η' Photoproduction at GlueX (Hall D), Brief introduction about ALERT Experiment(HALL B)

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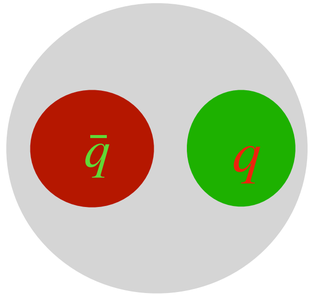
GlueX Experiment and Hybrid Search Program

- **Objective of GlueX Experiment:** Mapping out the spectrum of light exotic and hybrid mesons, enhances the understanding of quantum chromodynamics (QCD).

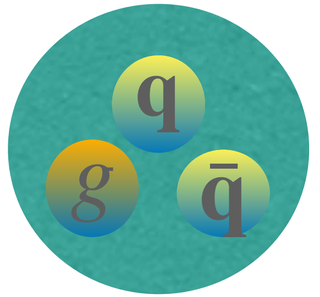
- **Hybrid Mesons with Unusual Quantum Numbers:** Some hybrid mesons such as $\pi_1(1600)$ J^{PC} : 1^{-+} exhibit quantum numbers that do not follow naive quark-antiquark model.

- **Production Mechanisms for Exotic Mesons:** The production of the lightest exotics involves an analogus exchange process with ordinariy pseudoscalar mesons such as η', π^0, and η involving Regge Exchanges.

- **Dual Parity Exchange Contributions:** Hybrid exotic mesons see contribution from both the natural ($P(-1)^J = 1$) and unnatural ($P(-1)^J=-1$) parity exchanges which can also be seen in the ordinary pseudoscalar mesons.



Ordinary Meson



Hybrid Meson

Beam Asymmetry (Σ)

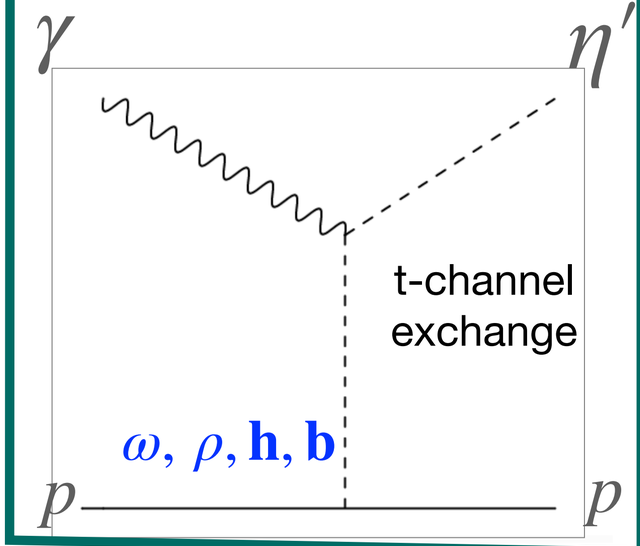
- Differential cross-section for the photons polarized perpendicular or parallel to the reaction plane, s and t are Mandelstam variables.

- Beam Asymmetry give access to exchange processes

- Putting new constraints to Regge models, understanding production mechanism

$$\Sigma_{\eta'} = \frac{d\sigma_{\perp} - d\sigma_{\parallel}}{d\sigma_{\perp} + d\sigma_{\parallel}}$$

$$d\sigma_{\perp,\parallel} \equiv \frac{d\sigma_{\perp,\parallel}(s,t)}{dt}$$

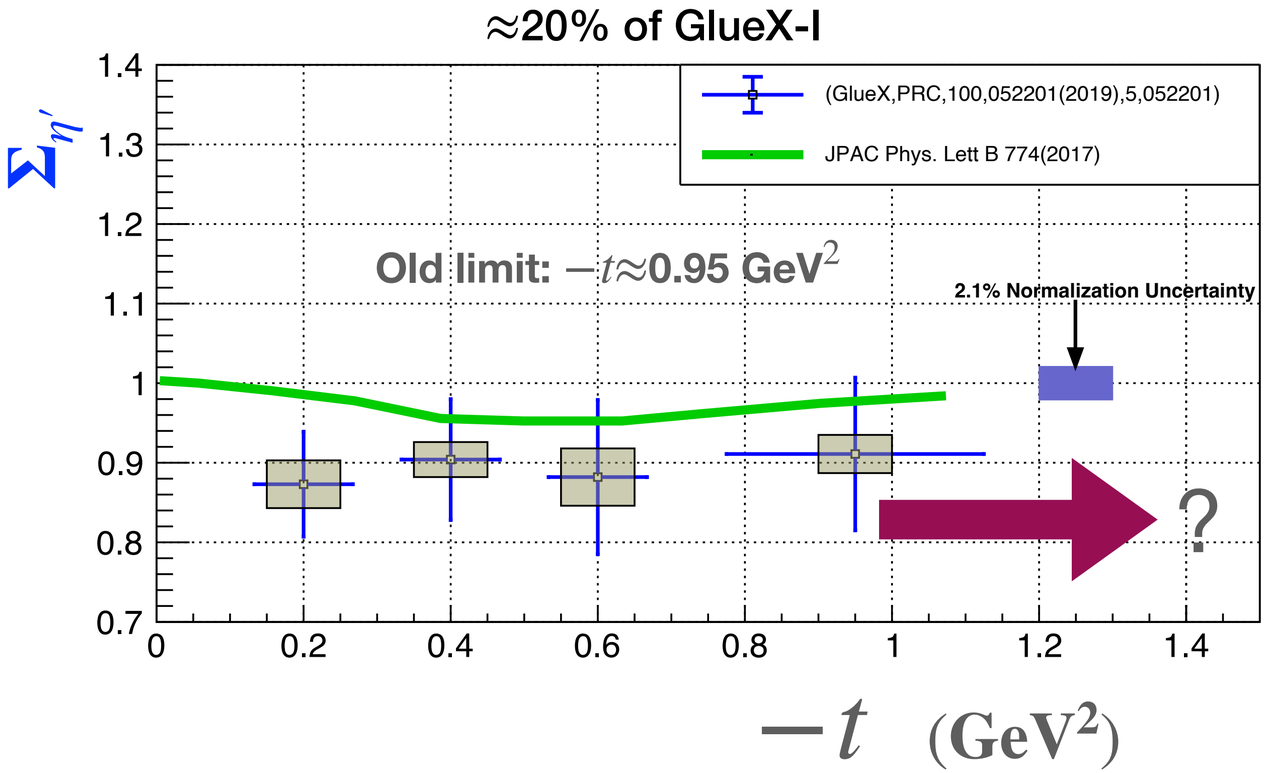


Natural Parity Exchange | Unnatural Parity Exchange

$$\Sigma = \frac{|\omega + \rho|^2 - |h + b|^2}{|\omega + \rho|^2 + |h + b|^2}$$

$\Sigma = \pm 1$ indicates vector meson/ axial vector meson dominance

Motivation



Results from GlueX Collaboration
(PRC,100,052201(2019),5,052201)

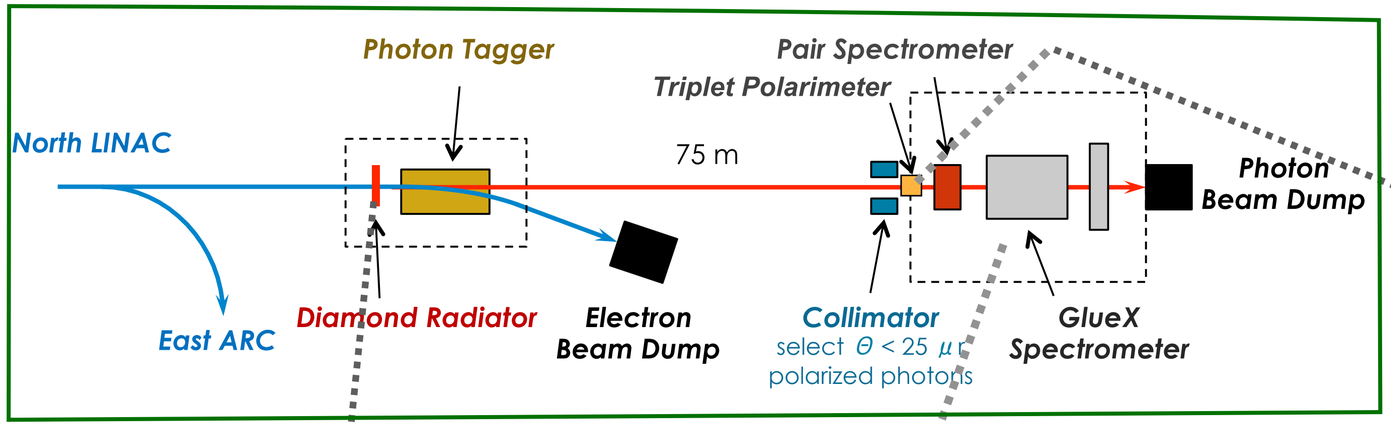
$\gamma p \to \eta' p,\ \eta' \to \eta\pi^+\pi^-,\ \eta \to \gamma\gamma$

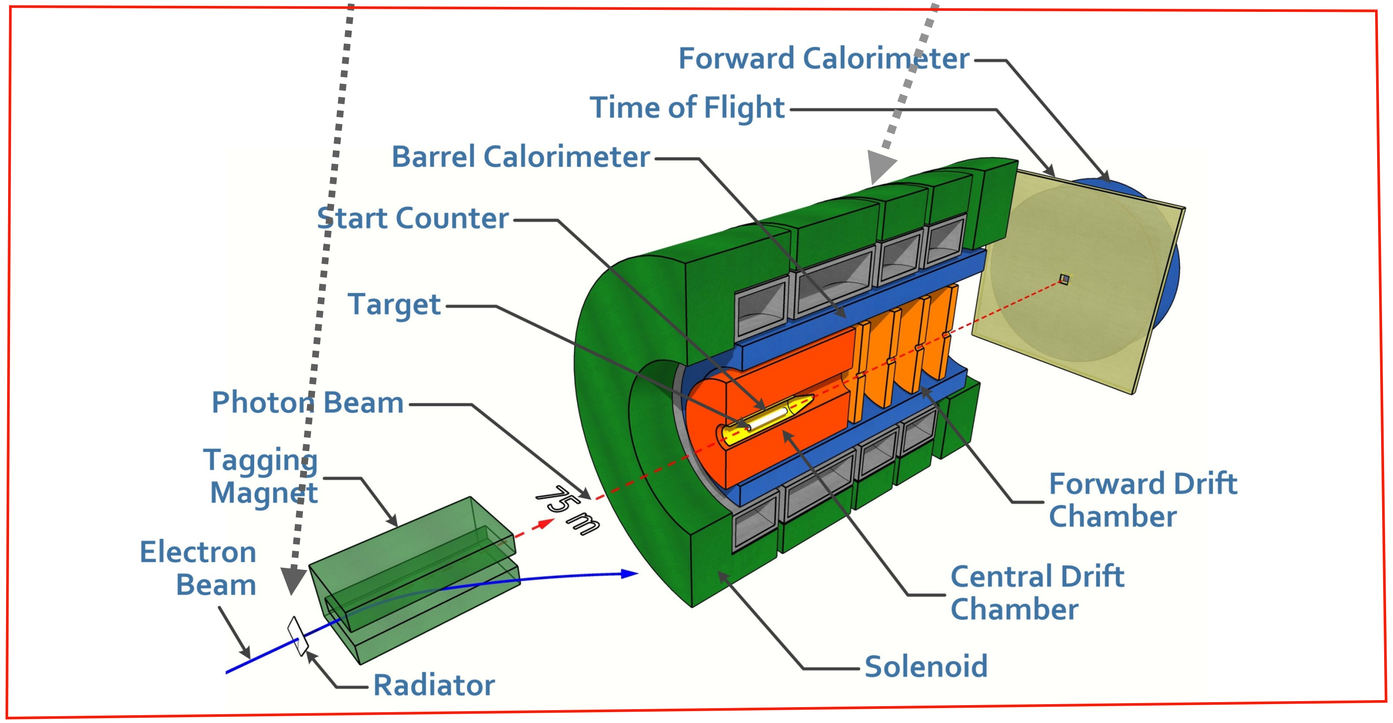
$\eta' \to \eta\pi^0\pi^0$

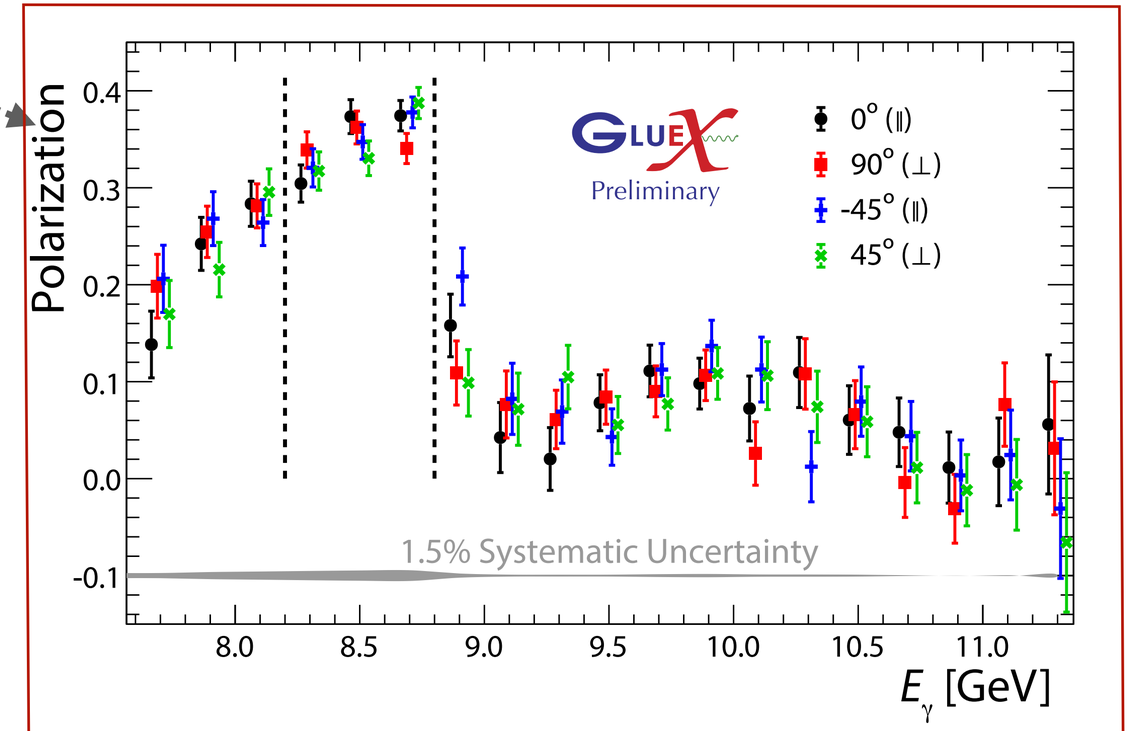
$\eta \to \gamma\gamma,\ \pi^0 \to \gamma\gamma$

- First results with ≈20% of data
- For the decay mode $\eta' \to \eta\pi^+\pi^-$
- Natural parity exchange dominance
- Higher $-t$ limit and Production Mechanism

GlueX Beamline, Detector & Polarization







Measurement of Polarization as a function of photon beam energy from Triplet Polarimeter (M.Dugger et.al).

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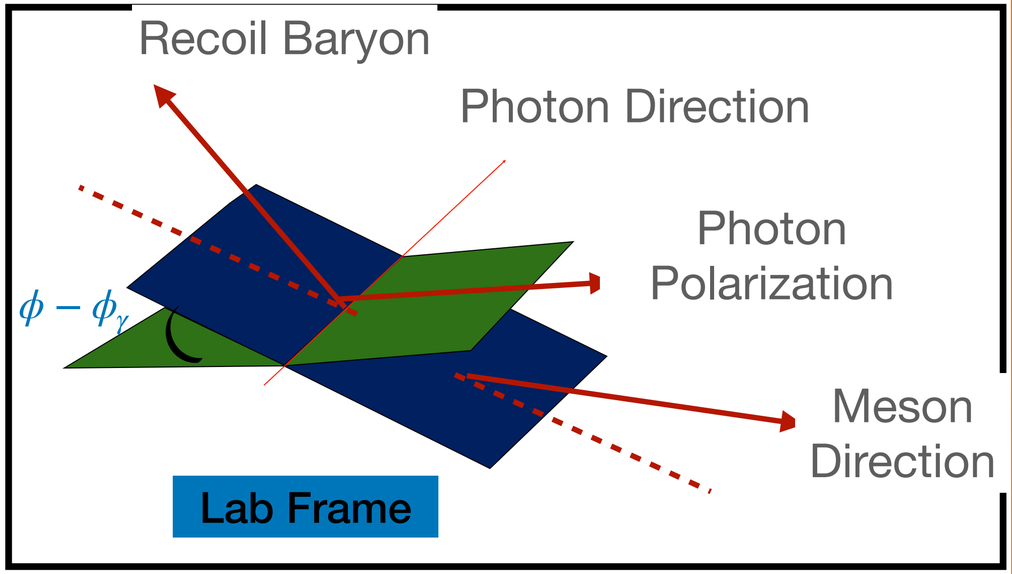
Beam Asymmetry Method

$$\sigma_{pol}(\phi, \phi_\gamma) = \sigma_{unpol}[1 - P_\gamma \Sigma cos(2(\phi - \phi_\gamma))]$$

$$Y_\parallel(\phi, \phi_\gamma = 0) \propto N_\parallel[\sigma_0 A(\phi)(1 - P_\parallel \Sigma cos2\phi)]$$

$$Y_\perp(\phi, \phi_\gamma = 90) \propto N_\perp[\sigma_0 A(\phi)(1 + P_\perp \Sigma cos2\phi)]$$

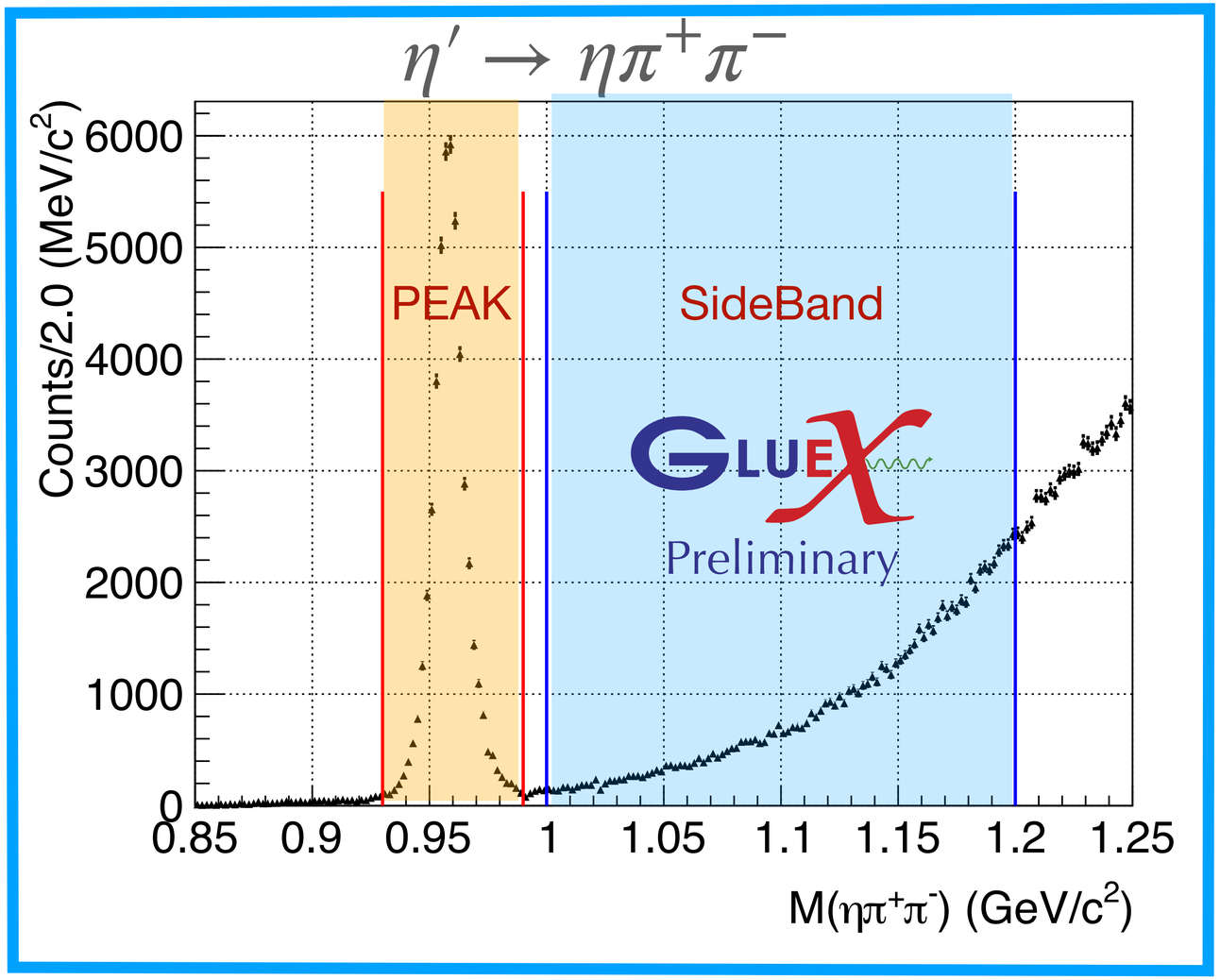
$$\Sigma = \frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel}$$

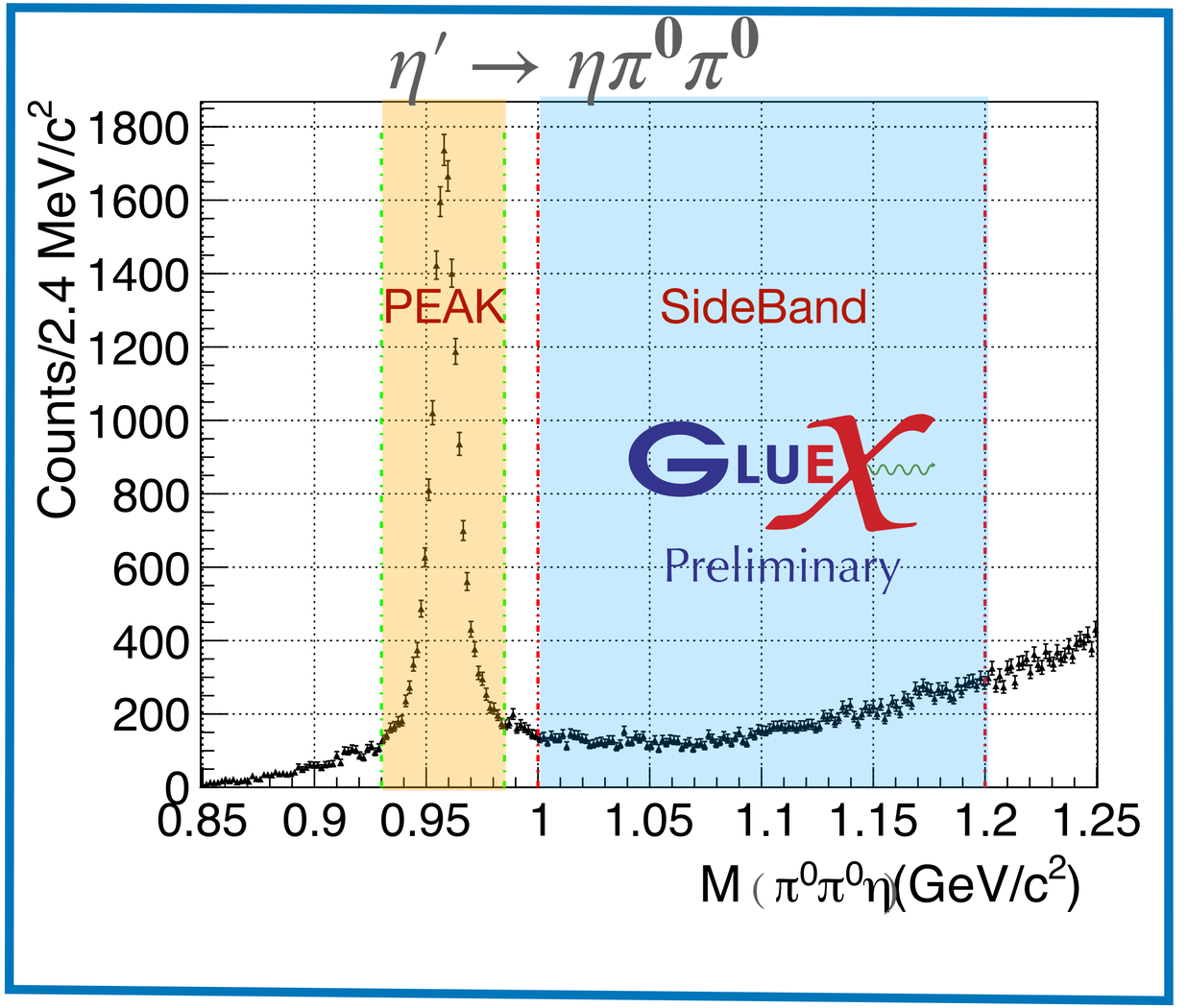


$$\text{YIELD ASYMMETRY (YA)} = \frac{Y_\perp - F_R Y_\parallel}{Y_\perp + F_R Y_\parallel} = \frac{(P_\perp + P_\parallel)\Sigma cos2(\phi - \phi_0)}{2 + (P_\perp - P_\parallel)\Sigma cos2(\phi - \phi_0)}$$

$$\mathbf{F_R} = \frac{\mathbf{N_\perp}}{\mathbf{N_\parallel}} \approx 1$$

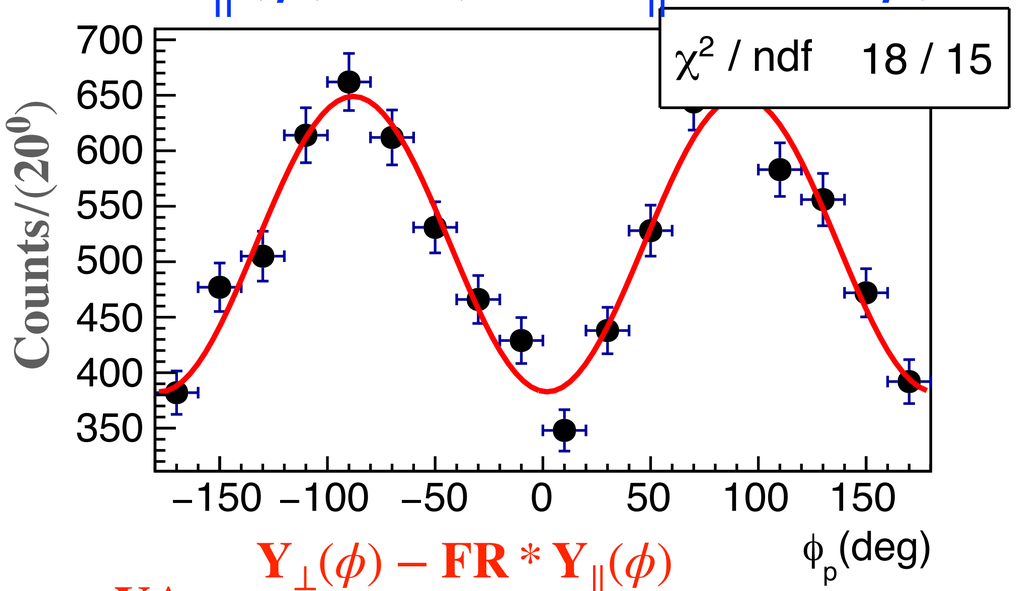
Invariant Mass Spectra



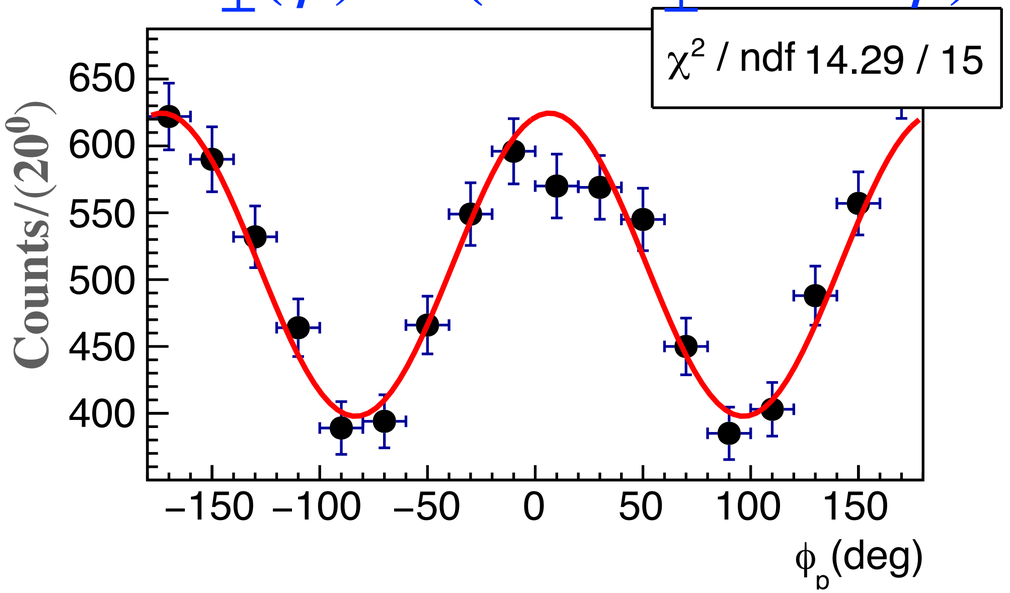


Angular Distributions, Yield Asymmetry, and SUM plot for the decay $\eta' \rightarrow \eta\pi^+\pi^-$

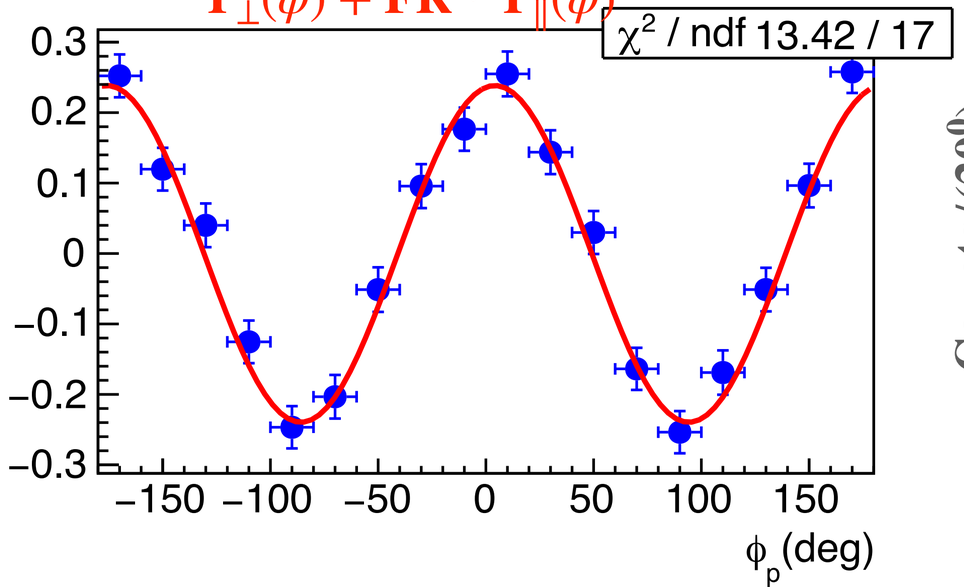
$$Y_{\parallel}(\phi) \propto (1 - P_{\parallel}\Sigma\cos 2\phi)$$

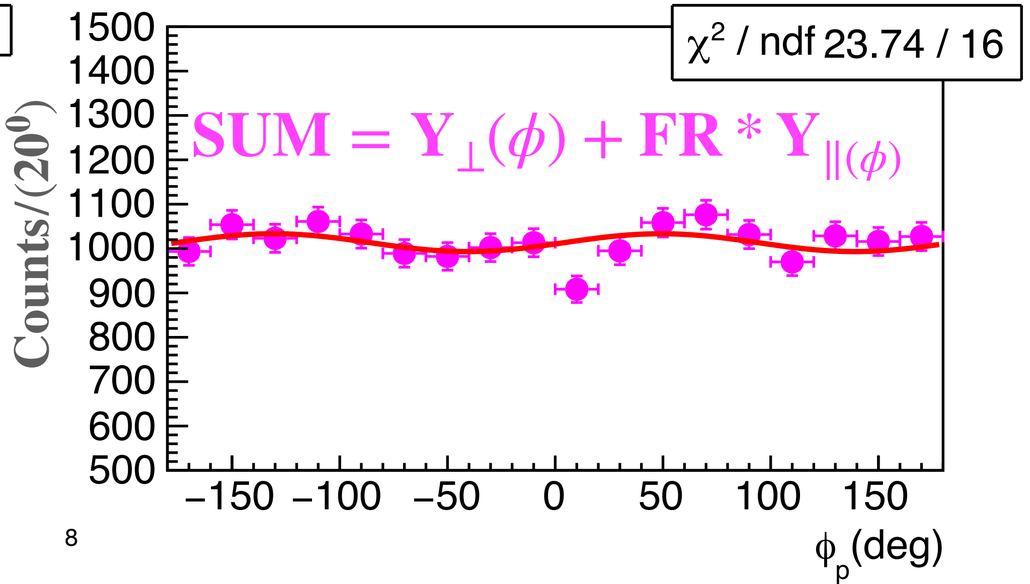


$$Y_{\perp}(\phi) \propto (1 + P_{\perp}\Sigma\cos 2\phi)$$

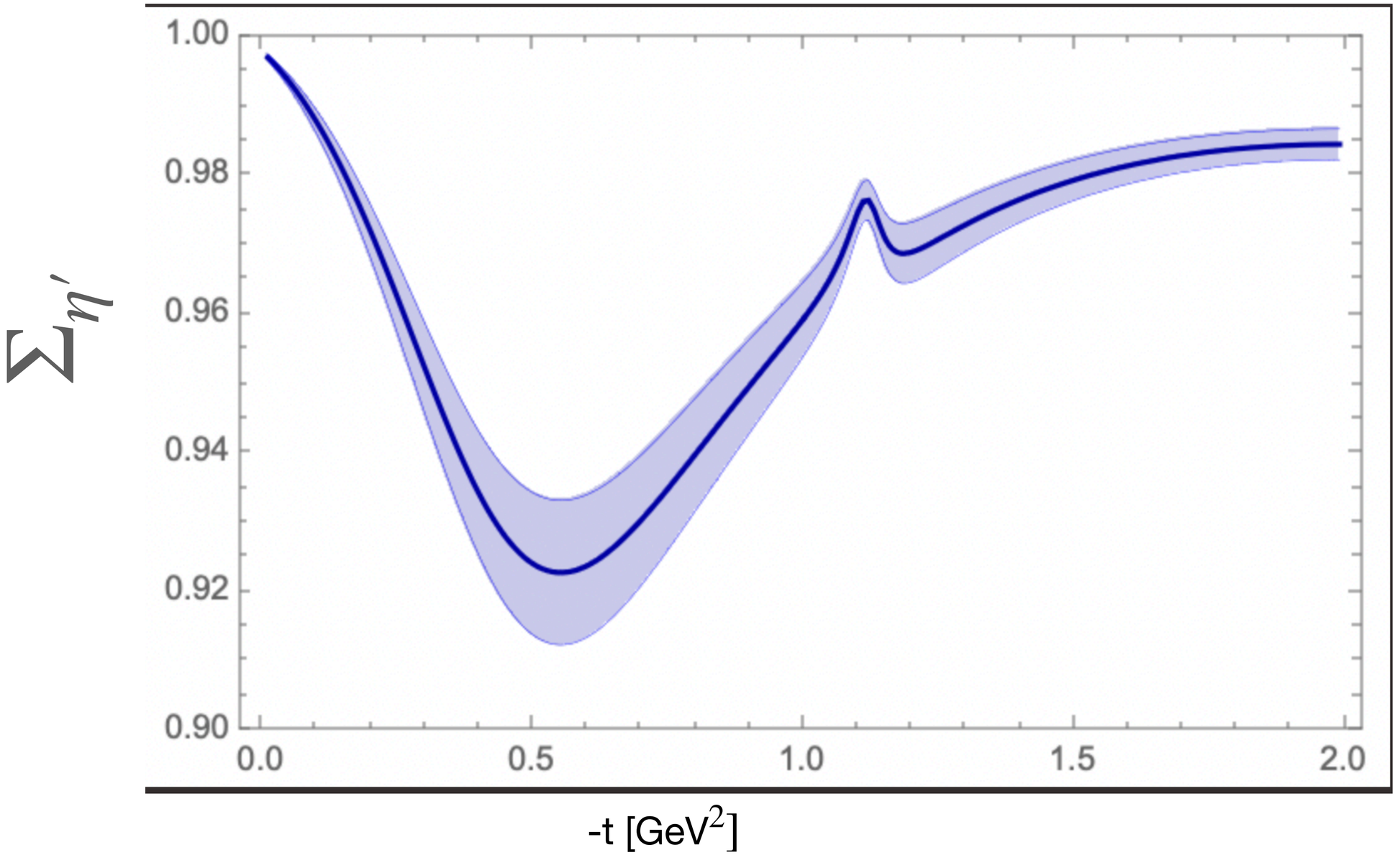


$$YA = \frac{Y_{\perp}(\phi) - FR * Y_{\parallel}(\phi)}{Y_{\perp}(\phi) + FR * Y_{\parallel}(\phi)}$$



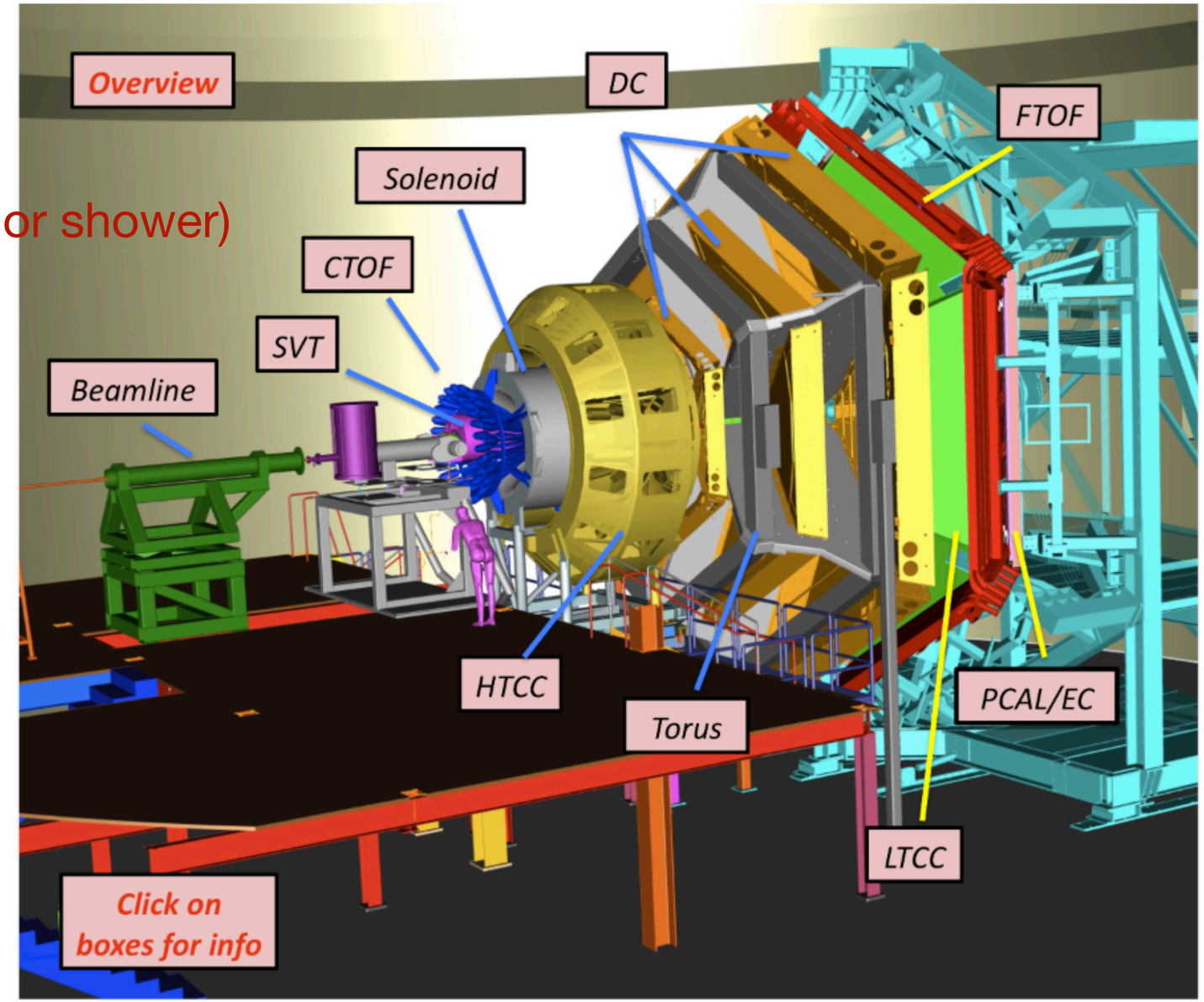


JPAC Model (η') Beam Asymmetry



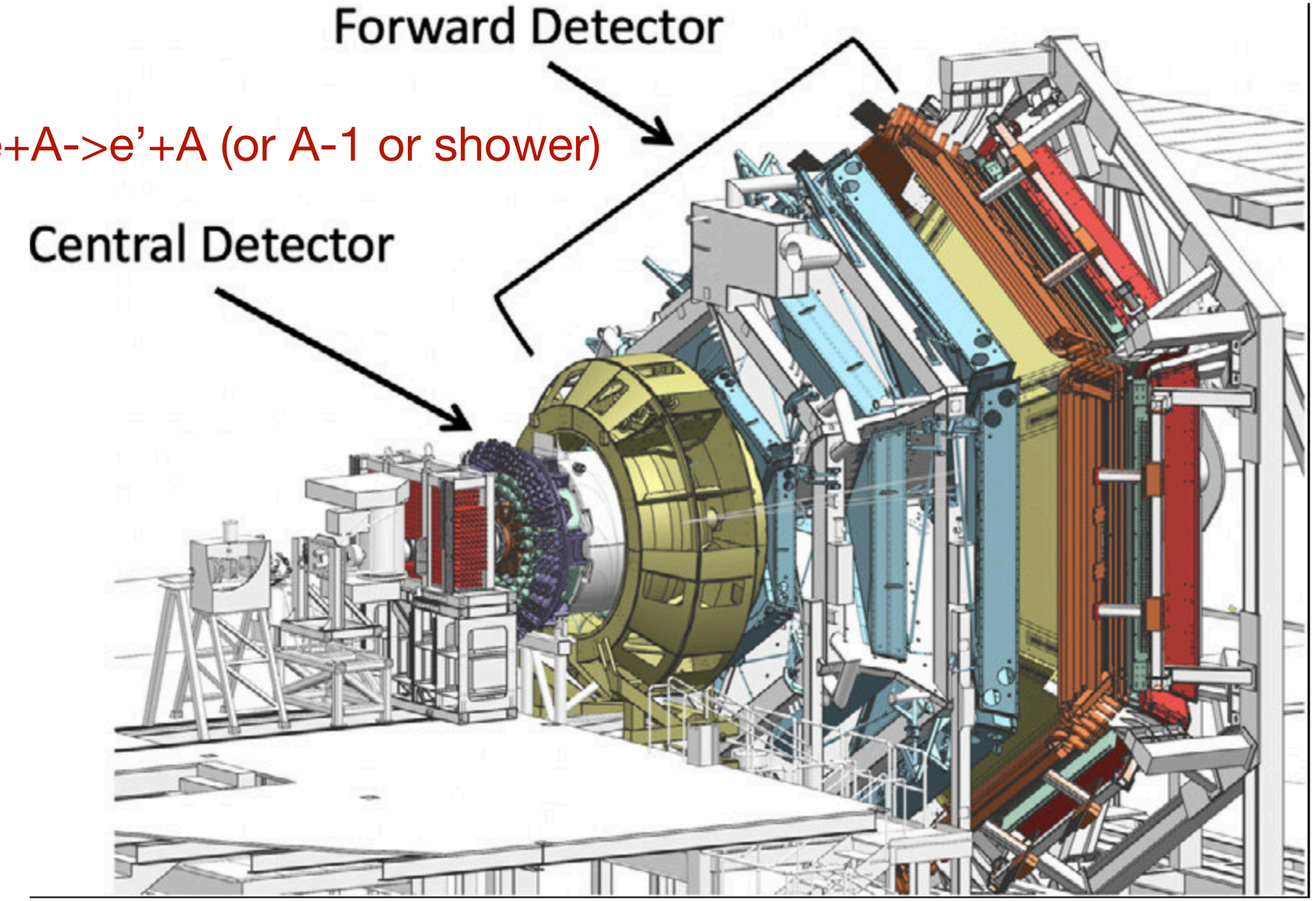
Clas12 Detector

e+A->e'+A (or A-1 or shower)



Source: clas12wiki

Clas12 Detector



Source : google

The ALERT Detector

- ALERT comprises two sub-detectors: A Hyperbolic Drift Chamber (AHDC) and A Time of Flight (ATOF).
  - Identify light ions: p, ^{2}H, ^{3}H, ^{3}He, ^{4}He.
  - Detect the lowest momentum possible.

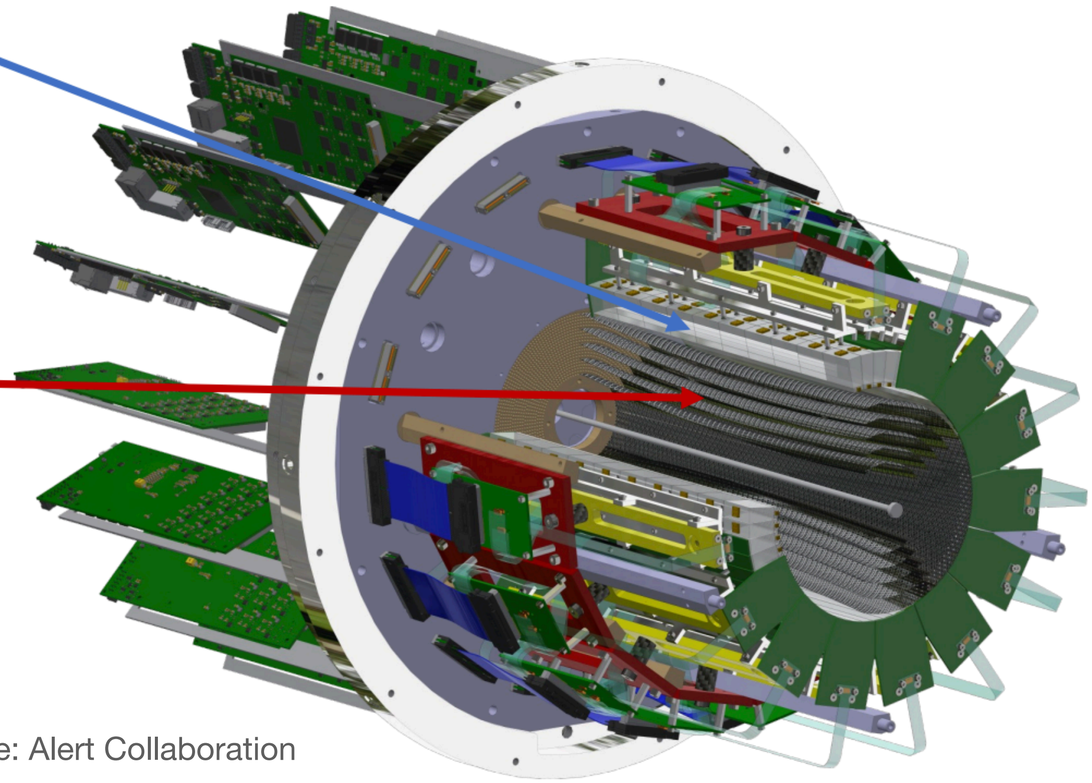
ALERT ToF

- Time-of-Flight: use for PID
- Small barrel of segmented scintillators
- The ToF measurement is degenerate for ^{2}H and ^{4}He, but *dE/dx* can distinguish the two nuclei bands

e+A->e'+A (or A-1 or shower)

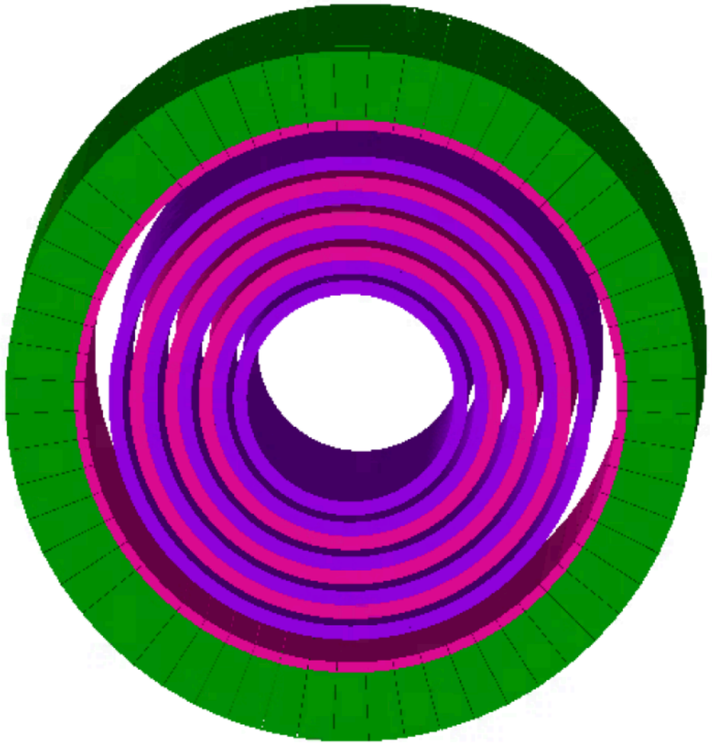
ALERT HDC

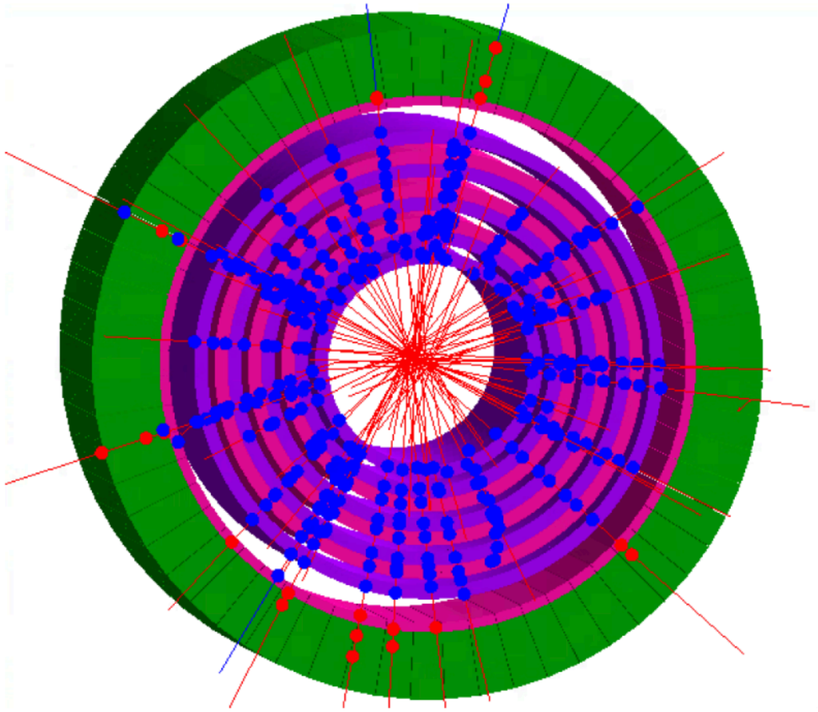
- Aluminum wire: 2mm spacing
- 20-degree stereo angle (hyperbolic shape)
- 5 superlayers, each composed of 2 layers
- 576 signal wires:
  - 47, 56, 72, 87, 99 for each superlayer.



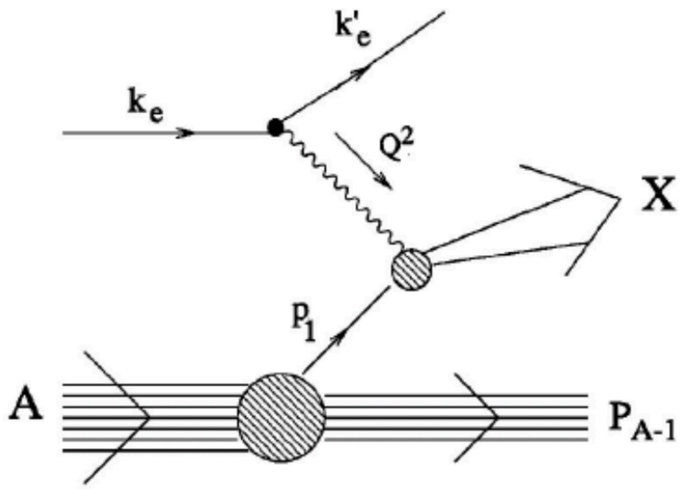
Source: Alert Collaboration

ATOF from GEMC





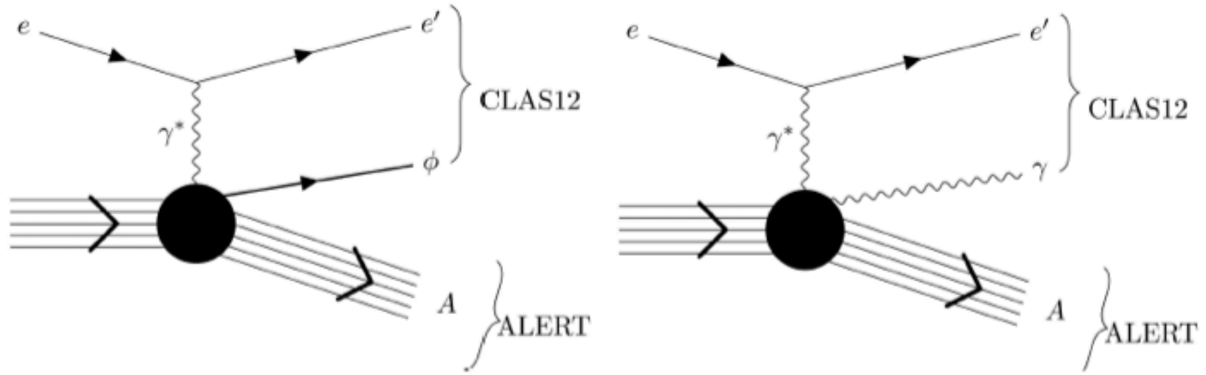
Physics Processes with ALERT



$^{4}\mathrm{He}(e, e' + {}^{3}\mathrm{H})\,\mathrm{X}$

$^{4}\mathrm{He}(e, e' + {}^{3}\mathrm{He})\,\mathrm{X}$

$^{2}\mathrm{H}(e, e' + p)\,\mathrm{X}$



$^{4}\mathrm{He}(e, e'\ {}^{4}\mathrm{He}\ \gamma)$

$^{4}\mathrm{He}(e, e'\ {}^{4}\mathrm{He}\ \phi)$

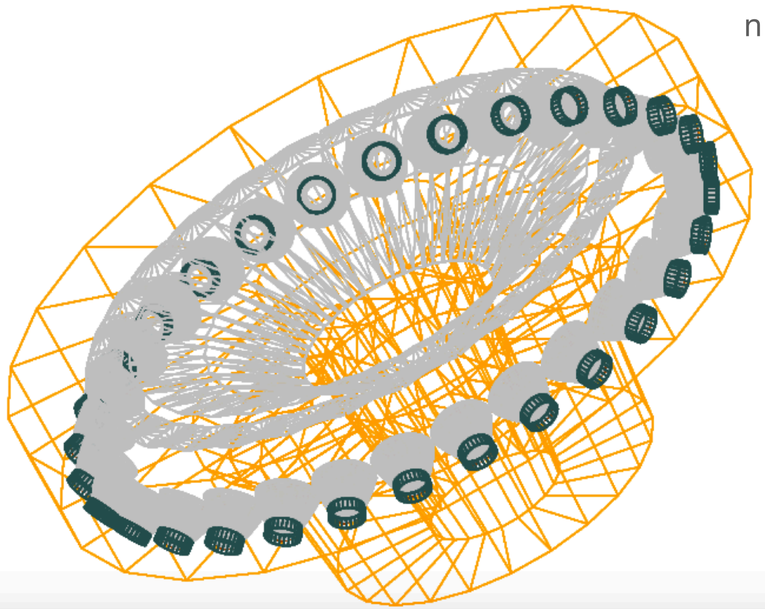
Light Gas Cherenkov Detector (For SoLID)

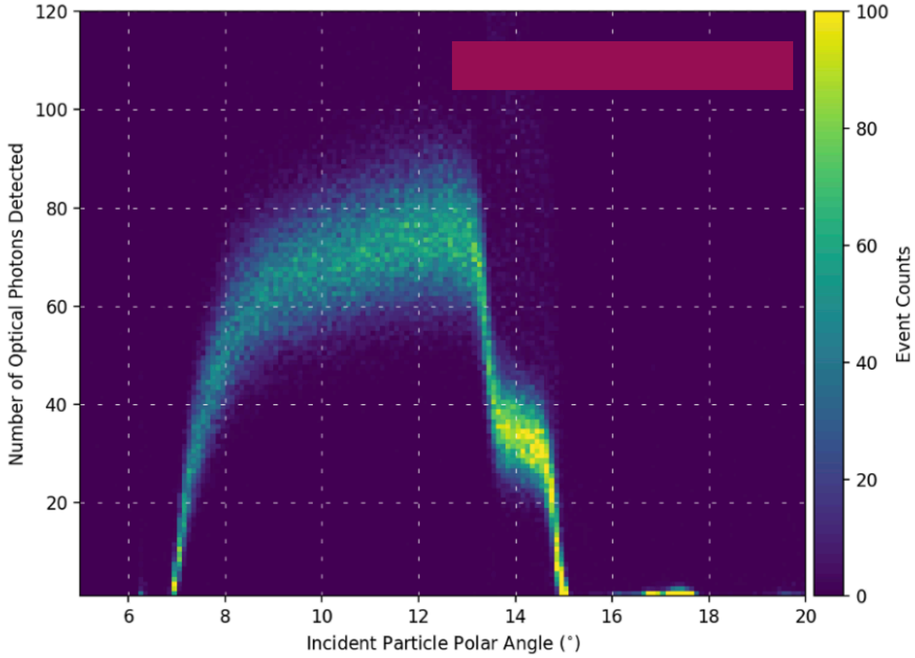
Cherenkov Light is emitted if $\beta > 1/n$

$$\beta = \frac{v}{c}$$

(Low density and low refractive index : CO2)

n is the refractive index





Cherenkov radition->Reflection (Mirrors)->PMTS PhotoCathode->PhotoElectric Effect->Electrons ->Measure ADC Pulse->Calibrate->Get No. Of Optical Photons vs angle

Summary

- η' : Paper writing in progress
- ALERT : Experiment currently running, data, software: reconstruction, calibration : many works are ongoing.
- Clean elastics seen (data)