Search for Strangeonia in Photoproduction using CLAS

Mukesh Saini

Florida State University, Tallahassee, FL

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Jefferson Lab

OUTLINE

- Introduction
  - Meson Spectroscopy
  - Strangeonia
- Experiment
  - CEBAF & CLAS
  - HyCLAS & g12
  - Calibrations
- Analysis
- Summary

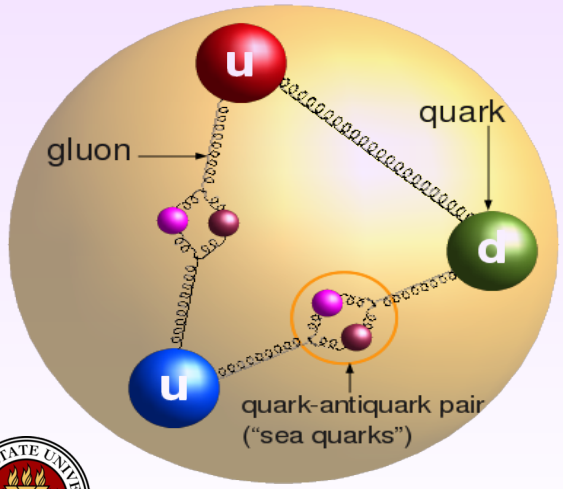
QCD

gluon

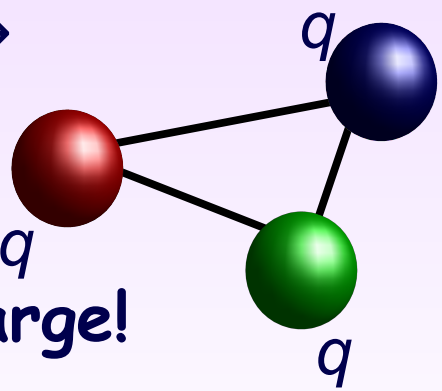
Quantum chromodynamics (QCD) is theory of the strong interaction (color force).

It describes the interactions of the quarks and gluons making up the hadron

QCD Picture



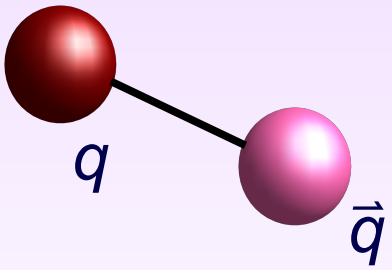
In constituent quark Model, →



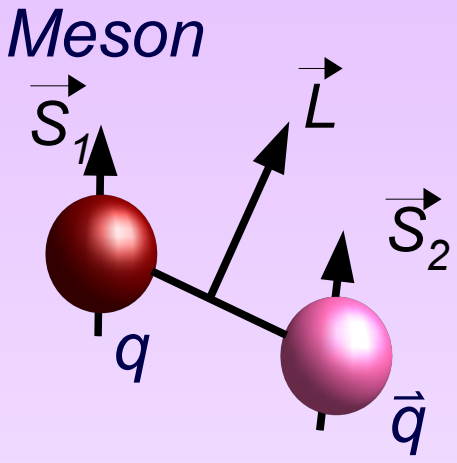
Color charge!

Baryon

Meson



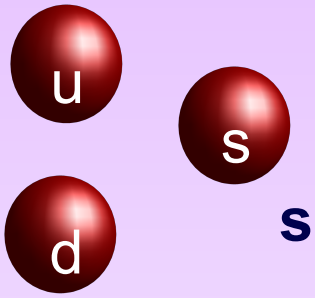
Meson Spectroscopy



$$\vec{J} = \vec{L} + \vec{S}$$

$$P = (-1)^{L+1}$$

$$C = (-1)^{L+S}$$



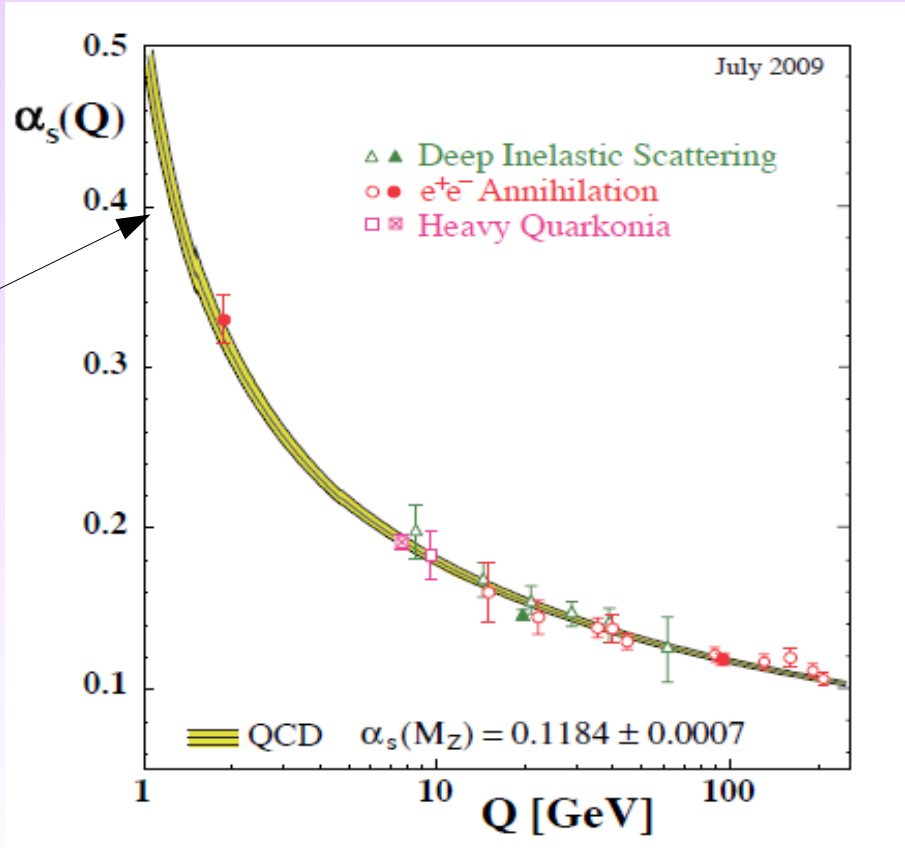
Light meson spectroscopy

$$\mathrm{J}^{PC}\Big|_{allowed} = 0^{-+}, 0^{++}, 1^{--}, 1^{+-}, 1^{++}, 2^{--}, \ldots .$$

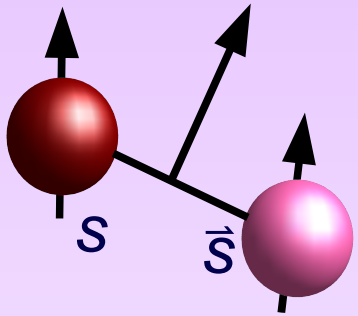
$$\mathrm{J}^{PC}\Big|_{exotic} = 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+}, \ldots .$$

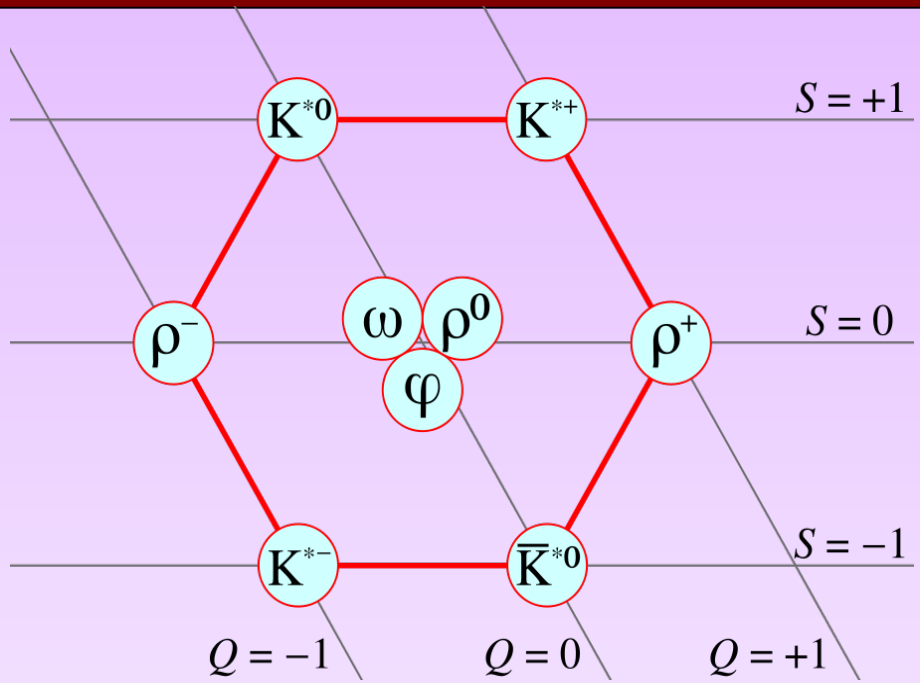
Quark Model and beyond

- Free quarks and gluons have not been observed in nature due to confinement
- QCD predicts exotic hadrons beyond the naive quark model [hybrids, glueballs and multi-quark states]
- Mapping of the meson spectra will help us identify exotic unconventional mesons and decays, to further our insight into soft (Non-perturbative) QCD



Strangeonia





- Of the **22** expected resonances, only **7** are well identified
  - η-η'
  - ϕ (1020)
  - h_1 (1386)
  - f_1 (1426)
  - f_2' (1525)
  - ϕ (1680)
  - ϕ_3 (1854)

Expected Strangeonia spectrum

			J^{PC}	Name	Mass (MeV)
n=2	L=0	S=0	0^{-+}	η_s	1415
		S=1	1^{--}	ϕ	1680
	L=1	S=0	1^{+-}	h_1	1850
		S=1	0^{++}	f_0	2000
			1^{++}	f_1	1950
			2^{++}	f_2	2000
n=3	L=0	S=0	0^{-+}	η_s	1950
		S=1	1^{--}	ϕ	2050

Radial excitations of ($I = 0$, $s\bar{s}$) meson.

			J^{PC}	Name	Mass (MeV)
n=1	L=0	S=0	0^{-+}	η,η'	548,958
		S=1	1^{--}	ϕ	1020
	L=1	S=0	1^{+-}	h_1'	1380
		S=1	0^{++}	f_0'	1500
			1^{++}	f_1'	1530
			2^{++}	f_2'	1525
	L=2	S=0	2^{-+}	η_2'	1850
		S=1	1^{--}	ϕ_1	1850
			2^{--}	ϕ_2	1850
			3^{--}	ϕ_3	1854

Orbital excitations of ($I = 0$, $s\bar{s}$) meson.

Why study Strangeonia?

- QCD is well tested at high mass meson states. Perturbative QCD, quarks essentially free ($\alpha_s << 1$).

  It works reasonably well in the charmonium sector and above.

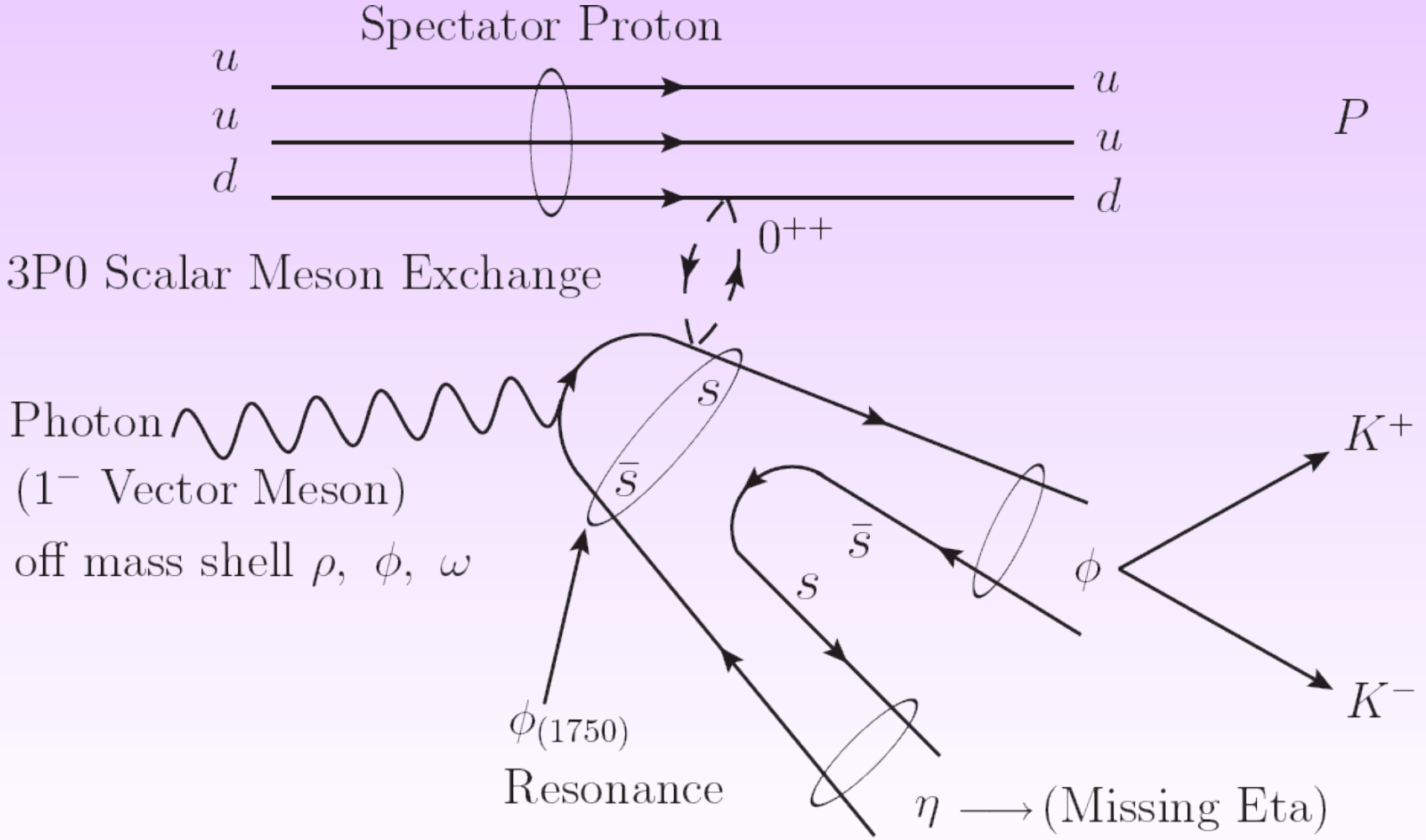
- Perturbative QCD breaks down at the low mass scale. QCD is non-linear in this non-perturbative regime ($\alpha_s \sim 1$). We have to resort to specific hadronic models now.

- Because of the intermediate mass of the strange quarks, study of strangeonium states will serve as a bridge between short and large distance behavior of QCD confinement potential.

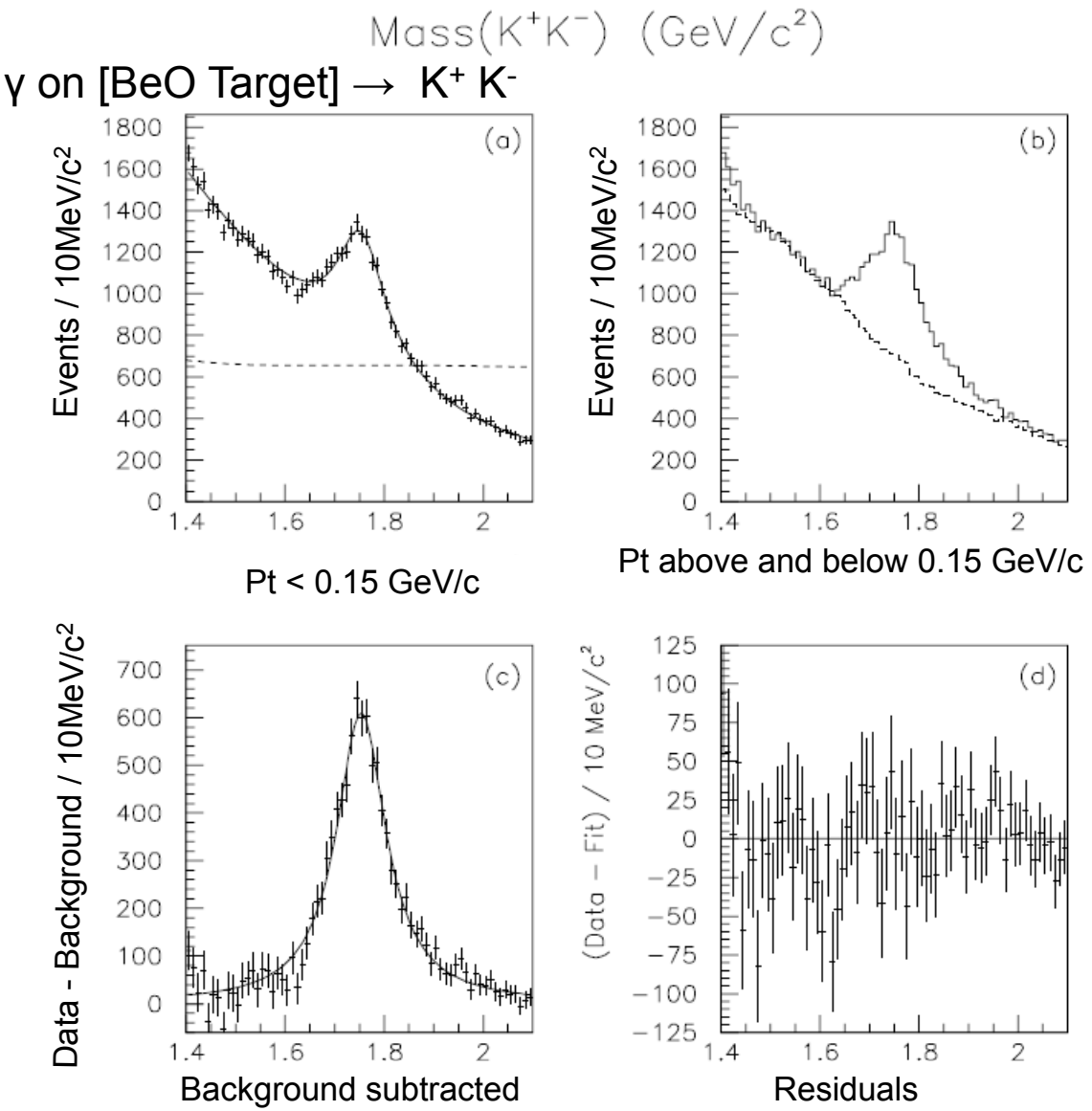
Photoproduction

Vector Meson Dominance

Photon can be regarded as a superposition of vector mesons (ρ, ω, ϕ) with an important $s\bar{s}$ component.

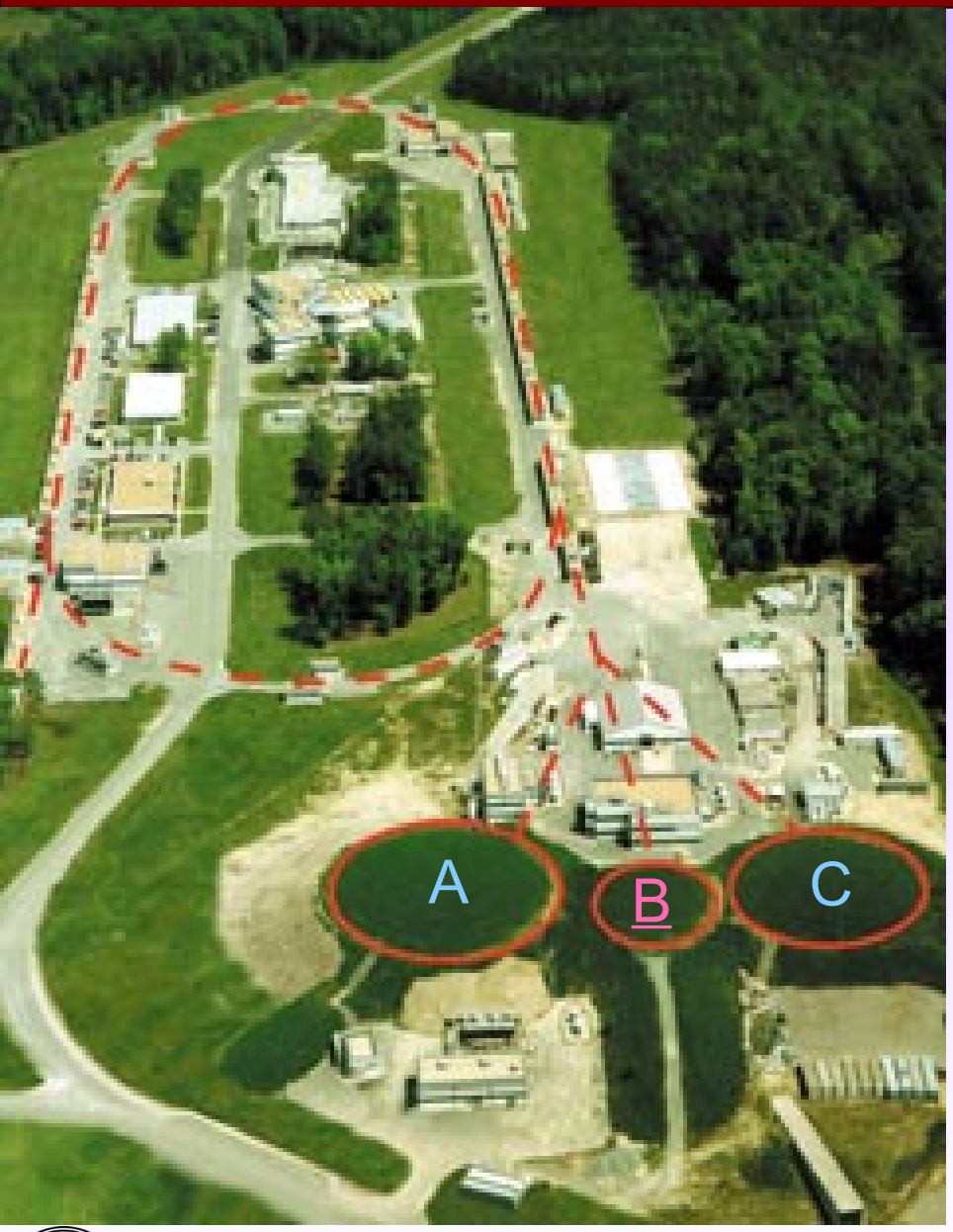


φ(1680)/φ(1750)



- e^+e^- production experiments observe the $\phi(1680)$
- $\phi(1750)$ is cited by PDG under $\phi(1680)$ with a note
- Focus experiment @ Fermilab has ~ 11,700 events for a resonance at $\phi(1750)$
- Exclusive K^+ K^- events
- Cleanest way to look for this resonance is in the $\phi\eta$ decay

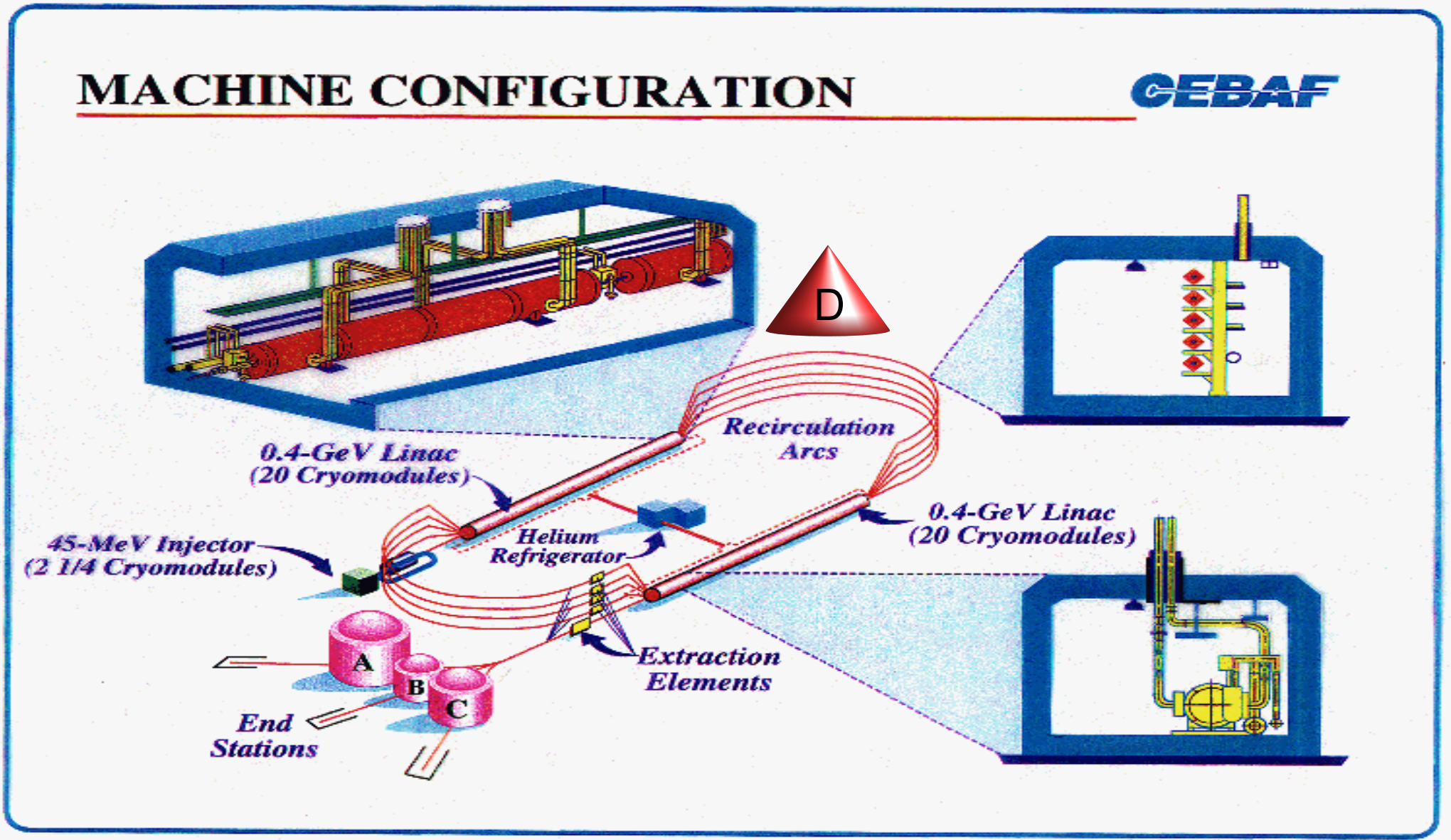
Jefferson Lab



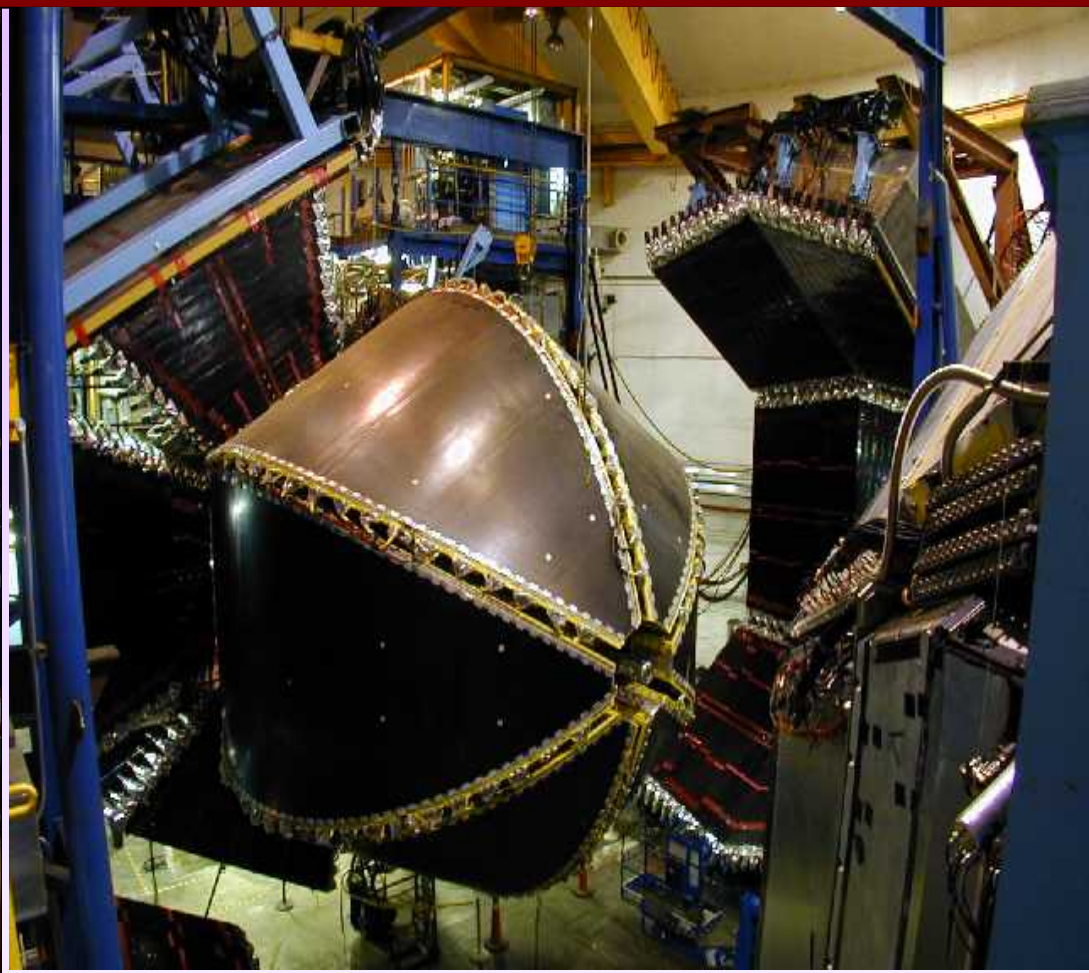
CEBAF: Continuous Electron Beam Accelerator Facility @ Thomas Jefferson National Accelerator Facility, Newport News, Virginia.

- Operated for U.S. DOE by JSA, LLC.
- CEBAF delivers e^- beams to the 3 Halls. Polarised if requested. 5-pass beam. Energies up-to 6 GeV (1.2 x 5).
- Hall-B is the smallest experimental Hall with the largest detector "CLAS".

CEBAF Layout



CLAS



- Skeletal superconducting Toroidal Magnets for CLAS.
- CLAS detector during assembly.

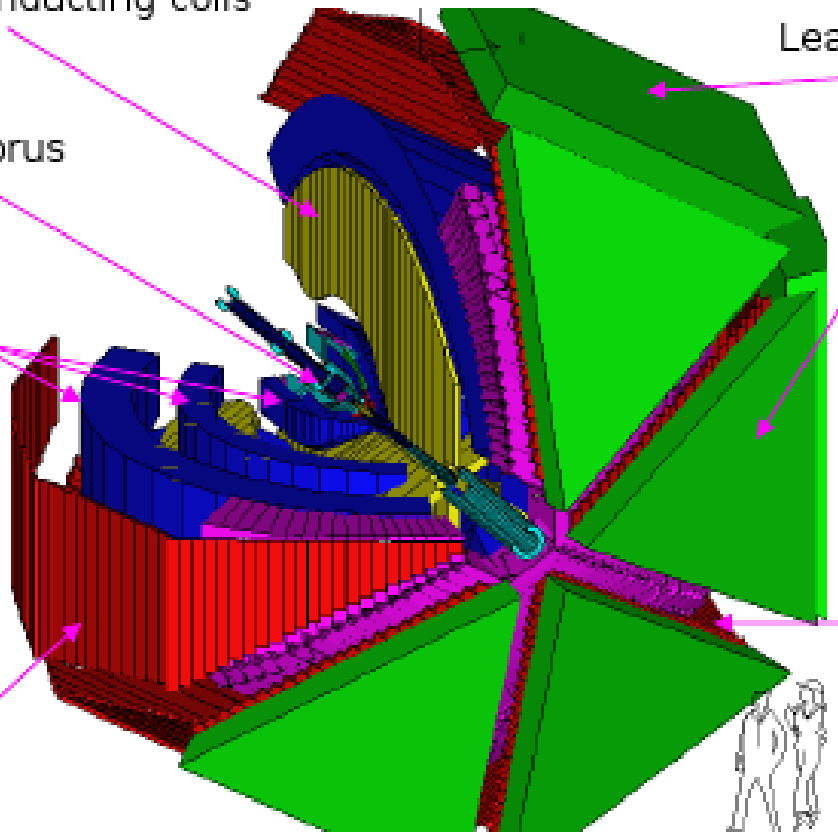
CLAS subsystems

CEBAF Large Acceptance Spectrometer

Torus magnet
6 superconducting coils

Liquid H_2 target +
γ start counter; e minitorus

Drift chambers
argon/CO_2 gas, 35,000 cells

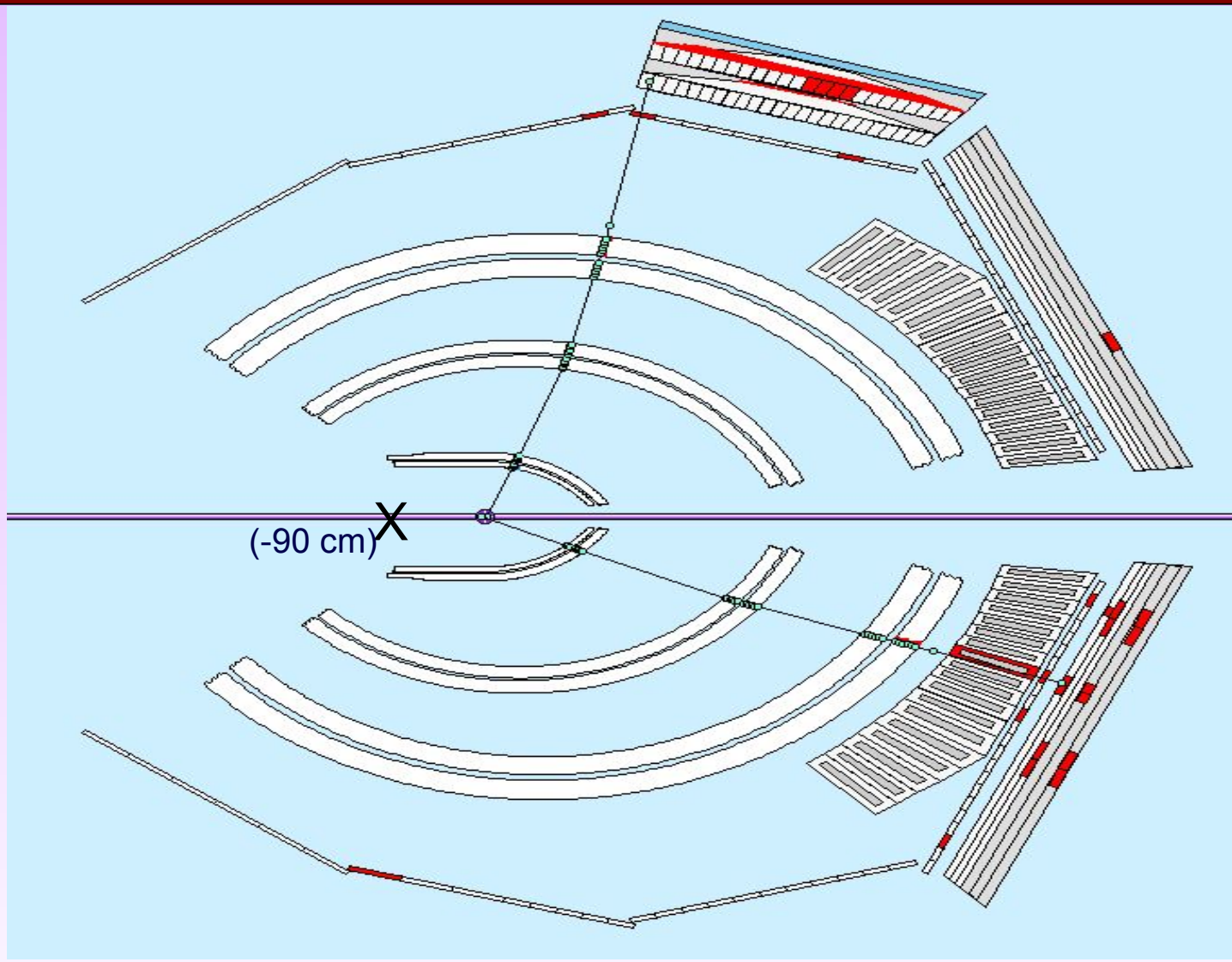


Electromagnetic calorimeters
Lead/scintillator, 1296 photomultipliers

Gas Cherenkov counters
e/π separation, 256 PMTs

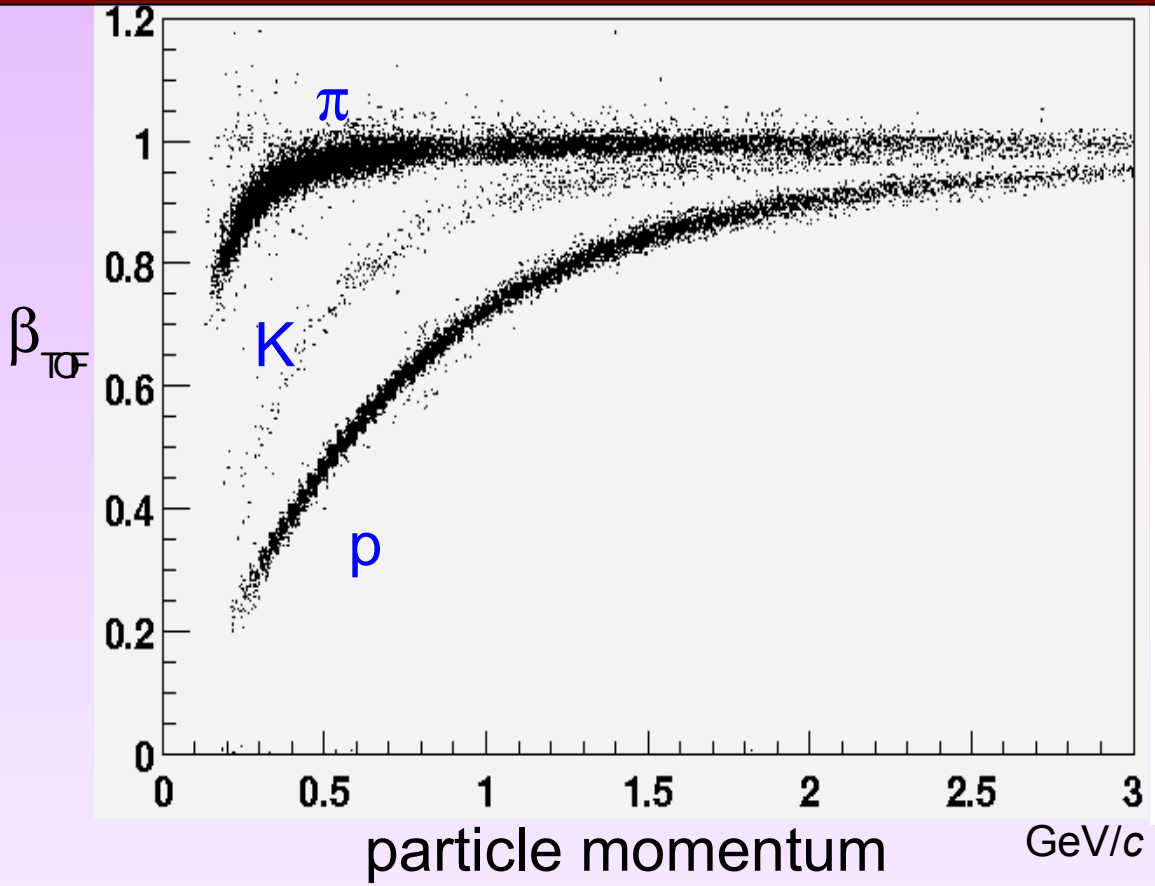
Time-of-flight counters
plastic scintillators, 516 photomultipliers

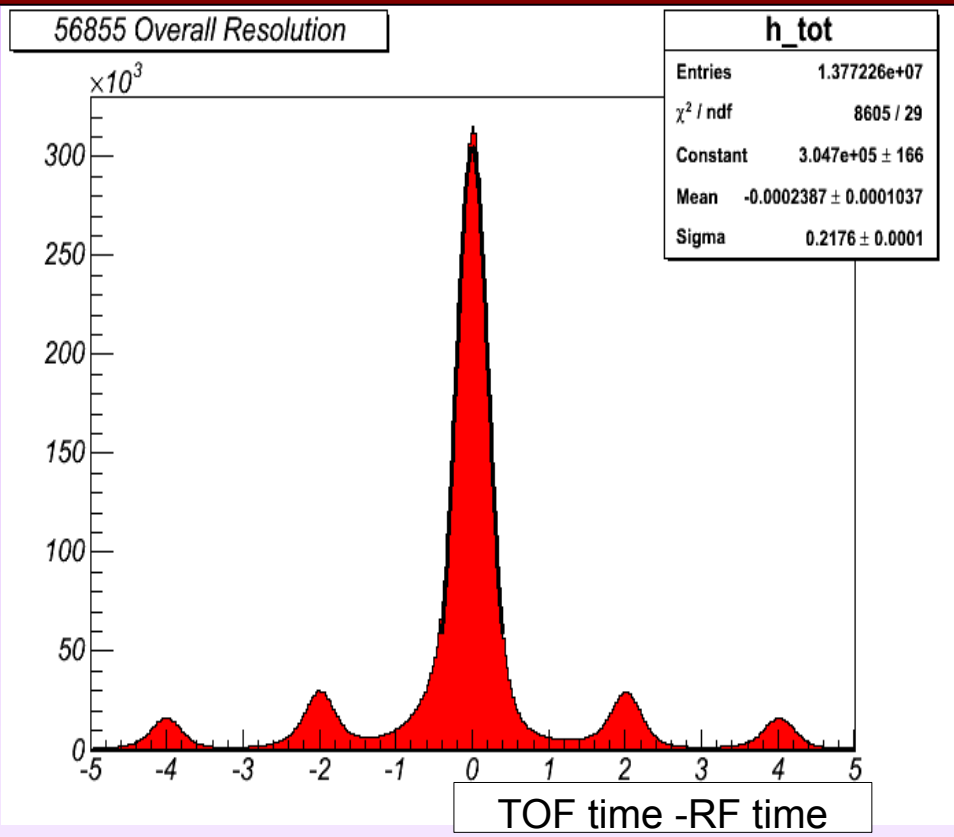
Tracking



- g12 used modified CLAS geometry to increase acceptance in the forward region for low t events.

Particle ID using TOF

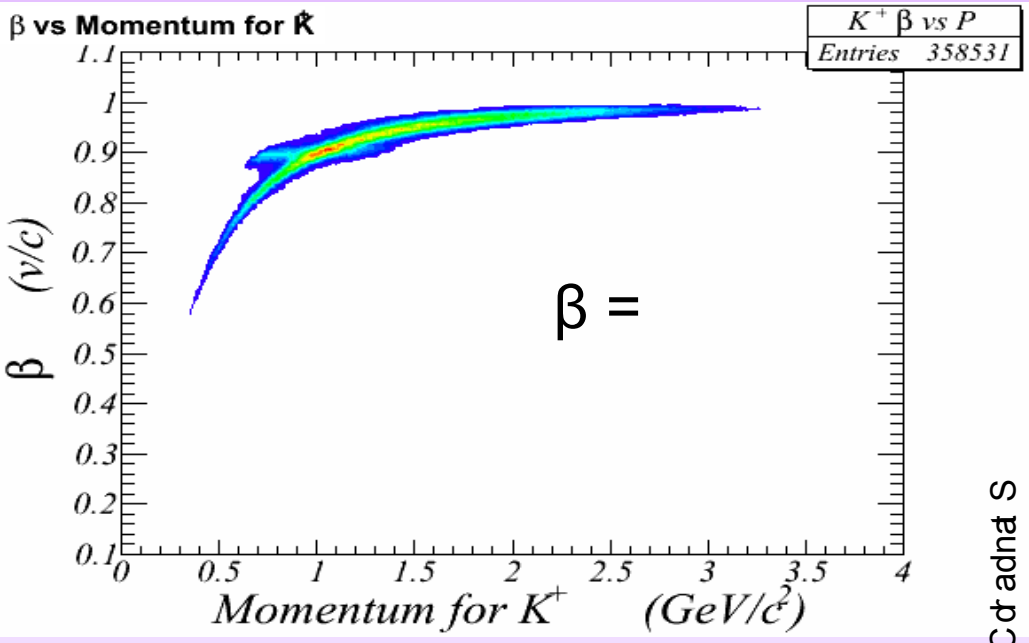




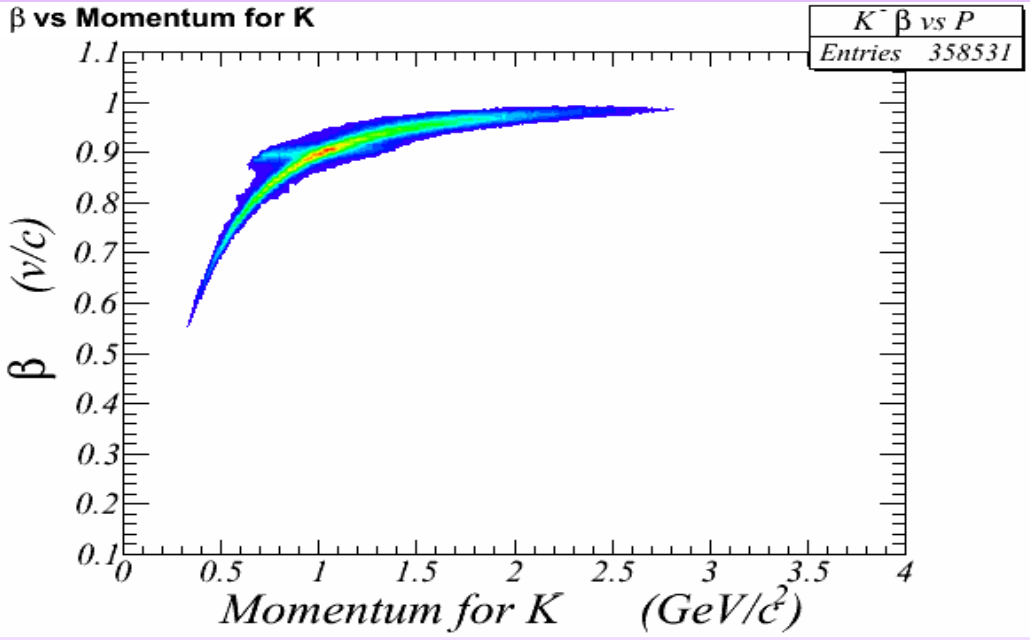
$$\beta = \frac{v}{c} = \frac{pathlength\ from\ event\ vertex\ to\ TOF}{Particle's\ flight\ time * \ c}$$

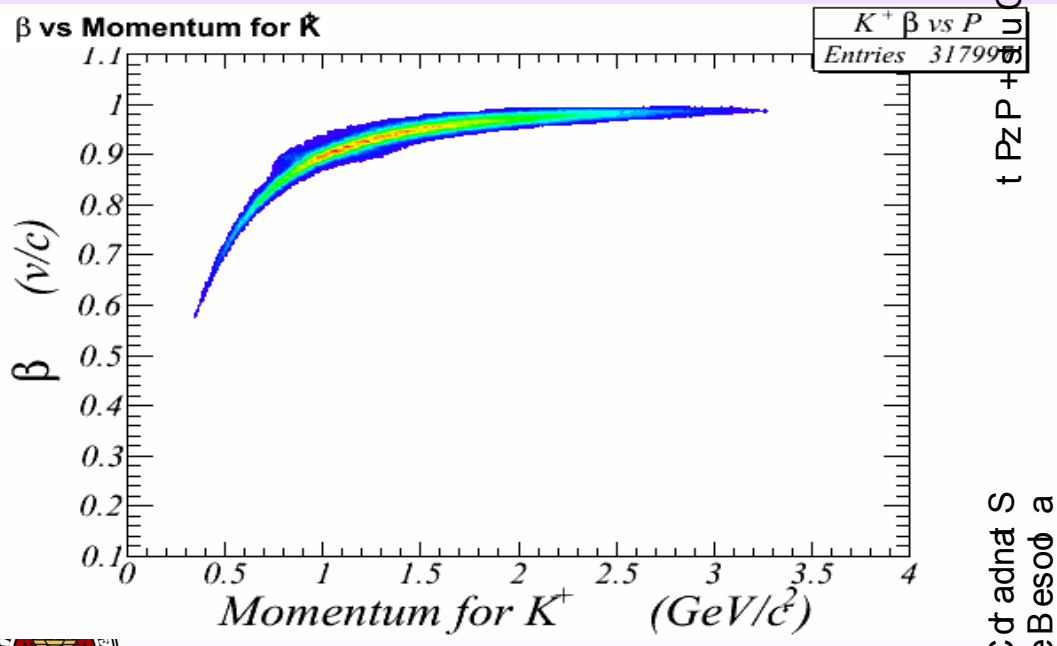
$$Mass = \frac{P}{\beta.\gamma(\beta)}$$

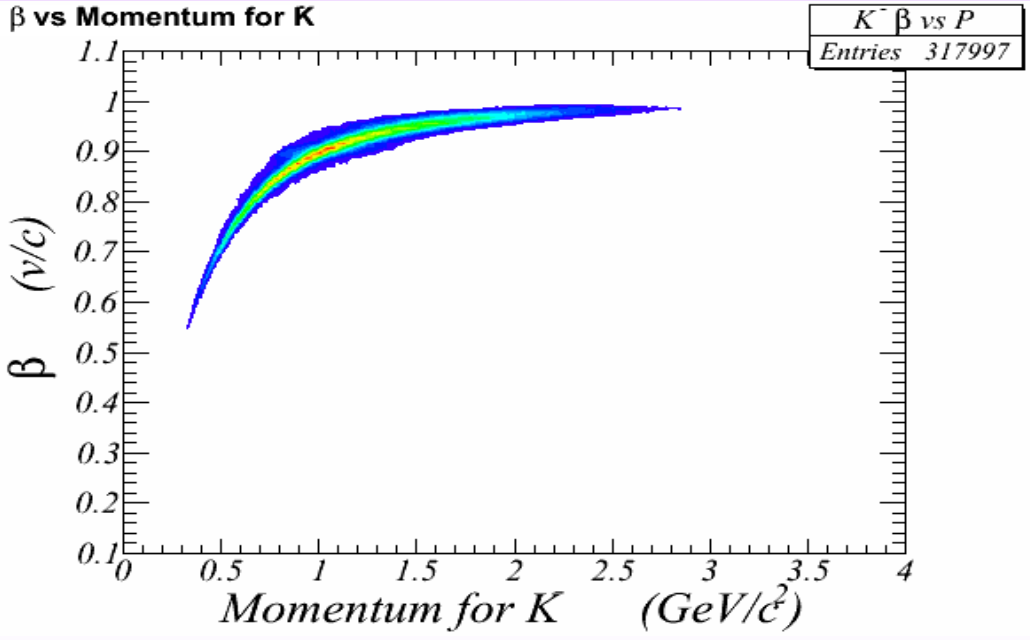
Particle ID (Kaons)



β =







g12 Data Summary

Commissioned : April 1, 2008 Completed : June 9, 2008

- 44.2 Days of beam-time over 70 calendar days
- **Beam current ~ 60-65 *nA***
- **E_e = 5.71 *GeV***, DAQ Rate ~ 8 *KHz*
- 26.2 billion triggers, 68 pb^{-1} of data
  - 2 prong or more, **$E_\gamma \geq 4.4$ *GeV***
  - 3 prong with no MOR, etc.
- **126 *TB*** of raw data on tape

Preliminary plots from ~ 1/3rd of g12 data

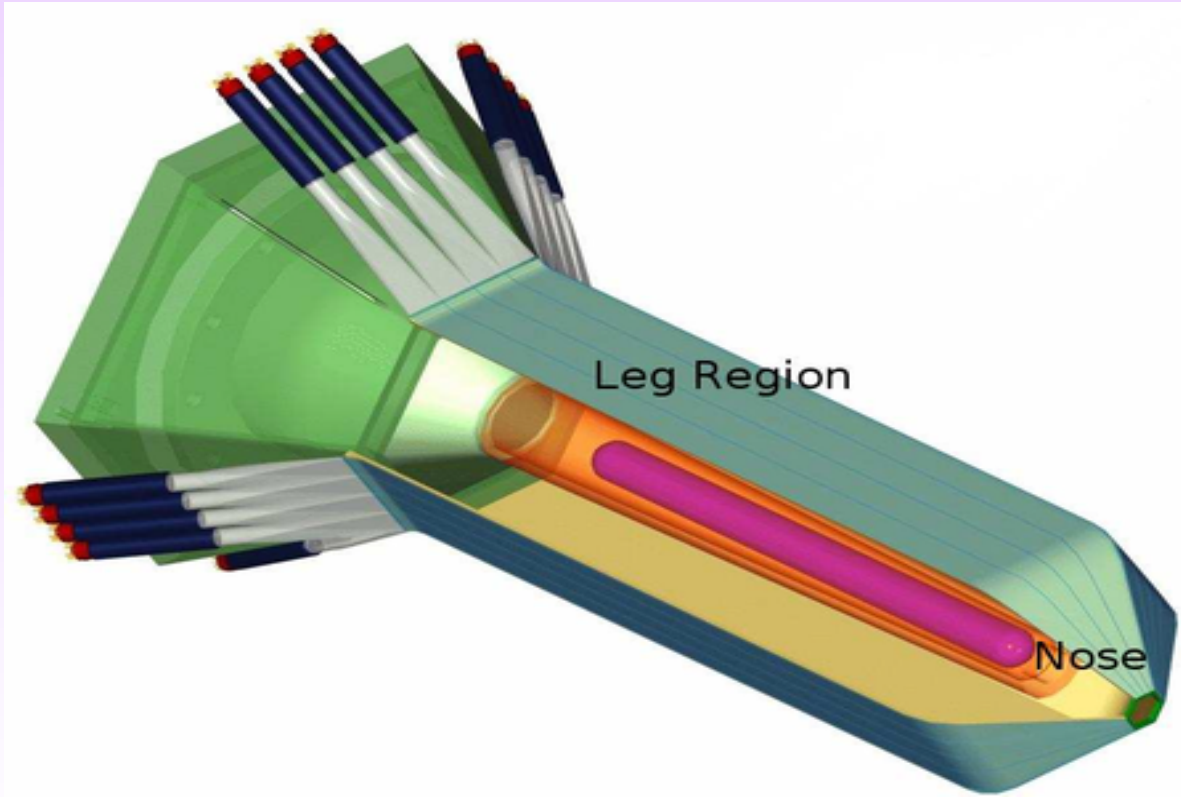
Calibrations

As part of my contribution to the experiment, I am responsible for calibrating the Tagger and the Start counter.

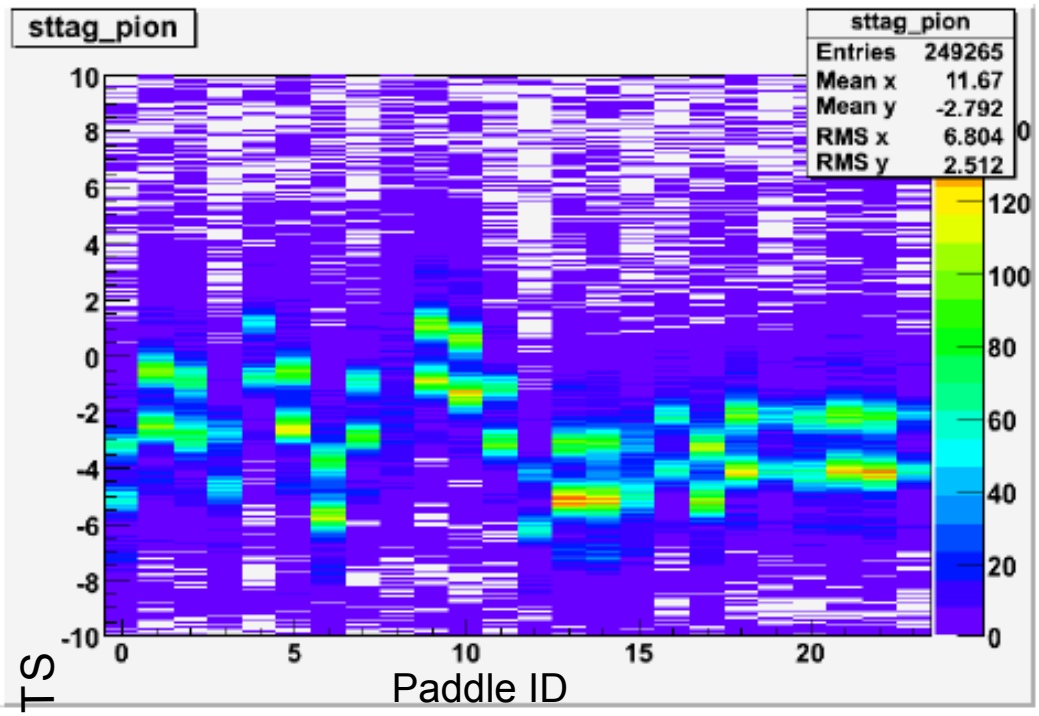
- Tagger tags the beam photon in CLAS with its energy and time using energy-momentum conservation for e^-.
- Start Counter helps find the right photon for the event as it is the closest of all detectors to the Target.

Start Counter

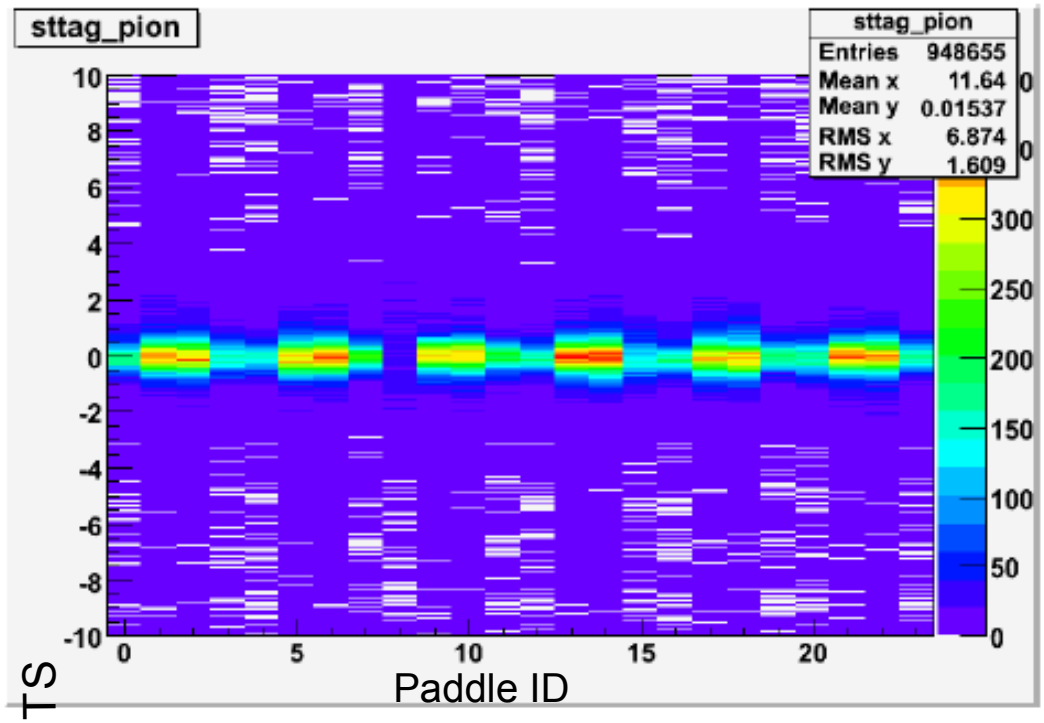
- Incorporates the independent sector based tracking of CLAS
- Covers the whole azimuthal (ϕ)
- g12 had ST pulled back from the center of CLAS to increase acceptance for low t, forward going particles
- ST is crucial for picking the right photon as well as Particle ID due to its proximity to the target



ST Alignment



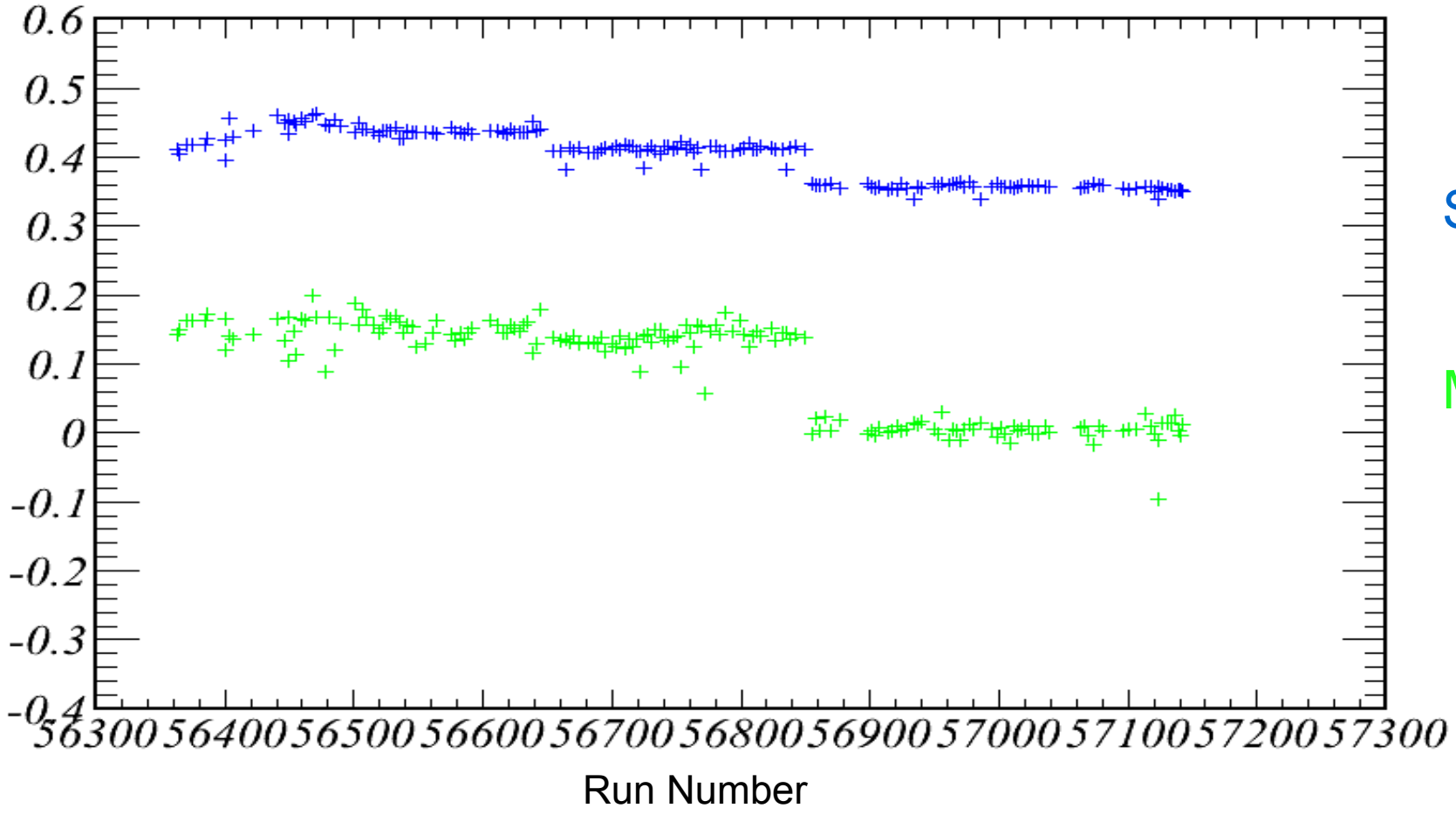
(a) Before



(b) After

- On the left is the plot of the time distribution of events in the 24 paddles before the iterative calibration process
- A month later with all paddles aligned and in time

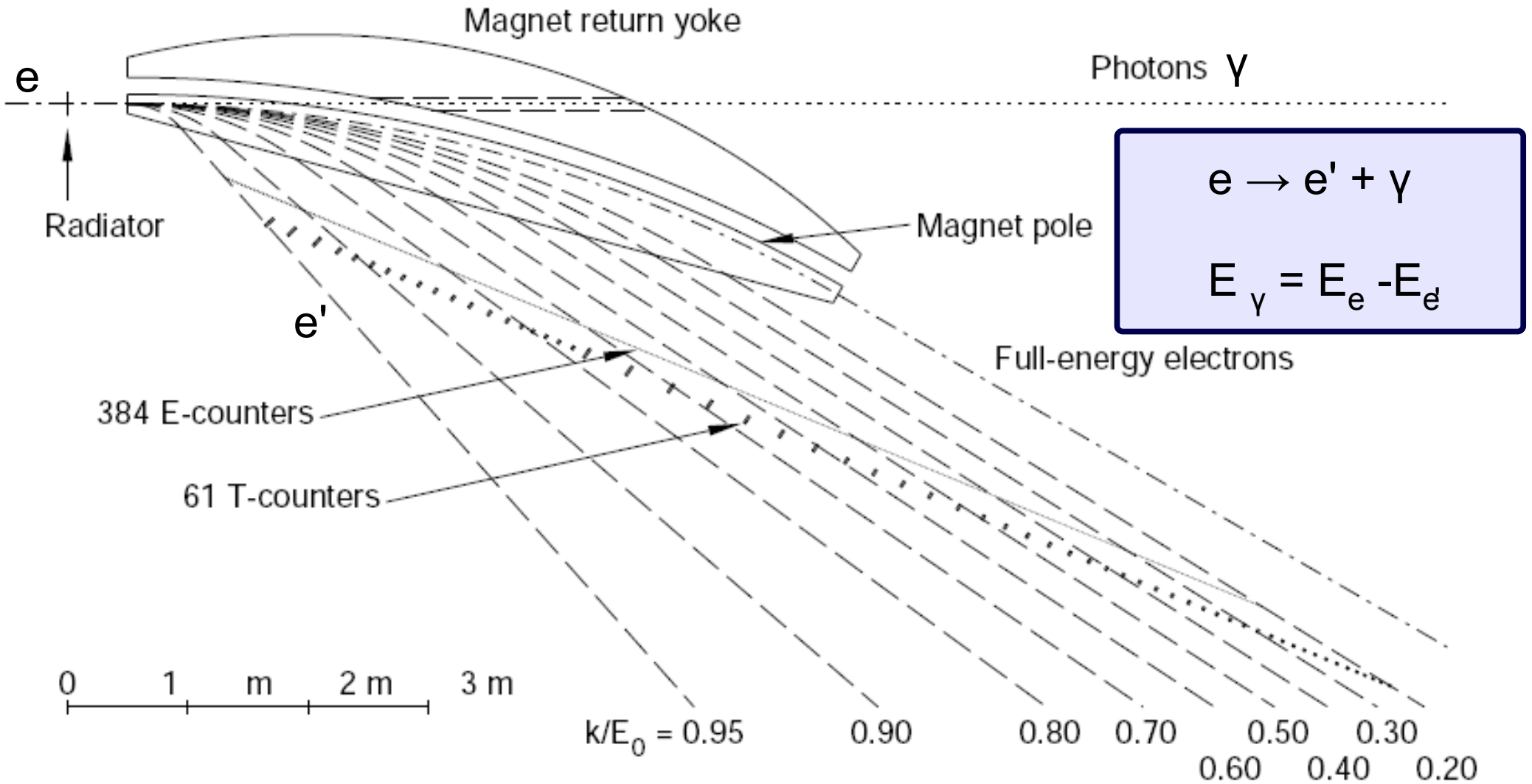
ST Run by Run Calibration



ST Resolution

- Resolution remains approx. constant through run-periods except for
- low current runs and runs after 56653 when we had a trigger change.

Tagger

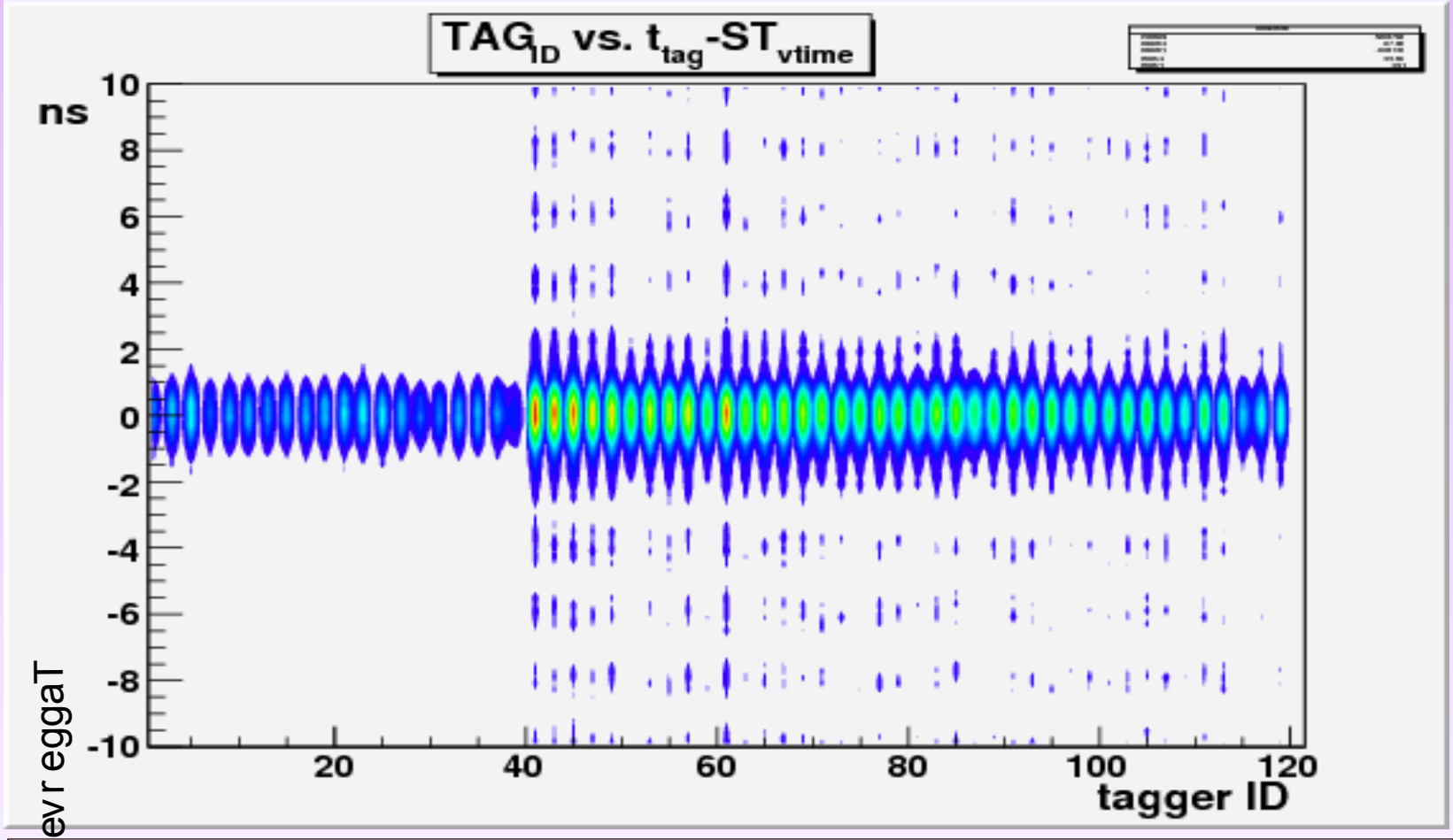


$e \rightarrow e' + \gamma$

$E_\gamma = E_e - E_{e'}$

Fig. 23. Hall B photon-tagging system.

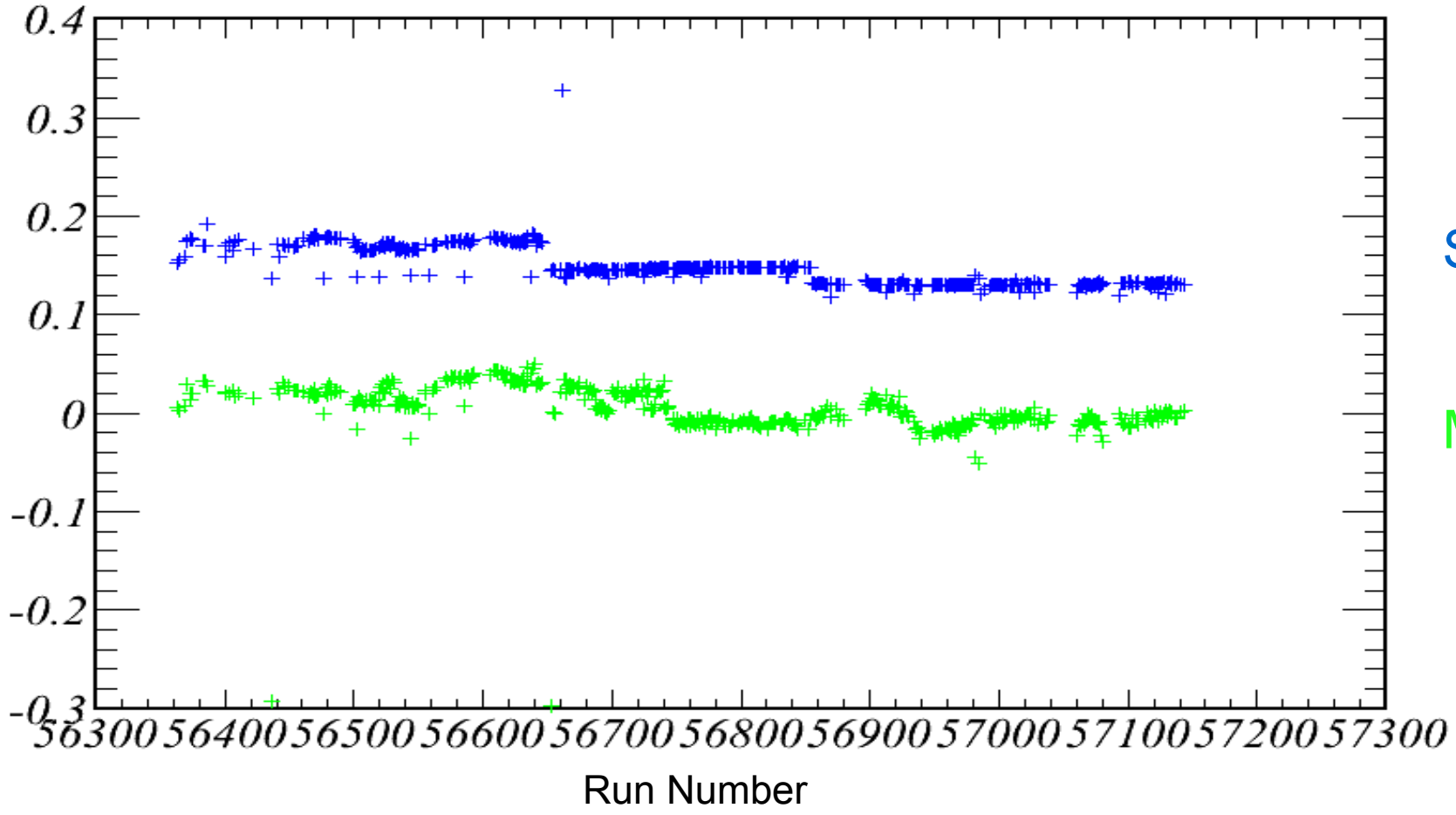
Tagger Calibration



Tagger Calibrations

This plot shows that a hit in the start counter picks the right RF bucket. If timing for one of the counter was misaligned, it would show up here.

Tagger run by run Calibration



Tagger Calibrations

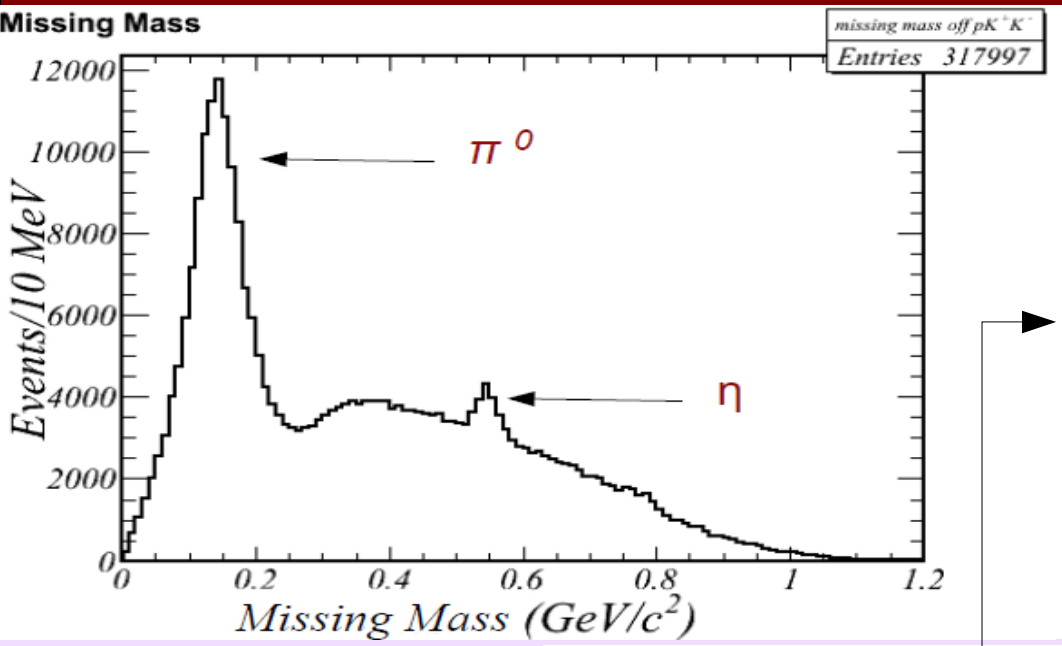
- Resolution remains more or less constant except for low current runs and runs after 56653 when we had a trigger change.

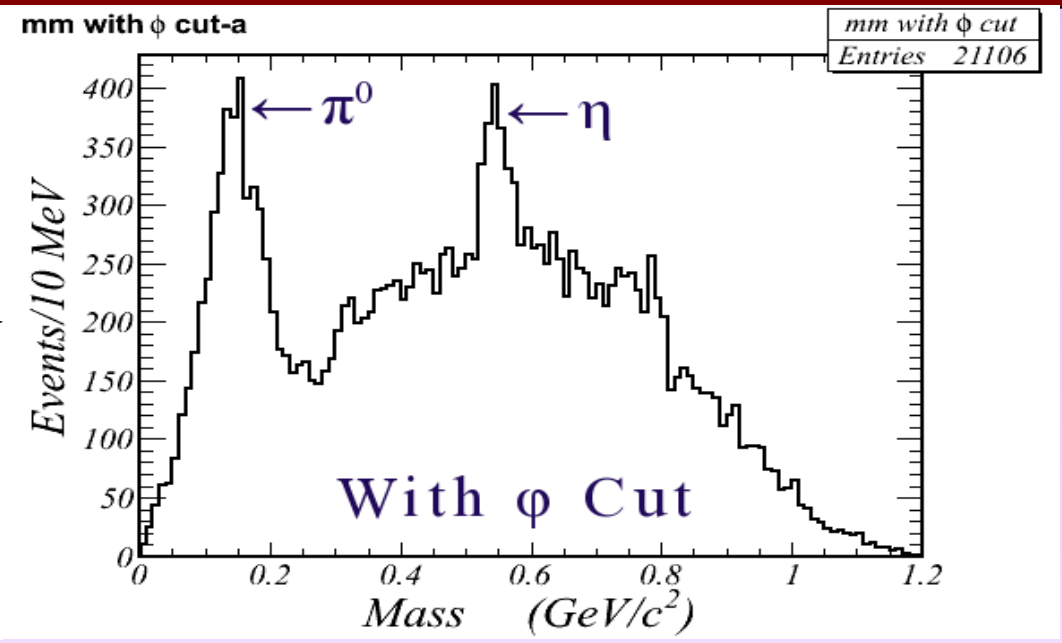
Analysis & Event Selection

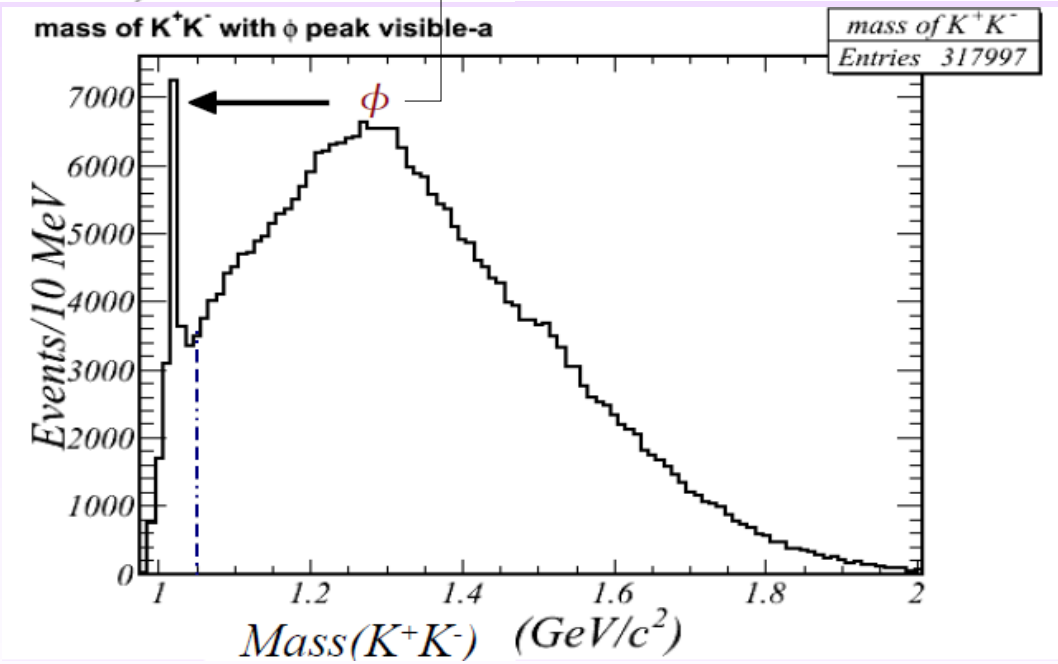
- $\gamma \; p \rightarrow p \; \varphi \; (\eta / \pi^0)$
- $\varphi \rightarrow K^+ K^-$
- η / π^0 *identified by missing mass*

- **Standard Cuts**
  - 3 charged tracks
  - Proton, K^+, K^-
  - Beam Energy > 4.4 GeV
  - Event Vertex (|x| < 1cm, |y| < 1cm, -70cm < z < -110cm)
  - |Photon time – Event vertex time| < 1 ns
- **Beta Cut**
  - | TOF β – Calculated β | < 0.01

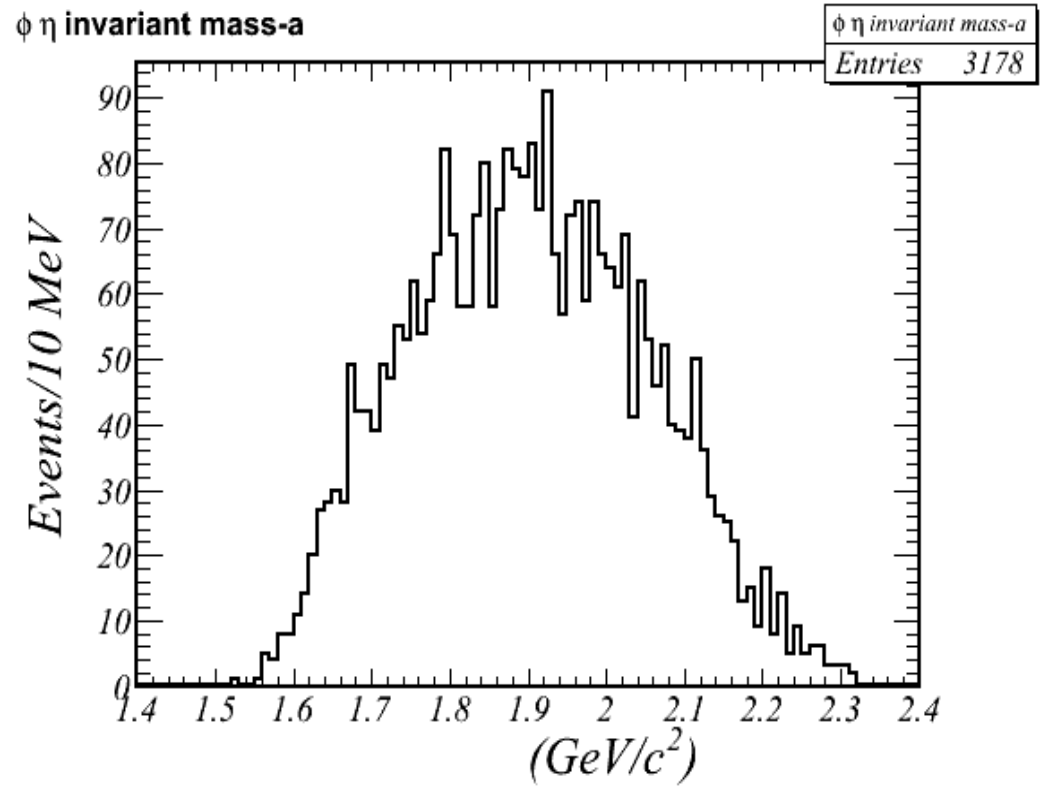
$\gamma\ p \rightarrow p\ K^+\ K^-\ [X]$



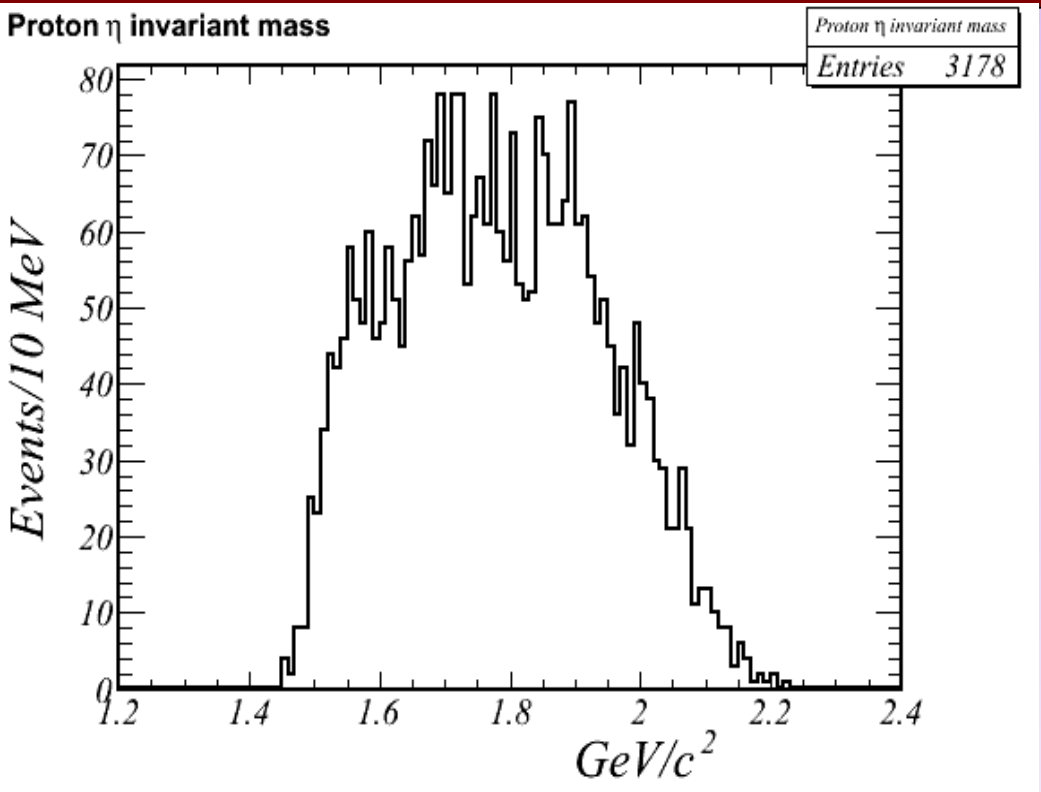




$\gamma\ p \rightarrow p\ \varphi\ [\eta]$



Mass(φ [η])

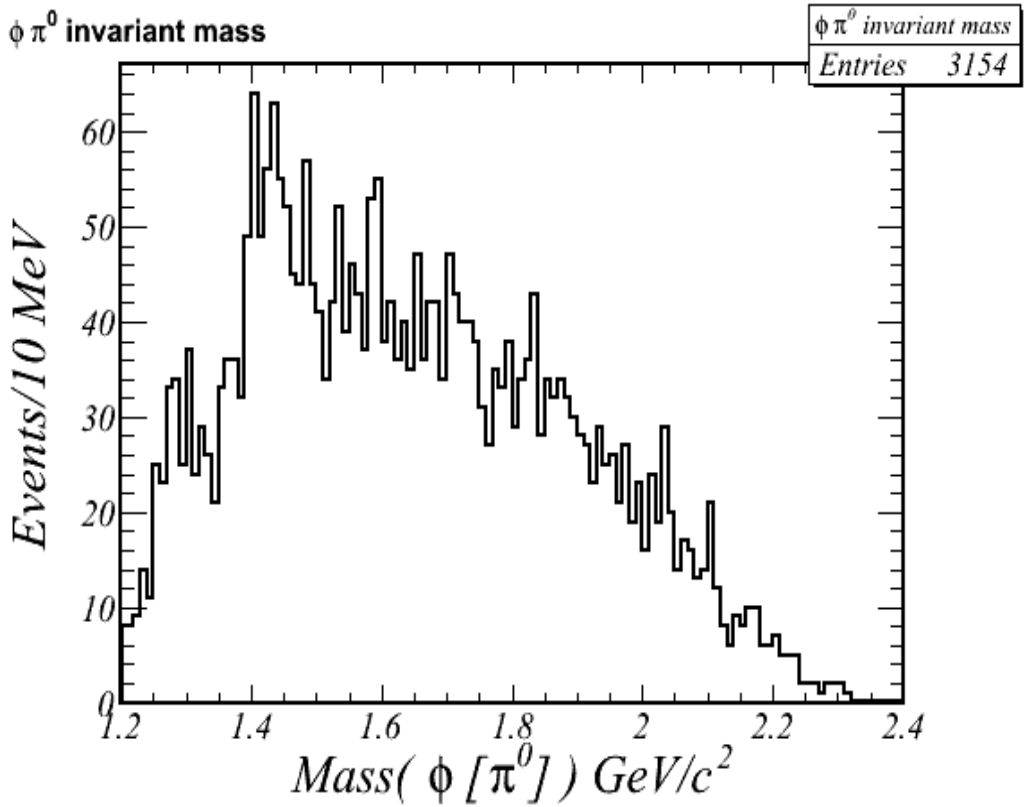


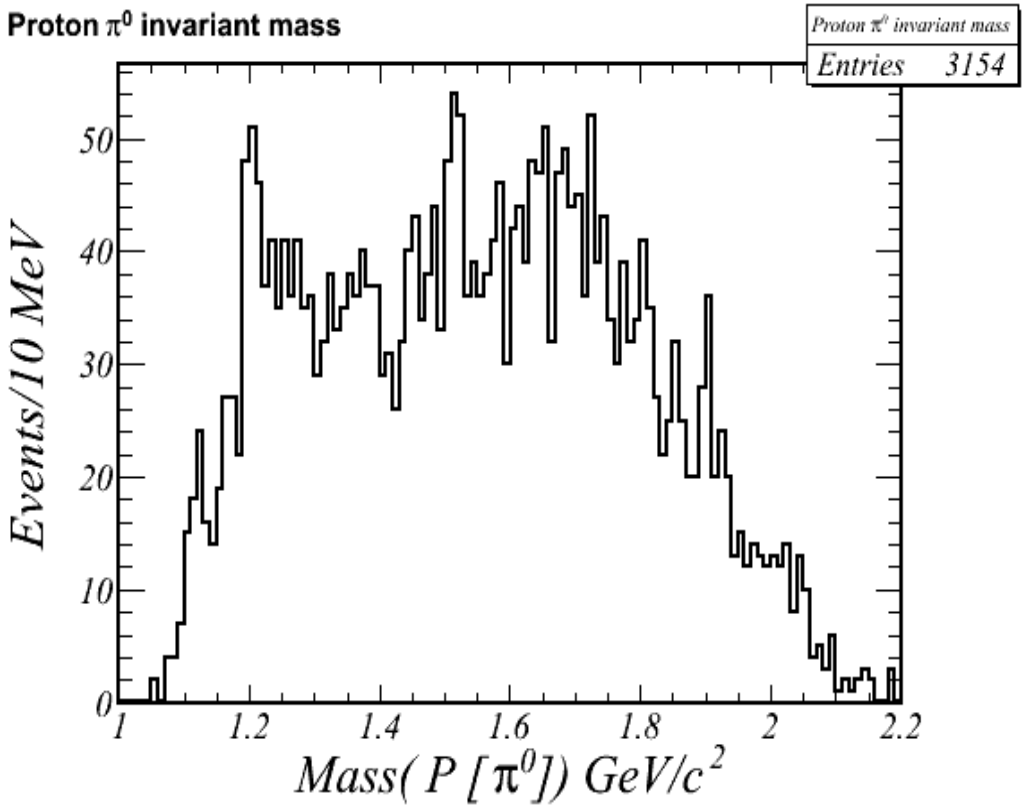
Mass(p [η])

Cuts (φ , η) → Mass ($K^+ K^-$) < 1.050 GeV/c^2 ,
0.500 GeV/c^2 < Missing Mass < 0.600 GeV/c^2

- Invariant mass for events with a φ meson and an eta meson identified through cuts on missing mass

$\gamma\ p \rightarrow p\ \varphi\ [\pi^0]$





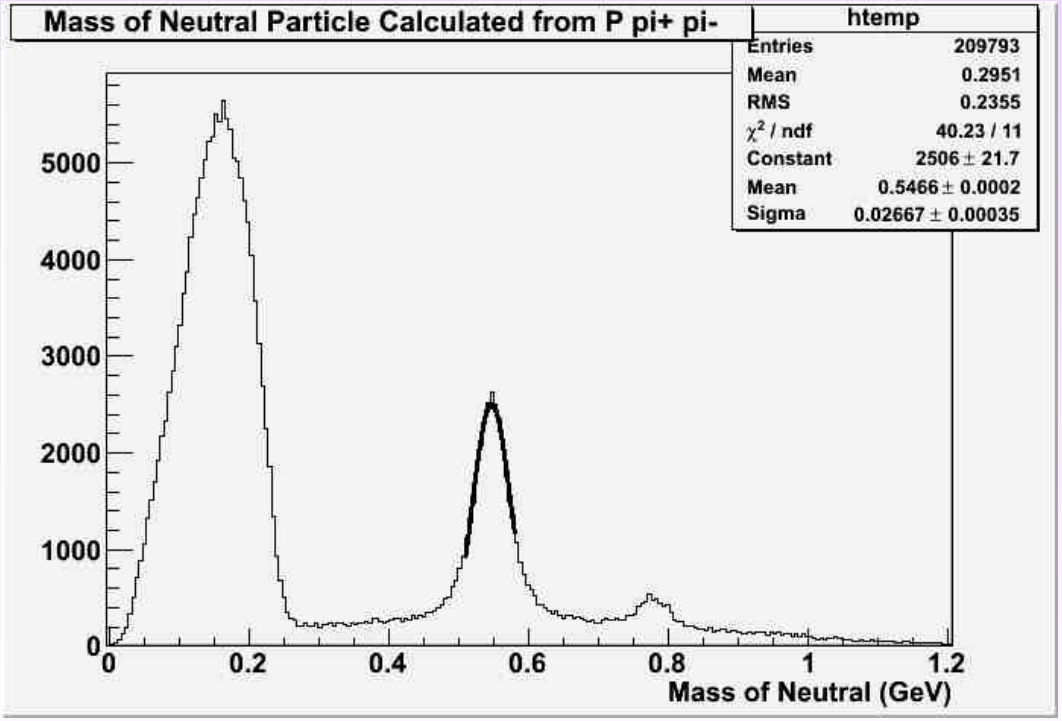
Cuts (φ , π^0) $\rightarrow$ Mass ($K^+ K^-$) < 1.050 GeV/c^2 ,
0.090 GeV/c^2 < Missing Mass < 0.190 GeV/c^2

- Invariant mass for events with a φ meson and a π^0 meson identified through cuts on missing mass

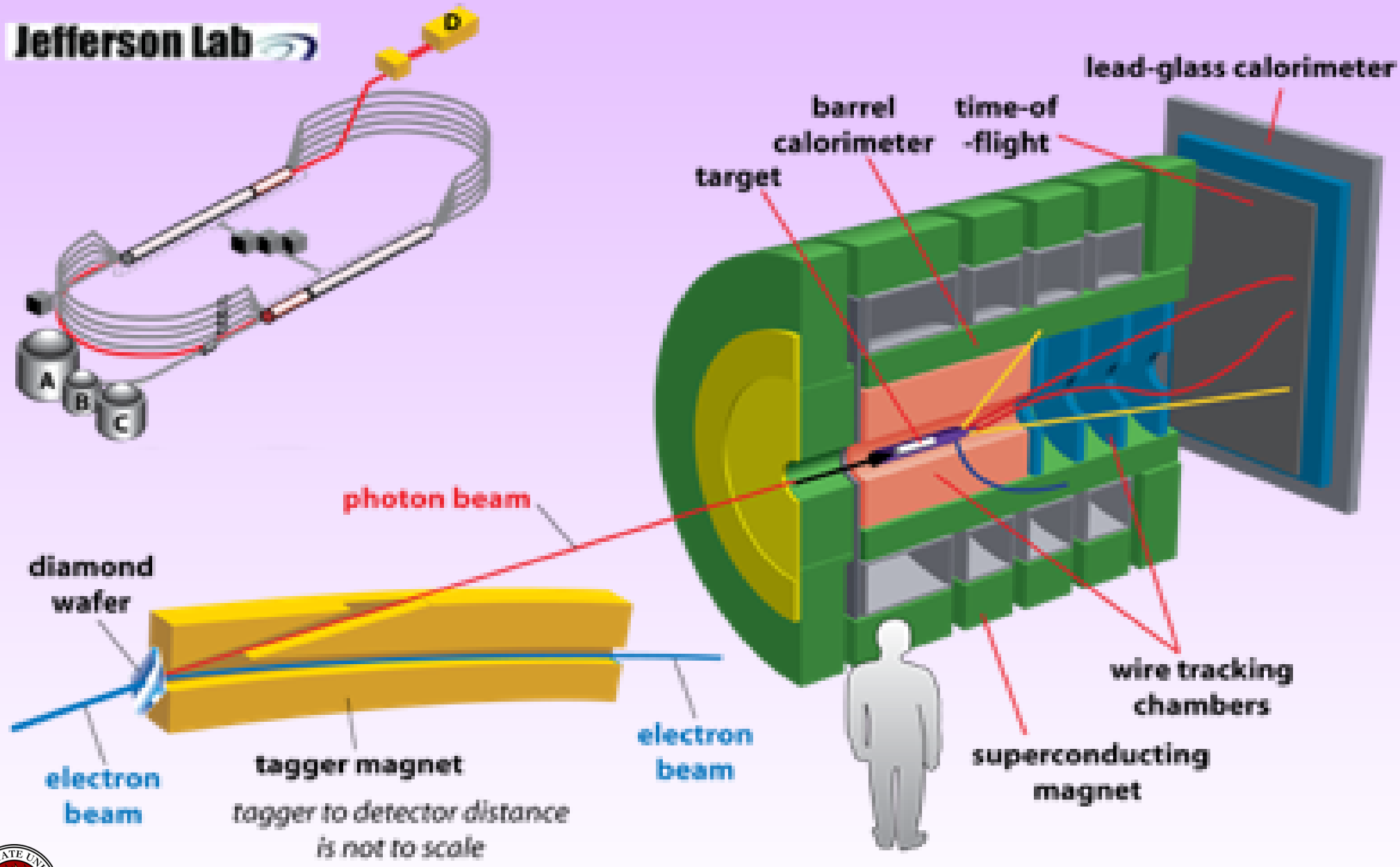
Things to do

- Momentum corrections
- Monte-Carlo simulations
- Tagger energy corrections
- Acceptance corrections
- Use EC to clean up Data

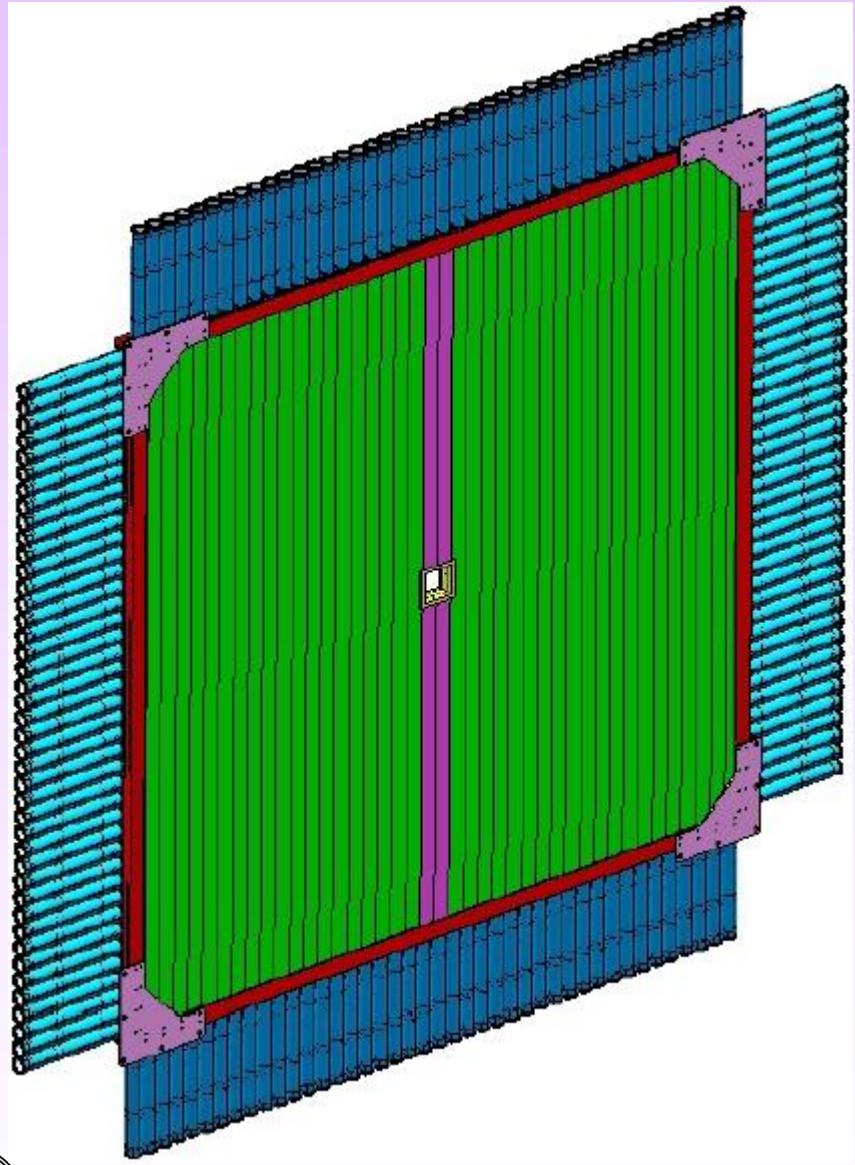
Plot from η-π^0 analysis from g12
by
Diane Schott (FIU)



GlueX


Jefferson Lab
D
A
B
C
lead-glass calorimeter
barrel calorimeter
time-of -flight
target
photon beam
diamond wafer
electron beam
tagger magnet
tagger to detector distance is not to scale
electron beam
wire tracking chambers
superconducting magnet

GlueX TOF



- Designed to understand Confinement of Quarks and Gluons in QCD
- Experiment will be located at the Under-Construction Hall D at Jefferson Lab
- 12 GeV e^- beam will be used to produce 9 GeV photon beam
- Time of Flight detector components are being designed and tested at FSU

TOF Test Lab

Summary

- Strangeonia is quite an interesting and important sector to look at. It will give us an insight into Non-perturbative QCD regime.
- g12 has a huge data set that has been calibrated, is being processed and is now available for analysis.
- From preliminary analysis, we observe $\gamma p \rightarrow p \varphi \eta$, which is an ideal channel for observation of strangeonia.