- K/π separation for p>2.6 GeV/c highly desirable!





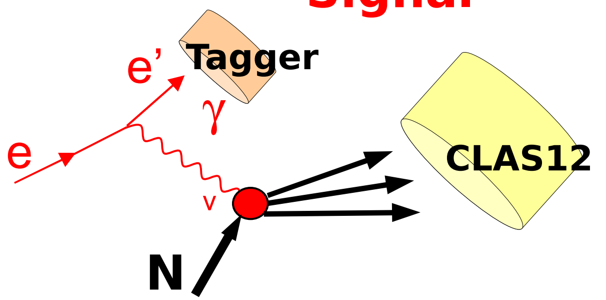


Rates in the FT and CLAS12

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

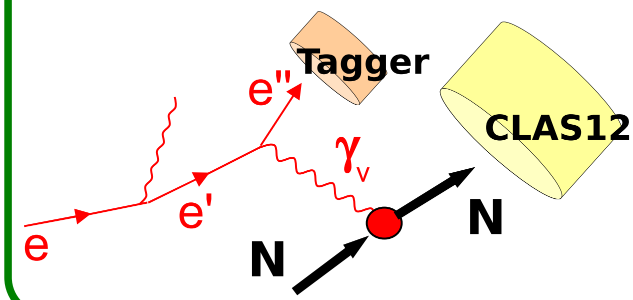
Inelastic electro-production

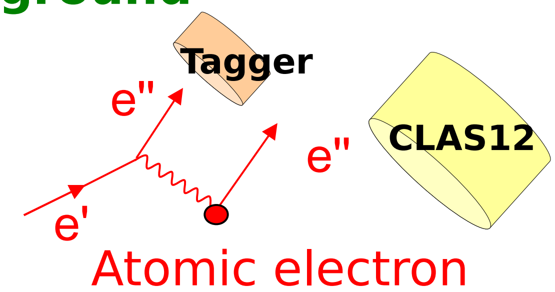
Signal



Elastic radiative tail **Moeller scattering**

Background





		Signal	Rad elastic	em bg	CLAS12 hadrons	RND ($\Delta t \sim 50ns$)
FT	All e' energy	60kHz	70kHz	50MHz		$2\ \Delta t\ R_{FT}\ R_{CLAS12}$ = 2 50ns 250kHz 36kHz
FT	$0.5<E_{e'}<4.5$ GeV	7 kHz	40kHz	180kHz		
All e' energy/ $0^o<\vartheta<5^o$ ε(3ch in CLAS12)~0.1					36kHz	
FT/CLAS12 trigger ε(3ch in CLAS12)~0.2		1.3kHz	0	0	1.3kHz	0.9kHz

DAQ FT/CLAS12 online trigger rate ~ 2·(1.3kHz + 0.9kHz) ~ 4 kHz
DAQ standard electro-production trigger rate ~ 2·(2kHz) ~ 4 kHz

Partial Wave Analysis

✯ **The development of robust PWA techniques is a crucial step for the succesful completion of any meson spectroscopy program**

✯ **Advancements in detectors, beam and experimental techniques are leading to a high precision and high statistics data sets**

Are the prently available PWA tools adequate for the new data that are and will be produced?

Workshop on Hadron Spectroscopy
INT - Seattle, November 9-13 2009
Organizers: M. Battaglieri, C. Munoz Camacho, R. De Vita, J. Miller, A.P. Szczepaniak

- **~ 40 participants from the theoretical and experimental community**
- **address open issues in experimental techniques, pwa, and theoretical interpretation**
- **interest from the theory community to work with experimentalists to develop more sophisticated analysis approaches, going beyond the isobar model**
- **white paper being written**

Next meeting:

Workshop on Amplitude Analysis in Hadron Spectroscopy
ECT* - Trento, January 24-28 2011
Organizers: C. Hanhart, M. Pennington, E. Santopinto, A.P. Szczepaniak (coordinator), U. Wiedner

Calorimeter options

- Radiation hardness
- light yield (cooling?)
- timing
- temperature dependence
- Magnetic field effect
- light read-out (APD/SiPM)

- **Homogeneous (crystals)**

EM shower: ionization energy of charged particles (electrons)

Longitudinal size:

Radiation lenght X_0 (e loses 1-1/e E)

~ 180 A/Z^2 (gr/cm^2)

Transverse size:

Moliere Radius R_M (90% of shower)

~ 7 A/Z (gr/cm^2)

- **PbWO**
  Fast, rad hard, few light, well known
- **LSO/LYSO**
  Quite fast (8x), more light (100x)
  poorly known
- **LaBr**
  Fast, a lot of light (600x), expensive

PbWO4

τ_{Decay} ~ 6.5 ns

R_M ~ 2.1 cm

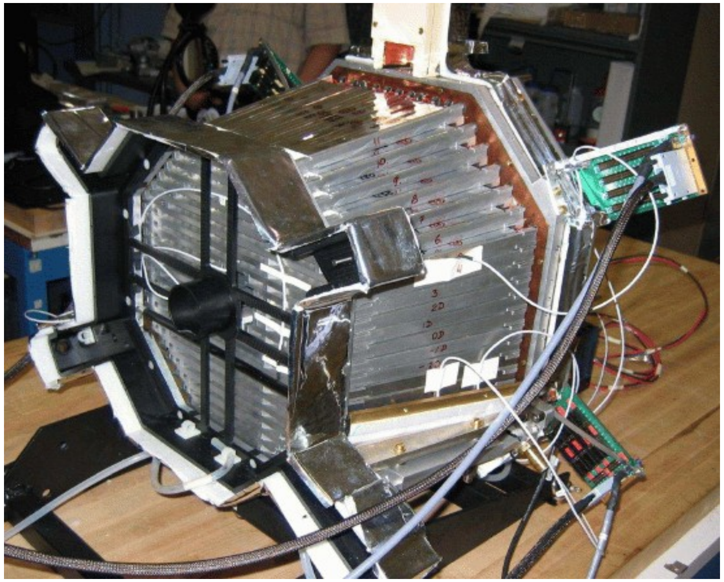
ρ ~ 8.3 g/cm^3

X_0 ~ 0.9 cm

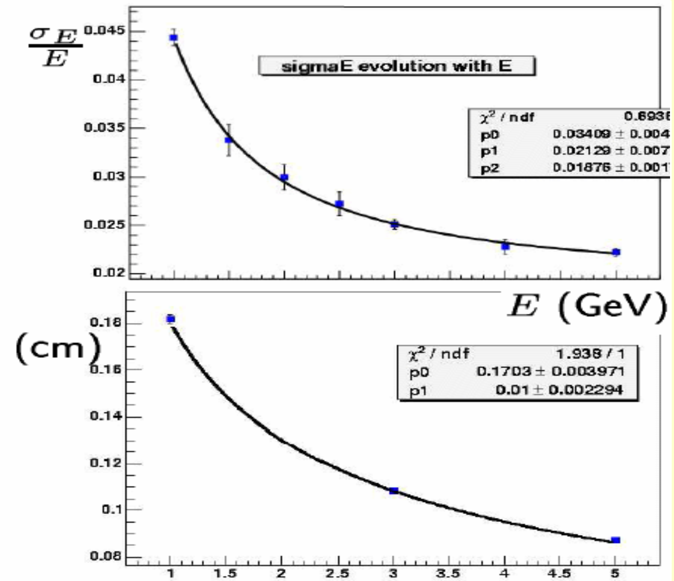
light yield 0.3% (LY NaI(Tl))

CMS(LHC)	ECAL
ALICE (LHC)	PHOS
CLAS (JLab)	IC
PANDA (GSI)	EMC

CLAS Inner Calorimeter



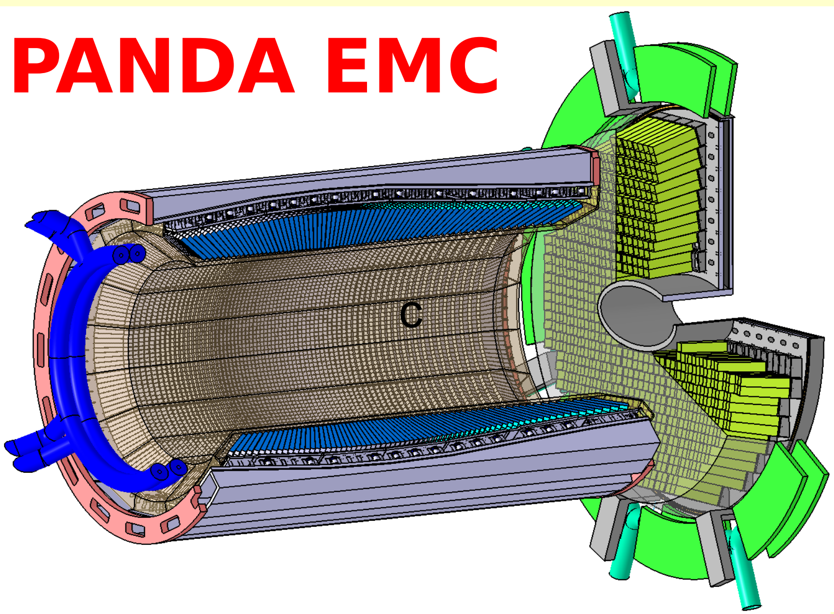
- 424 PbWO4 crystals
- L = 16 cm = 17 X_0
- Front size 1.3x1.3 cm^2
- Back size 1.6x1.6 cm^2
- Controlled Temperature (0.1 ^{0}C)
- APD readout



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

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

PANDA EMC

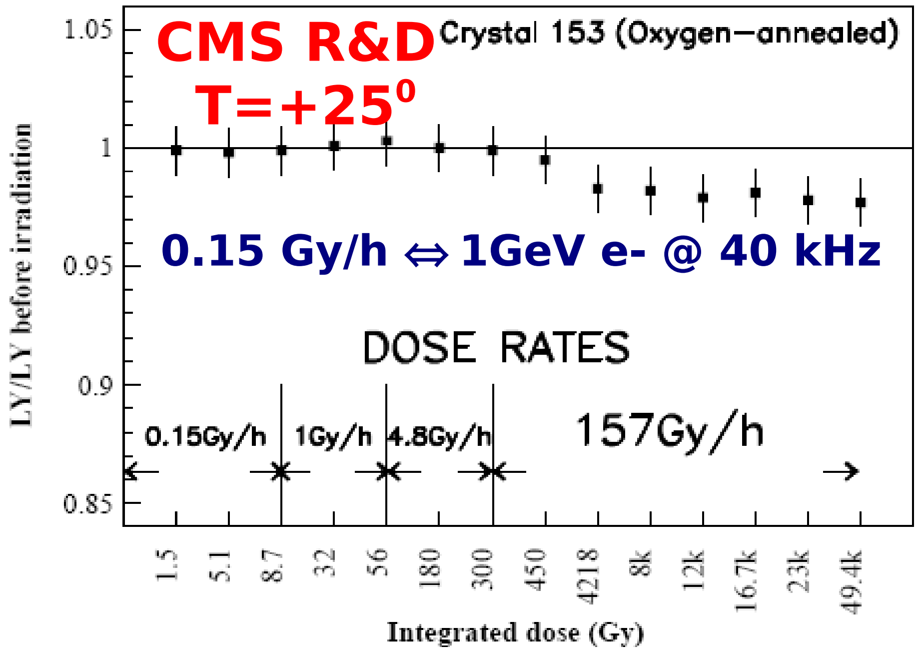


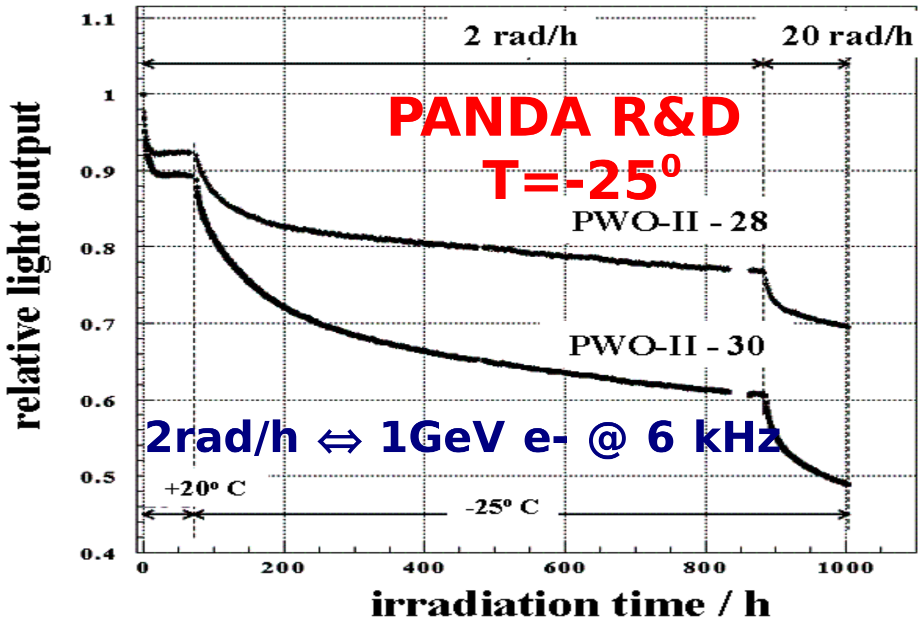
- 16k PbWO-II crystals
- Size = 2 x 2 x 20 cm3 (23 X_0)
- LY = 20 phe/MeV (80 phe/MeV @ -25^{0}C)
- APD readout
- Resolution (2/√E ⊕ 1)%

PbWO4 Radiation Hardness

CMS R&D

- Damage can only be attributed to em interaction (insensitive to n)
- Radiation does not affect the scintillation mechanism
- Radiation damage affects the crystal's transparency (colour centers)
- Irradiation does not change the longitudinal uniformity
- The loss in light is proportional to the dose rate





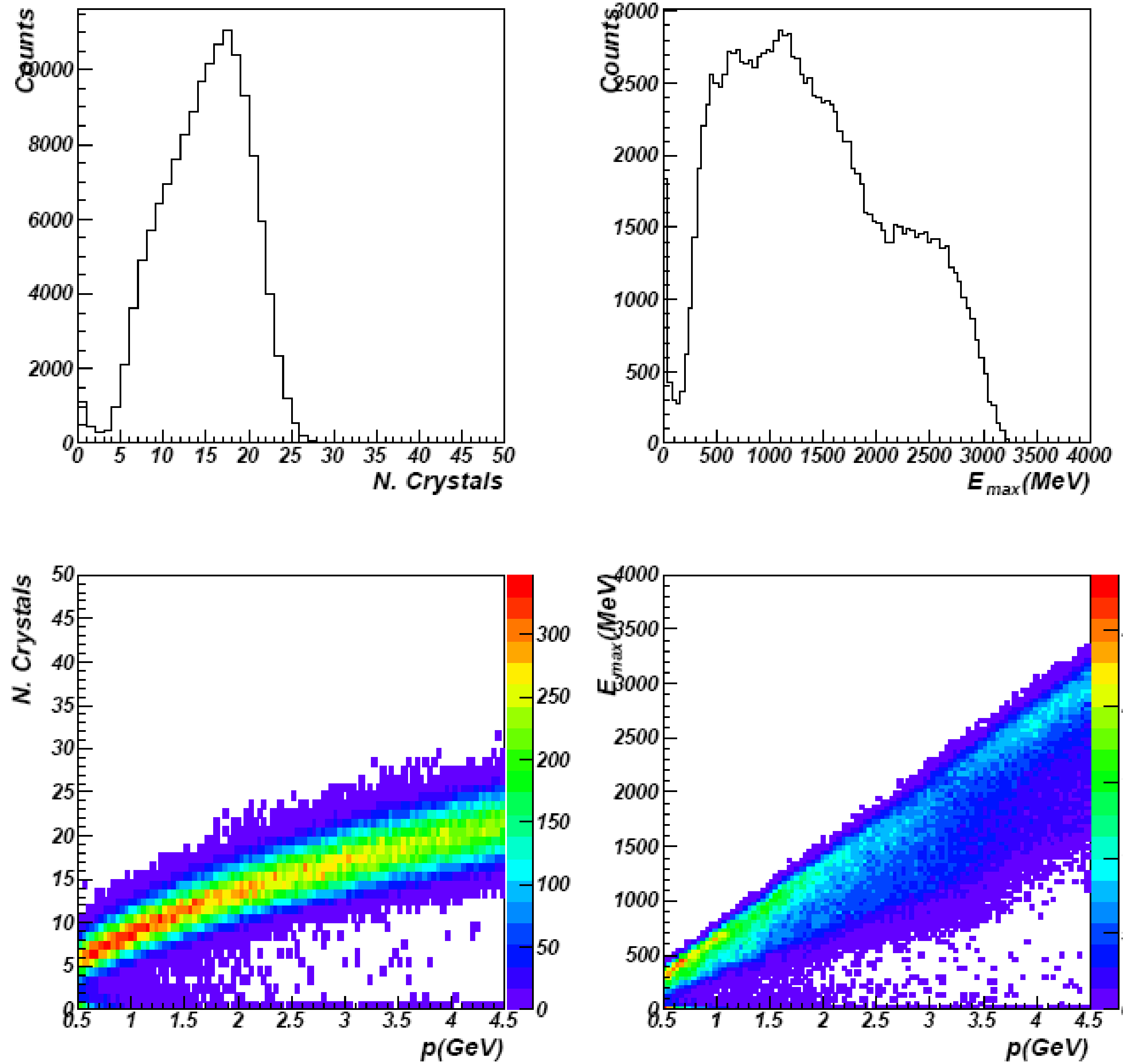
PbWO is almost insensitive to EM background but this does not hold for low T

GEANT4 Simulations: Calorimeter

ELECTRON CLUSTERS

Average number of crystals above the 10 MeV threshold of the order of 15

Highest energy deposition in the cluster hundreds of MeV to GeV

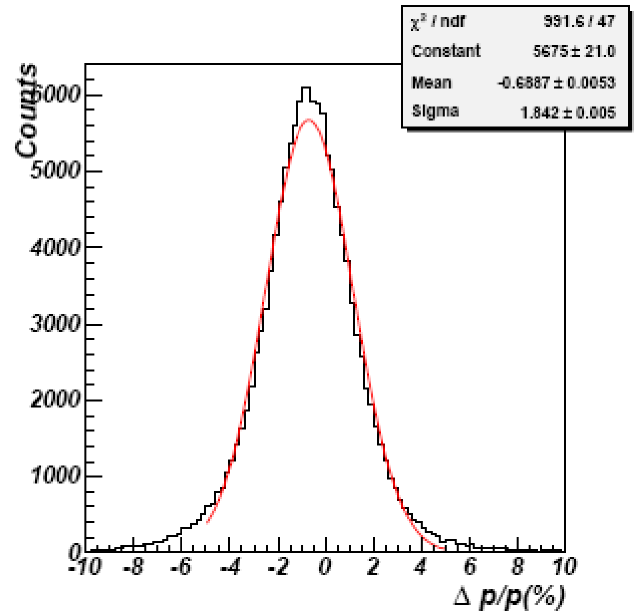


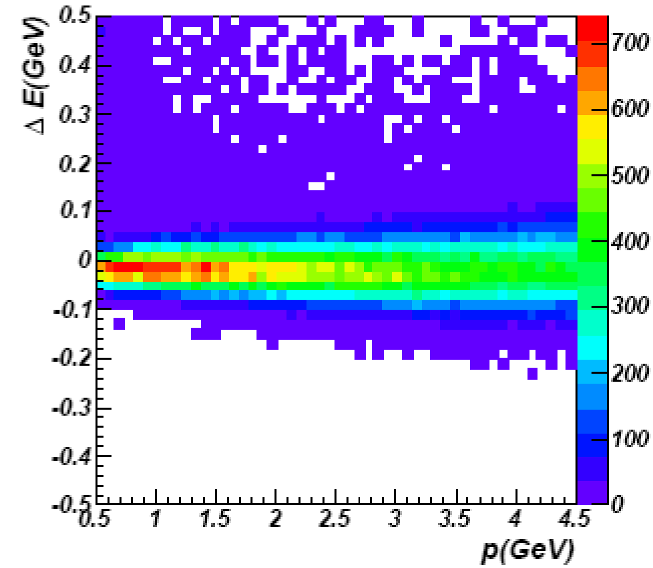
GEANT4 Simulations: Calorimeter

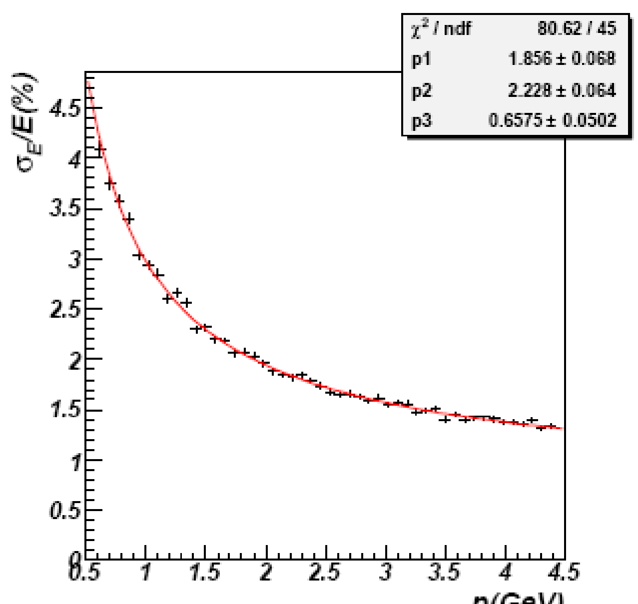
ENERGY RESOLUTION

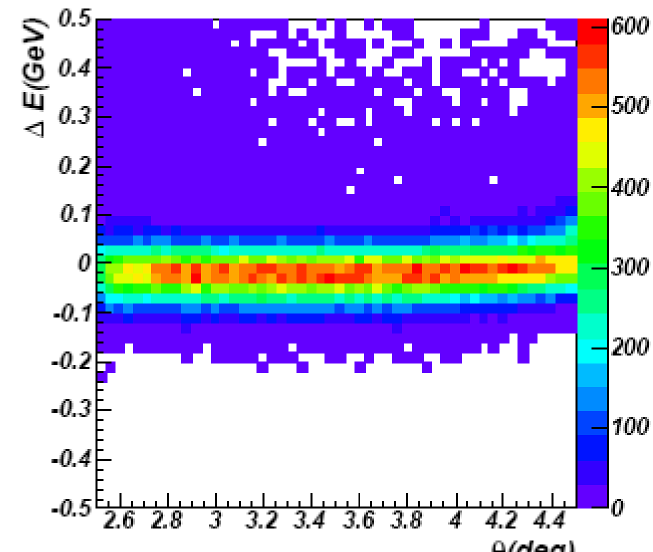
Overall energy resolution for the kinematic of interest is about 3% @ 1GeV

Energy resolution is independent on polar angle and improves as a function of energy









GEANT4 Simulations: Tracker

2 PLANE TRACKING

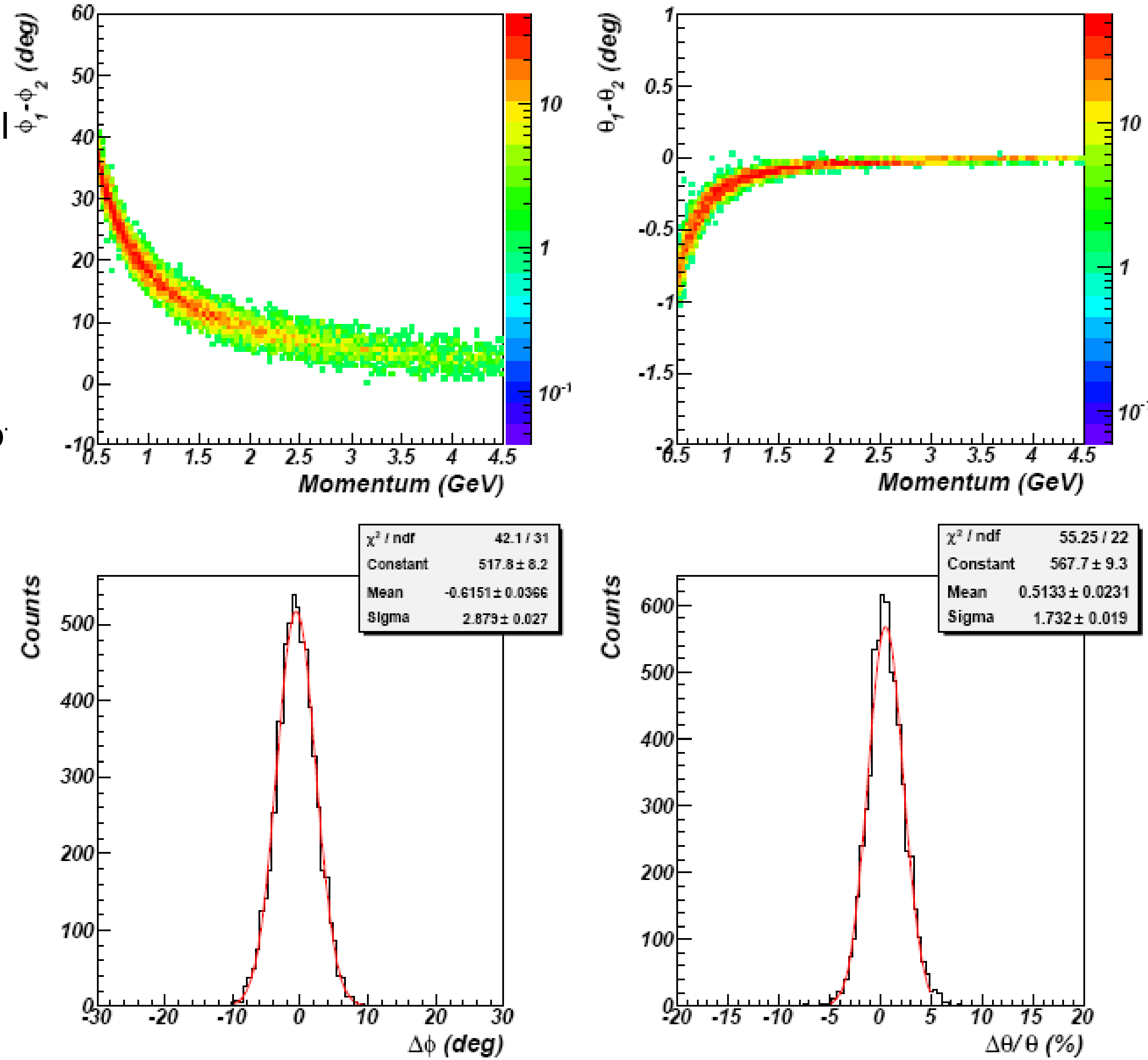
Charged particles emitted at smal angles undergo a rotation in phi because of the solenoid field

The size of the rotation depends on the momentum

Small effect on polar angle excep for low momenta (<1 GeV)

Expected angular resolution assuming 200 µm spatial resolution is
$\sigma(\phi) \approx 2.8°$
$\sigma(\theta)/\theta \approx 1.7\%$

These are conservative values because the calorimeter information on energy and hit position are not used



GEANT4 Simulations: photons

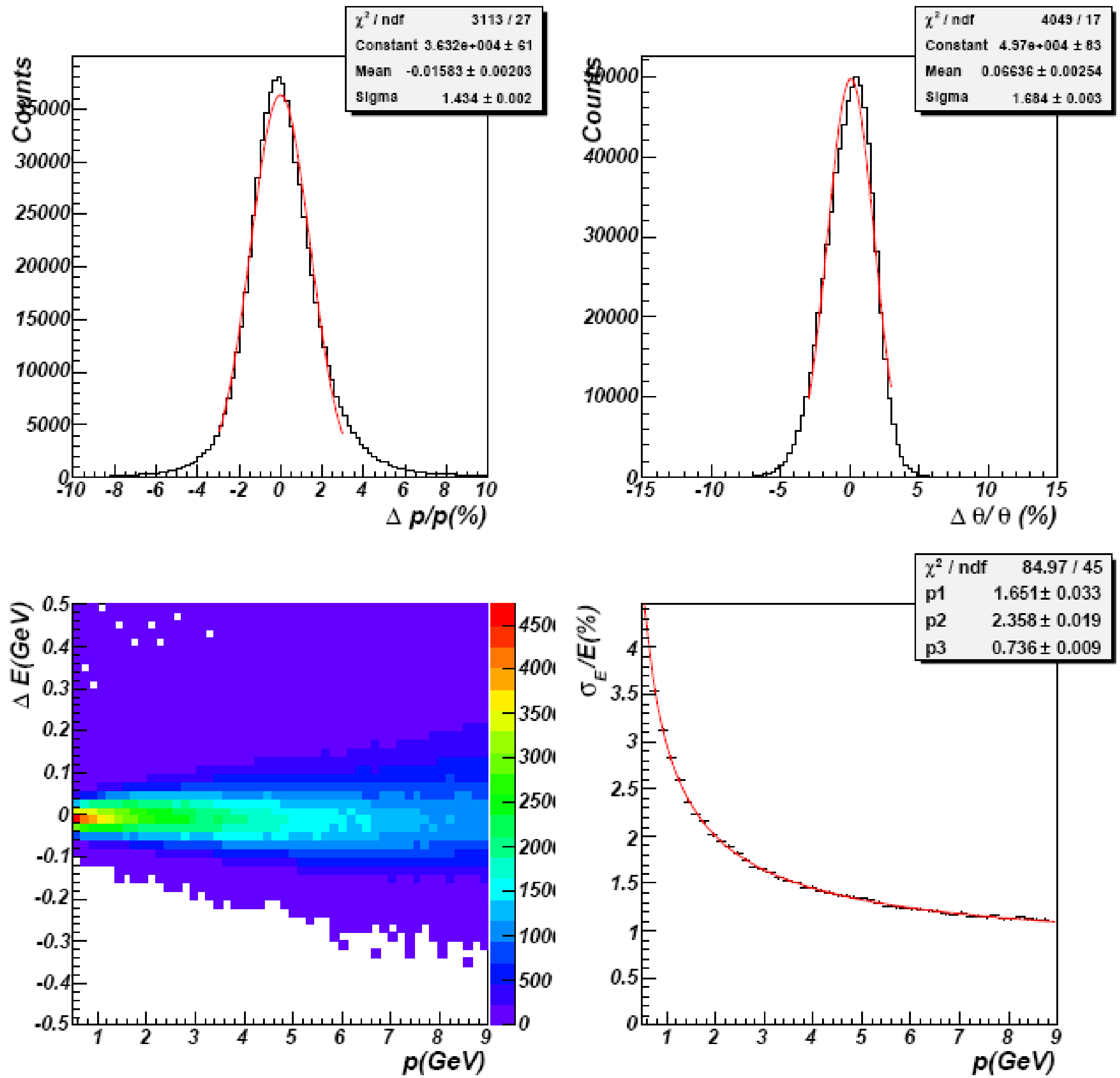
RESOLUTIONS FOR PHOTON DETECTOIN

Photon from 500 MeV to 9 GeV were generated in the angular range of the FT

Cluster in the calorimeter were reconstructed as for electrons

The energy resolution varies from about 2.8% at 1 GeV to 1% at 9 GeV

The angular resolution is about 1.7%



Responses

TAC Comments (I)

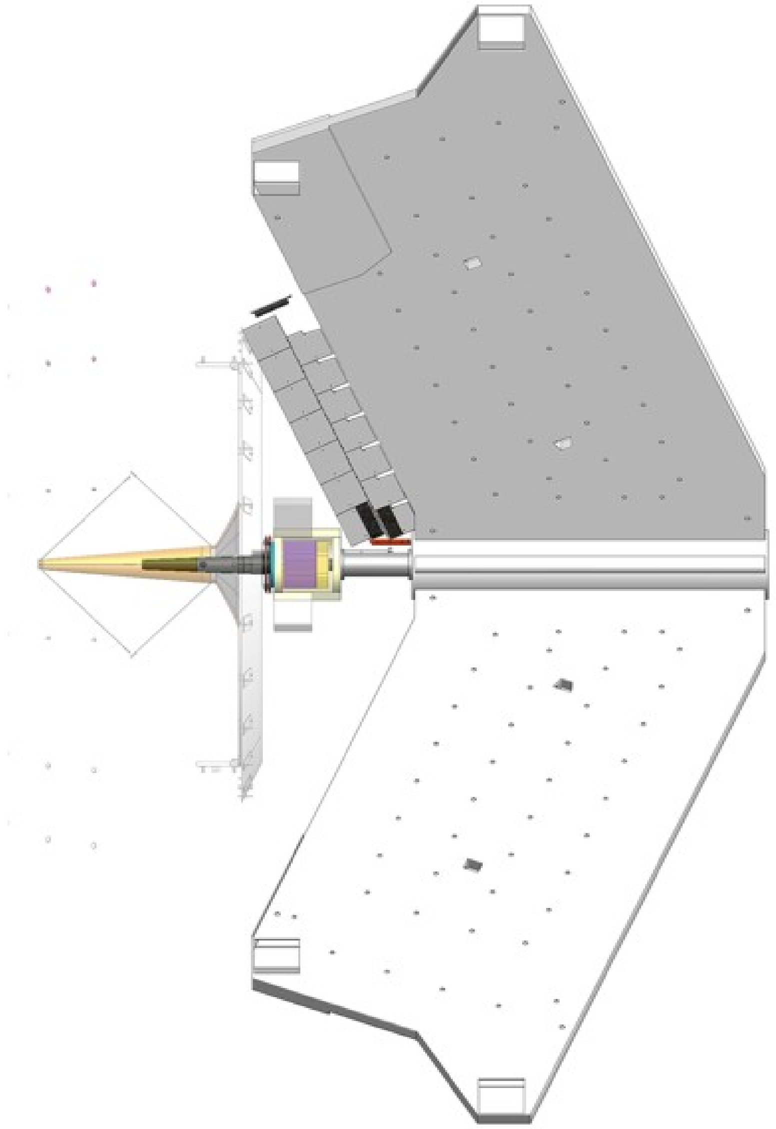
1) The FT is not part of the base equipment and will likely be supplied by the proposers of the experiment. Also, construction of the FT is not part of the overall 12GeV project schedule. This detector must be incorporated in a densely populated area full of readout electronics and cabling. To avoid interference with other CLAS12 detector components the FT must become part of the overall design of the entire space between the HTCC and the region I drift chamber system. Decisions on design options must be made as soon as practical to allow the fully engineered integration of the FT into the overall CLAS12 design.

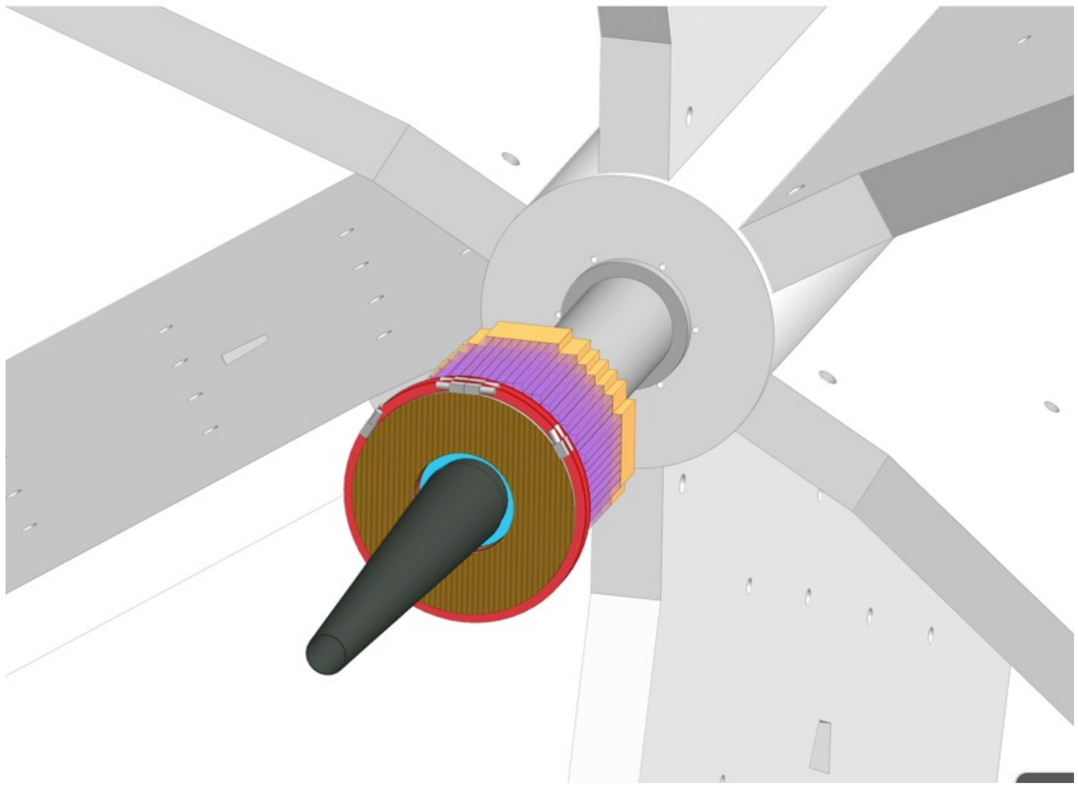
- Funds for the FT hardware will be provided by the proponents. Specific requests have been presented to european funding agencies and submission of an MRI is under discussion.
- We foresee 1 year for the completion of the necessary FT R&D, 1 year for technical design with integration in CLAS12 and 1 year for construction and testing. This would allows us the FT ready for installation and commissioning in 2014 before the beginning of CLAS12 operation. If the proposal is approved, the detailed FT construction plan will be integrated in the 12GeV project schedule.
- Discussion on FT integration within available clearance in the CLAS12 region between the HTCC and DC already started. First meeting with the Hall-B engineering staff was held in November 2010 leading to a preliminary design as shown in Fig.6, pg. 18, of the proposal and in the following slide. Cables, electronics and other services can fit in the shadow of torus coils with no impact on the CLAS12 acceptance.
- As mentioned above decisions on the design will be made within 1 year from now with the completion of the R&D phase. This will leave us enough time to define the FT integration In CLAS12.

2) A critical part of the proposal is the desire to run the experiment parallel with the standard CLAS12 operation. This requires a moderate extension of the currently planned trigger system to reconcile the requirements of this proposals with the standard trigger requirements for large angle electron selection, while keeping the data acquisition rate within the design limits of the upgraded DAQ (10KHz event rate, 100MB/sec data rate).

- As mentioned in the proposal in Sec. 5.5, this experiment requires a dedicated trigger system that will improve the performances of the CLAS12 trigger system. This will be based on an array of FPGAs that will process on-line signals from FT (calorimeter and hodoscope) and CLAS12 (TOF, EC, PCAL, DC). A similar system, based on commercial available boards, is already being used in CLAS operations. Algorithms for cluster recognition in calorimeters and fast coincidences with other detectors has already been developed and used.

TAC Comments (II)





Readers Comments (I)

1. You mention the issue of the relatively low light yield of the lead tungstate crystals (even though the PANDA version would give you a factor 8 improvement). In your analysis you use a 10 MeV threshold for the energy deposition in a single crystal, however later in the proposal (page 26) you state that electron clusters have a minimum energy deposition per crystal of 100 MeV: is this a mis-print or could please comment on this? What would be an acceptable level for the low energy threshold?

-Yes, it is a mis-print: the sentence in the proposal you refer to is confusing. What we meant to say on page 26 is that a cluster for a good electron (in the energy range 0.5 – 4.5 GeV) would be reconstructed only if AT LEAST one of the crystals has more than about 100 MeV energy deposited. The hardware threshold on the single crystal will be set as low as possible (~10 MeV) in order to measure most of the cluster energy. These are preliminary numbers based on GEANT4 simulations and existing experience (CLAS IC and PANDA EC). More studies on minimum thresholds are in progress via simulations and hardware tests on a prototype.

2. On page 20 of the proposal you state that a measurement of the energy deposition in the hodoscope elements is not critical, because most particles are relativistic minimum ionizing particles with an energy deposition independent on the particle type. The only case which is not addressed is photon conversions, which might produce coalescent e+e- pairs which could be distinguished by single tracks via their double ionization in the scintillator tiles. Has this case been considered ? (or do all e+e- pairs open up in the magnetic field so that they are never mistaken for a single particle ? Or is the conversion probability too low ? …)

- Photons produced by the electromagnetic interaction, mainly from Moeller scattering are already included in the background simulations we performed, resulting in a negligible pair production rate. The energy of e+/e- pairs is mainly below 500 MeV (the minimum tagged energy) and they usually spiralize in the magnetic field not reaching the active detectors. See the next slide for detailed plots.

High energy photons generated in a hadronic reactions can convert in a e+/e- pair within the target or in the tracker (being the rest of the path in vacuum or air). The corresponding total material budget is ~2.6 10^{-2} r.l. resulting in a small but not negligible conversion probability. A realistic hadronic background was generated using PYTHIA resulting in a photon rate of ~500 Hz in the energy range 0.5 – 8.0 GeV at the nominal CLAS12 operation luminosity. This value, multiplied by the conversion probability has to be compared with the 'good' electron rate in the FT that is ~7 kHz. Detailed simulations that include the effect of the complex magnetic field are under way.

Readers Comments (II)

EM background rates in the calorimeter (charged particles)

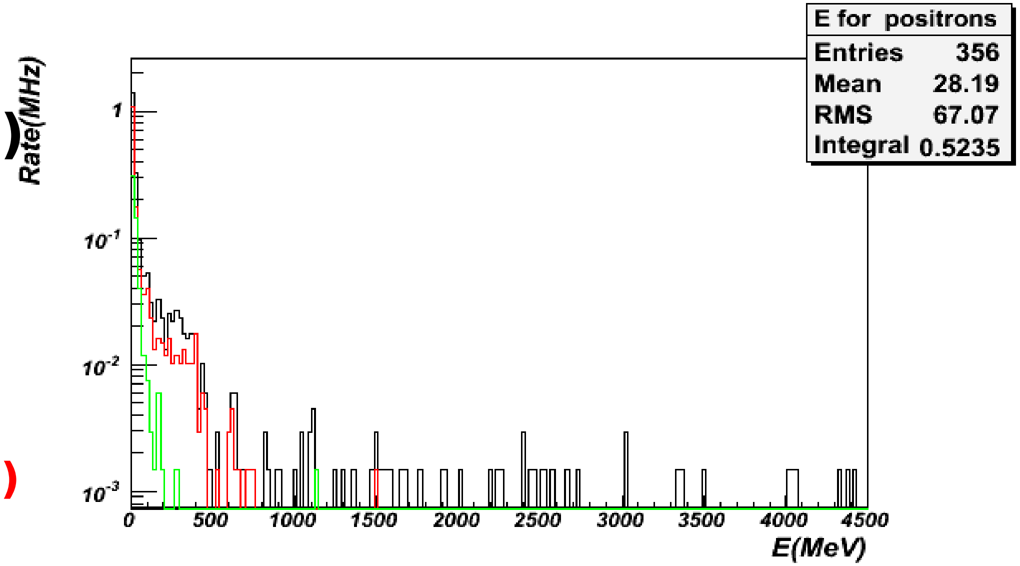
black = all

red= electron

green = positron

Negligible contribution in the energy range 0.5 -4.5 GeV

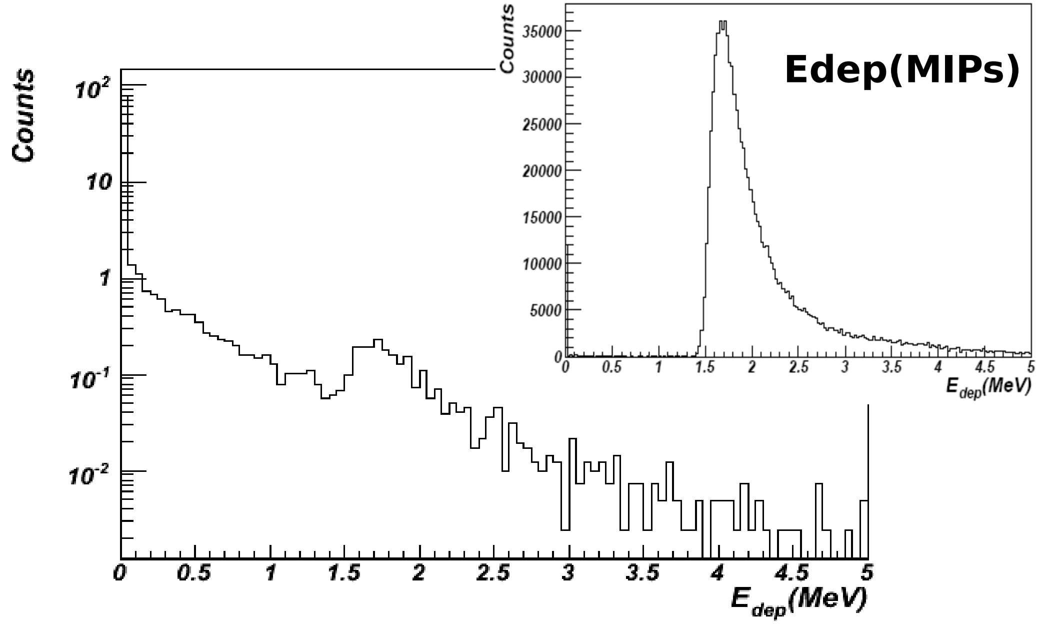
(included in the em bg rate of 200kHz)



EM background Edep in the hodoscope (neutral and charg)

Edep(MIPs)>1.5 MeV

A cut around Edep(MIPs) will help in reducing the em bacground



Readers Comments (II)

3. I notice that only one specific kinematical configuration has been simulated for the eta-pi channel: are there plans to do more?

- For the eta-pi channel, in the proposal we included only an example of isospin channel (eta-pi+) and a particular kinematic configuration (magnetic field setting, exotic resonance mass, …) while a more comprehensive study has been presented for the 3pi channel. In the experimental configuration we proposed, we expect anyway to cover a wide kinematic range and many different final decay modes. Therefore more studies will be done to identify the most promising configurations.

4. Would you care to comment on the exclusion of charm from the present proposal ?

- The limited energy of the primary beam (11 GeV) does not allow an extensive spectroscopy program on charm production. The FT may be used in the future to study charm production at threshold for physics goals other than spectroscopy (J/Psi production on nuclei, color transparency J/Psi bound in nuclei).

Readers Comments (III)

5. Your proposal has to my opinion a strong overlap with the approved Hall D program. What are in your opinion the strengths or advantages of your new setup in Hall B for investigating meson spectroscopy compared to Hall D.

	Low Q2 elctroproduction CLAS12 in Hall-B	Coherent Bremsstrahlung GLUEX in Hall-D
Tagged γ energy:	**6.5 - 10.5 GeV**	**8.4-9.0 GeV**
$\Delta E\gamma / E\gamma$	**$\sim 10^{-3}$**	**$\sim 10^{-3}$**
Linear Polarization	**70% - 10%**	**40%**
Linear Polarization	**event-by-event**	**average**
Photon Flux (30cm LH2)	**10^6 - 10^7 γ/s**	**10^6 – 10^7 γ/s**
Tagger rate (signal+bg @ 10^7 γ/s)	**0.25 MHz**	**10 MHz**
Acceptance (e.g. 3π)	**20%**	**90%**
Hadron σp/p	**0.5%**	**2%**
Hadron PID	**K/π separation for p<2.5GeV**	**no K id/ kin fit**
PWA capability	**YES**	**YES**

From the comparison reported above one can conclude that, with almost equivalent running conditions, the advantages of the Hall-B set up are:

- a reduced rate of random coincidences between the photon tagger and the the hadrons detection
- a better control on systematic errors on linear polarization value
- a simplif ed procedure to determine photon f ux for absolute cross sections extraction
- good momentum resolution that allows to use the missing mass technique to reduce the number of detected particles
- particle identif cation capability and in particular kaon/pion separation that allows to study strangeness-rich mesons
- the future possibility to run the spectroscopy program on nuclei using thin gas target with an equivalent luminosity

The two experiments, involving different detectors and different experimental techniques, are clearly affected by different and independent systematic errors. We believe this is a crucial advantage for JLab to cross check any possible discovery in meson spectroscopy. This is similar to what already happened at JLab for many hot topics as DVCS, parity violation experiments, spin structure functions where complementary experiments were run in Hall-A, Hall-B and Hall-C.