

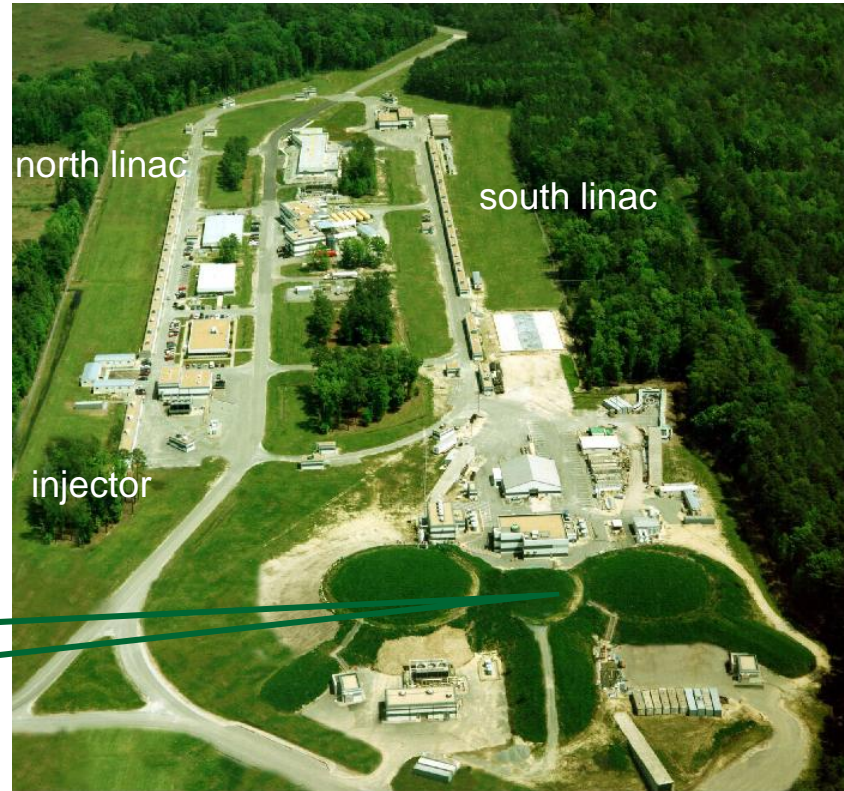
# **Jefferson Lab: Overview, Prospects, and First Attempts at Data Mining for A' search**

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Stepan Stepanyan, Jefferson Lab*

# Jefferson Lab



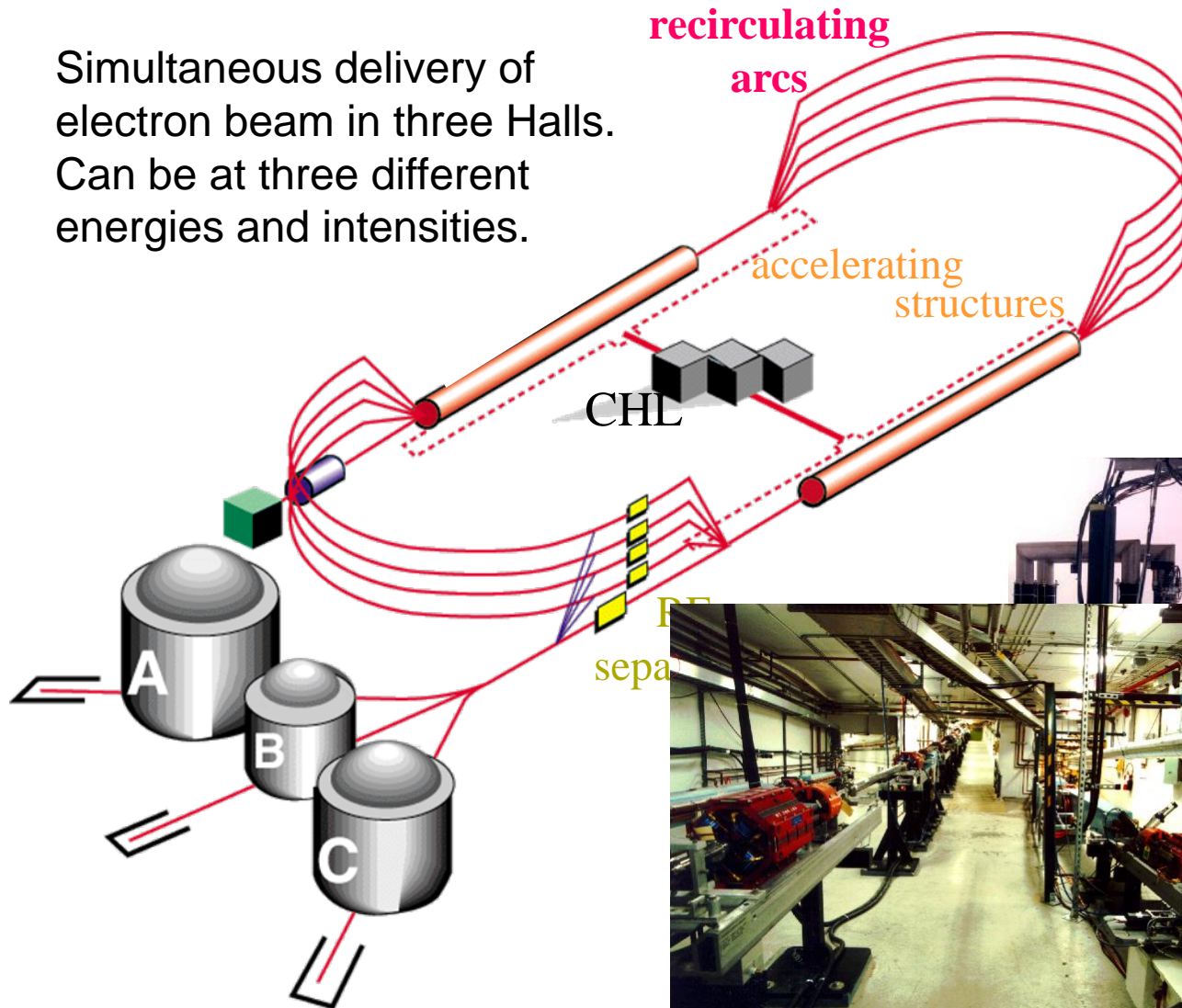
CEBAF



Experimental Hall B  
CLAS detector

# CEBAF - Continuous Electron Beam Accelerator Facility

Simultaneous delivery of electron beam in three Halls. Can be at three different energies and intensities.



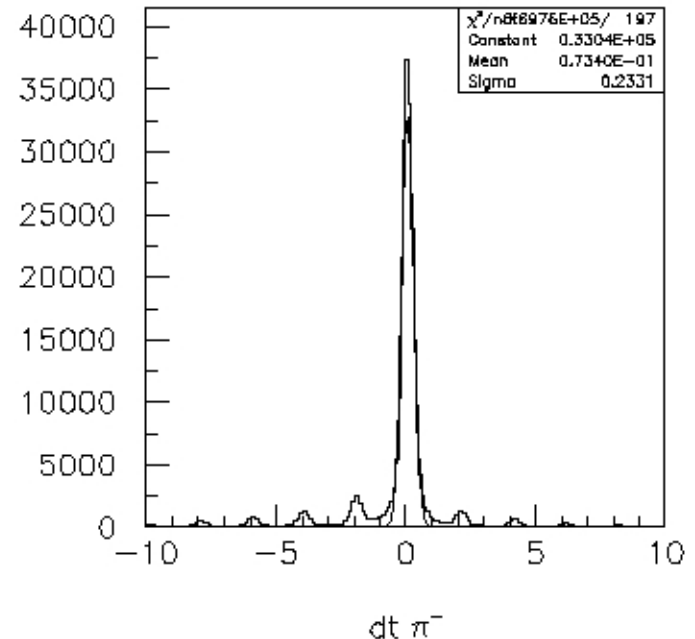
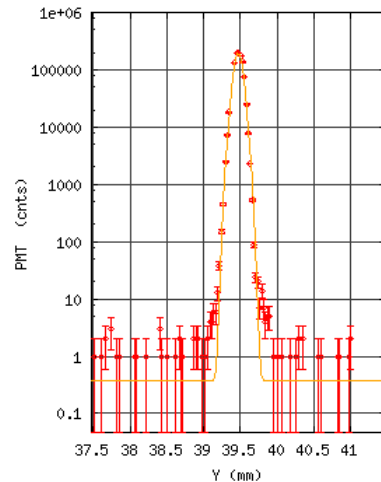
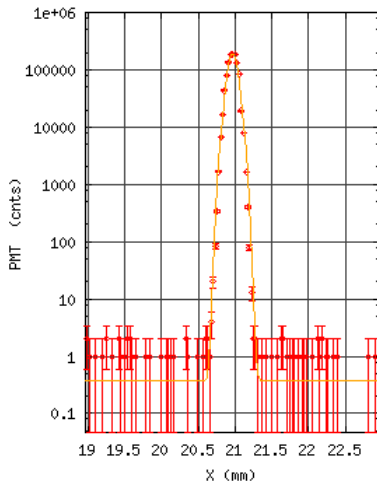
# CEBAF Beam Characteristics

**Energy** < 6 GeV  
**Beam size** <100  $\mu\text{m}$   
**Bunch length** 300 fs, 90  $\mu\text{m}$   
**Energy spread**  $2.5 \times 10^{-5}$   
**Beam current** < 100  $\mu\text{A}$  (A&C)  
 < 300 nA (B)

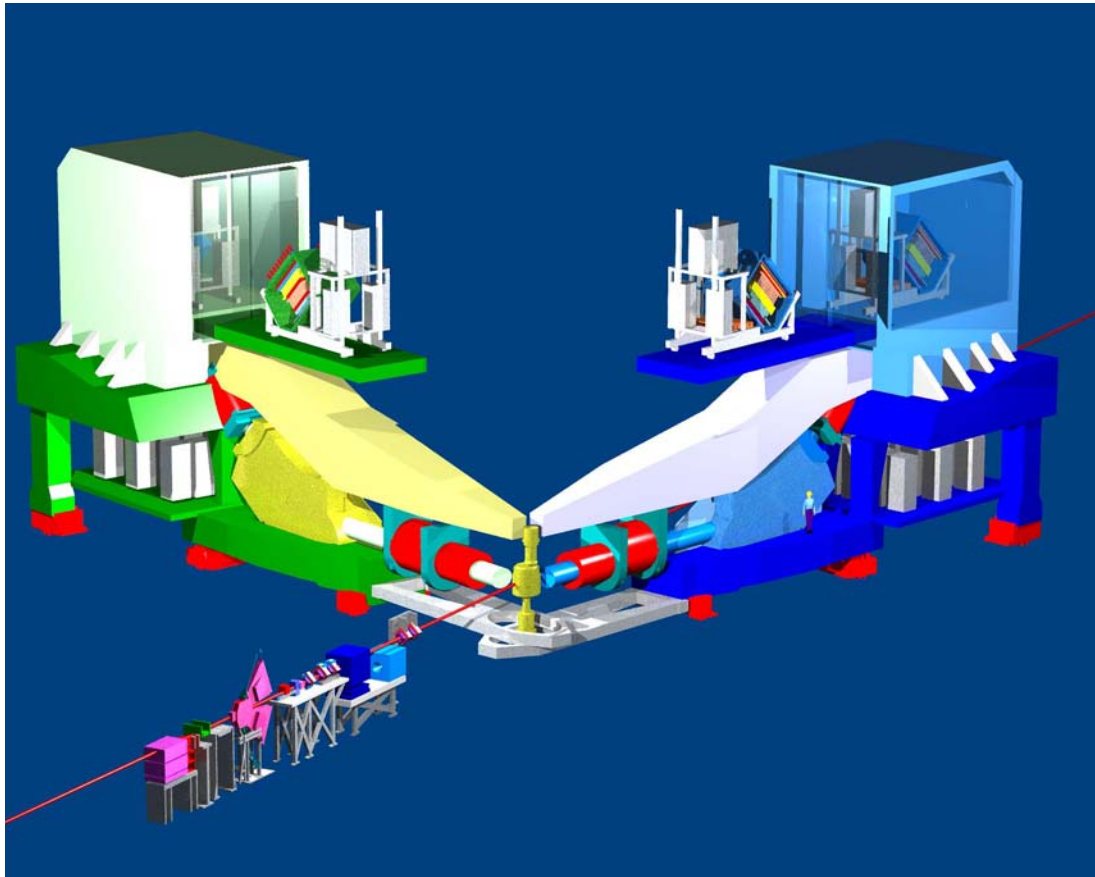
**Beam polarization**  $\sim 85\%$   
**Fundamental mode frequency** 1497 MHz  
**Bunch repetition** 499 MHz/Hall  
**Bunch separation** 2.004 ns

back\_x = 0.36697 +/- 0.029012  
 amp\_x = 195323 +/- 1721.57  
 mean\_x = 20.9676 +/- 0.000696924  
 sigma\_x = 0.0633411 +/- 0.000658366

back\_y = 0.36697 +/- 0.029012  
 amp\_y = 203099 +/- 1108.51  
 mean\_y = 39.4734 +/- 0.000425665  
 sigma\_y = 0.057157 +/- 0.00045369

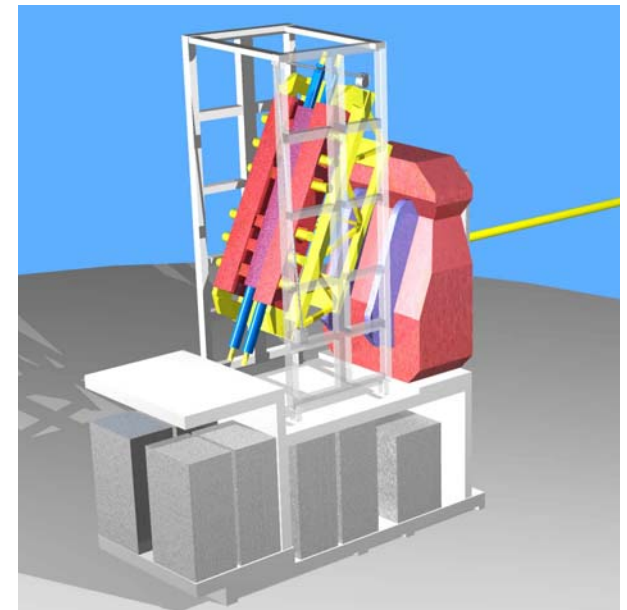


# Experimental Hall-A



Big-bite spectrometer

- Base equipment –
  - two high resolution ( $10^{-4}$ ) spectrometers ( $P < 4\text{GeV}$ ,  $\Delta\Omega \sim 6\text{msr}$ )
- Additional detectors –
  - Compton polarimeter
  - DVCS calorimeter and proton/neutron detectors

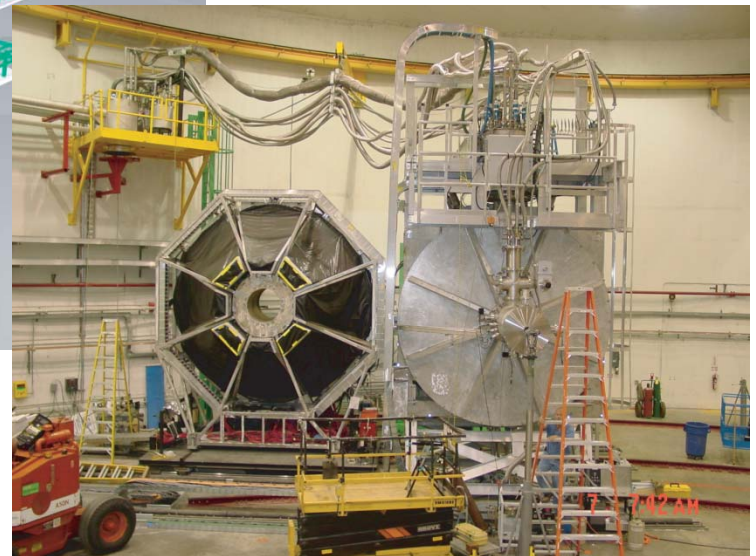
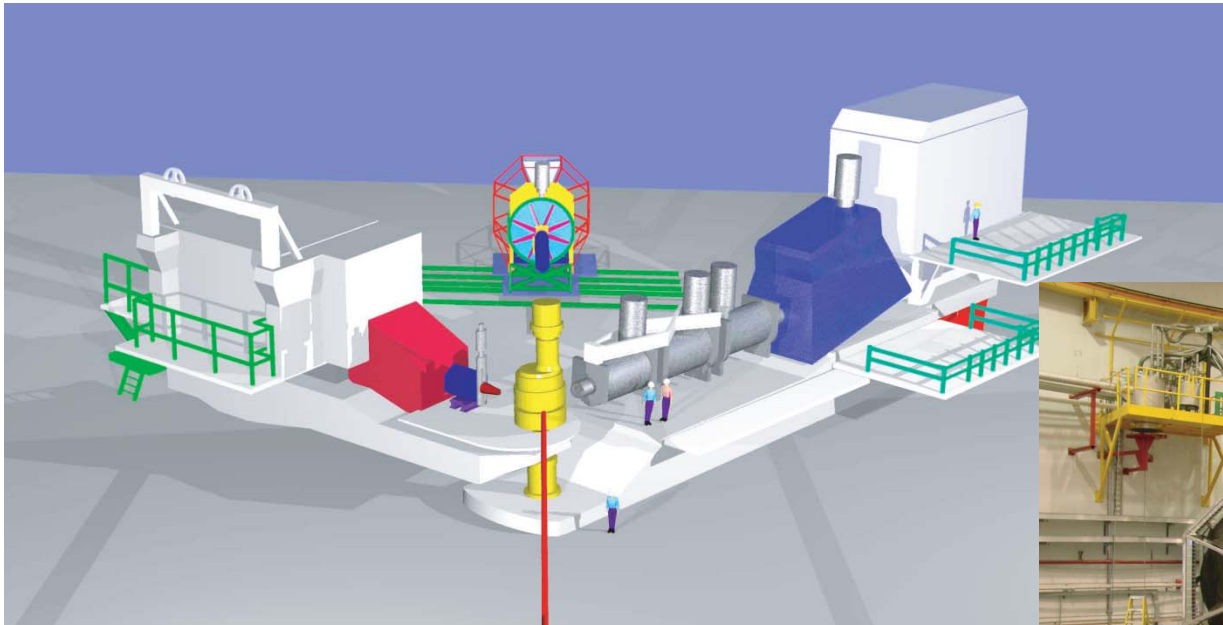


# Experimental Hall-C

Base equipment –

high momentum spectrometers,  $P < 7.5 \text{ GeV}$ ,  $\Delta P/P < 10^{-3}$ ,  $\Delta\Omega \sim 6 \text{ msr}$

short orbit spectrometer,  $P < 2 \text{ GeV}$ ,  $\Delta P/P \sim 10^{-3}$ ,  $\Delta\Omega \sim 9 \text{ msr}$



Additional detectors –  
Qweak, BigCal

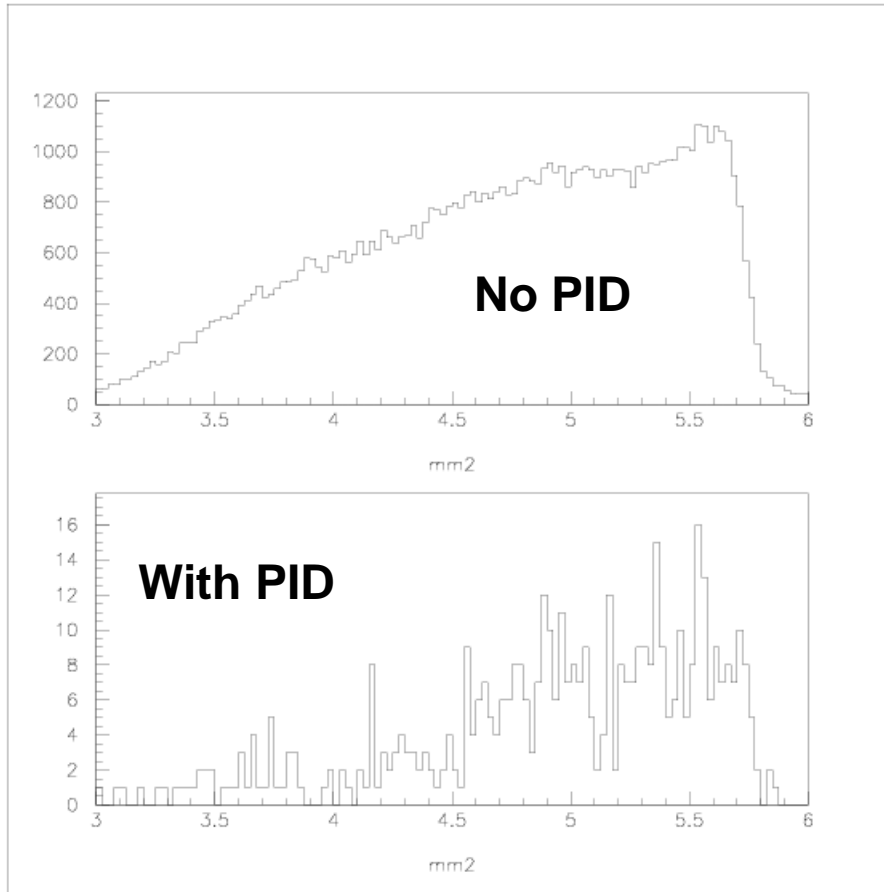
# “Data mining” from Hall C

- **“Baryon” experiment:  $E=5.5$  GeV, electrons in SOS at 47 deg,  $P=1.7$  GeV, pions, protons, positrons in HMS at 12 to 24 deg.,  $P=2$  to 5 GeV, 60 days**
- **Good particle ID needed (gas Cherenkov, EM calorimeter, timing) to separate  $e^+$  from 1000x more pions**

# “Data mining” from Hall C

- **Beam current 100 mA, target 4 cm liquid hydrogen.**
- **Mass resolution very good ( $dM/M=0.2\%$ ), but no peaks seen.**
- **Probably not enough events to set meaningful limits on coupling epsilon**





**Squared di-lepton mass from Hall C: mass region is 2 to 3 GeV.**

# “Data mining” from Hall C

- **Other experiments with SOS, HMS could be looked at: some had high-Z targets (Fe and Au).**
- **Next experiment, Qweak will run for 3 years on 35 cm LH2 with 150  $\mu\text{A}$  beam: very high integrated luminosity.**
- **Look for  $\mu^+$ ,  $\mu^-$  pairs behind tous magnet and shielding?**

# Future experiments in Hall C

- **After 2013, new SHMS spectrometer will replace SOS: can go to 4 deg.**
- **Many experiments will have opposite polarity for SHMS and HMS, and good electron/positron PID.**
- **Would be ideal for targeted search for a particular mass candidate in 0.2 to 4 GeV mass range.**



# Hall B CLAS detector

## Charged particles:

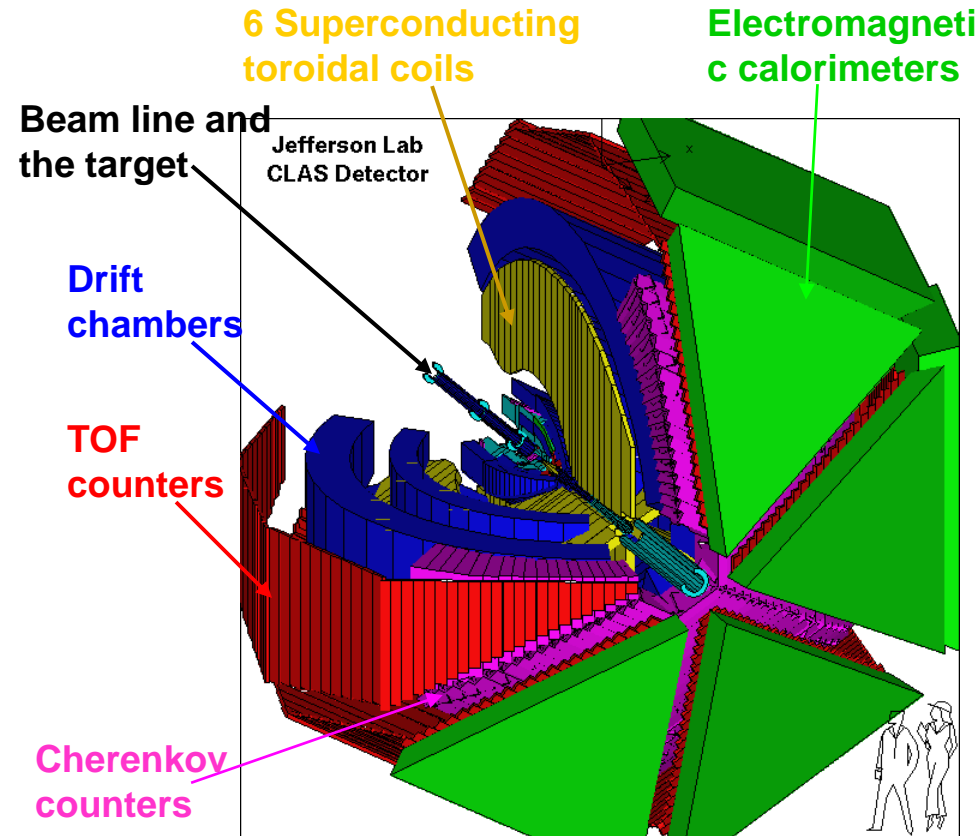
- $\Theta = 10$  to  $130$  degree
- $dP/P = 0.5\%$  to  $2\%$
- $\Delta\phi \sim 80\%$  of  $2\pi$

## Neutrals:

- $\theta = 2$  to  $45$  degree
- $\Delta\phi \sim 50\%$  of  $2\pi$

## Electrons:

- $\theta = 15$  to  $50$  degree
- $\Delta\phi \sim 50\%$  of  $2\pi$

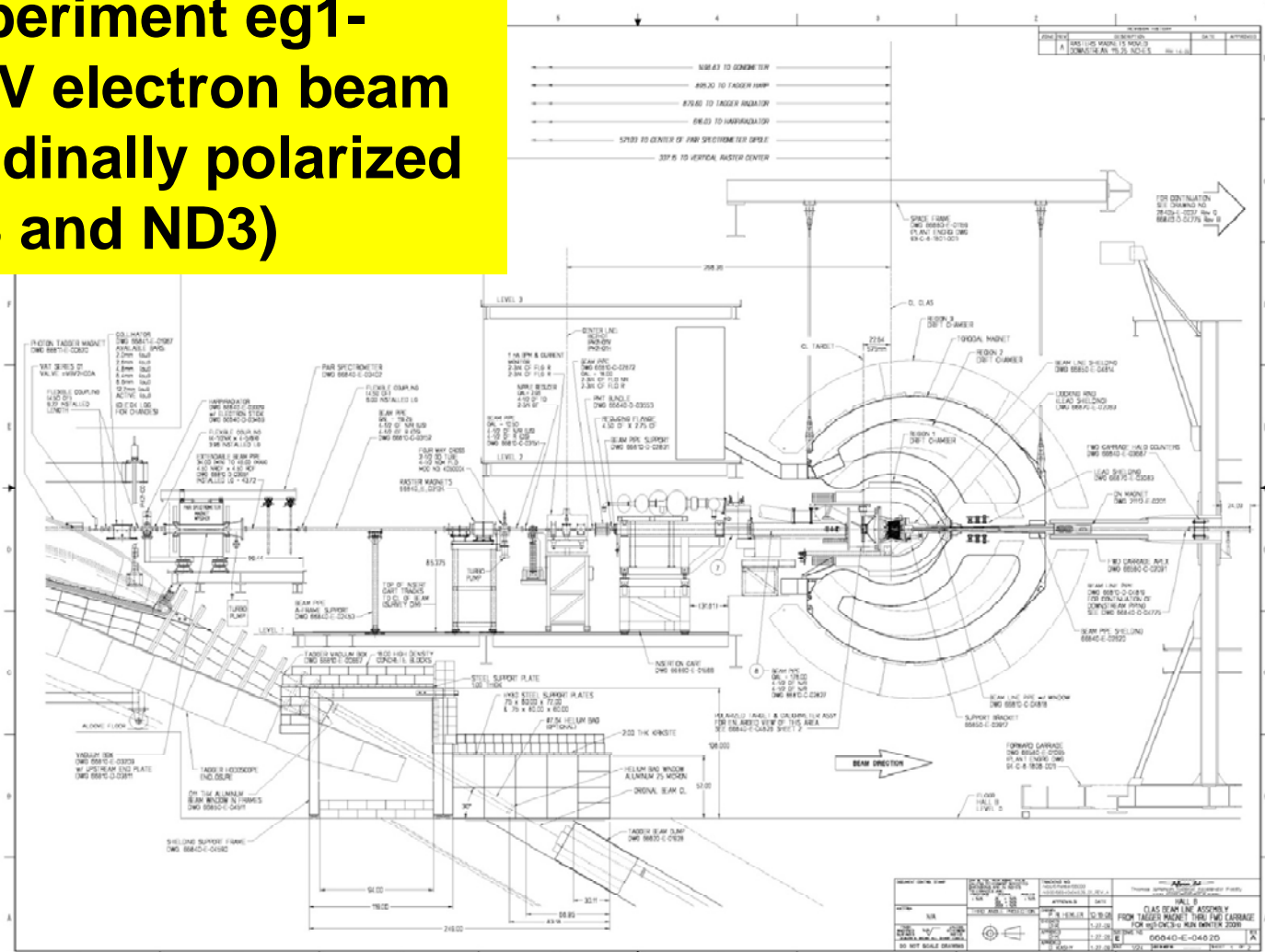


Best suited for multi-particle final states



# Hall B - CLAS layout

Current experiment eg1-dvcs– 6 GeV electron beam and longitudinally polarized target (NH<sub>3</sub> and ND<sub>3</sub>)

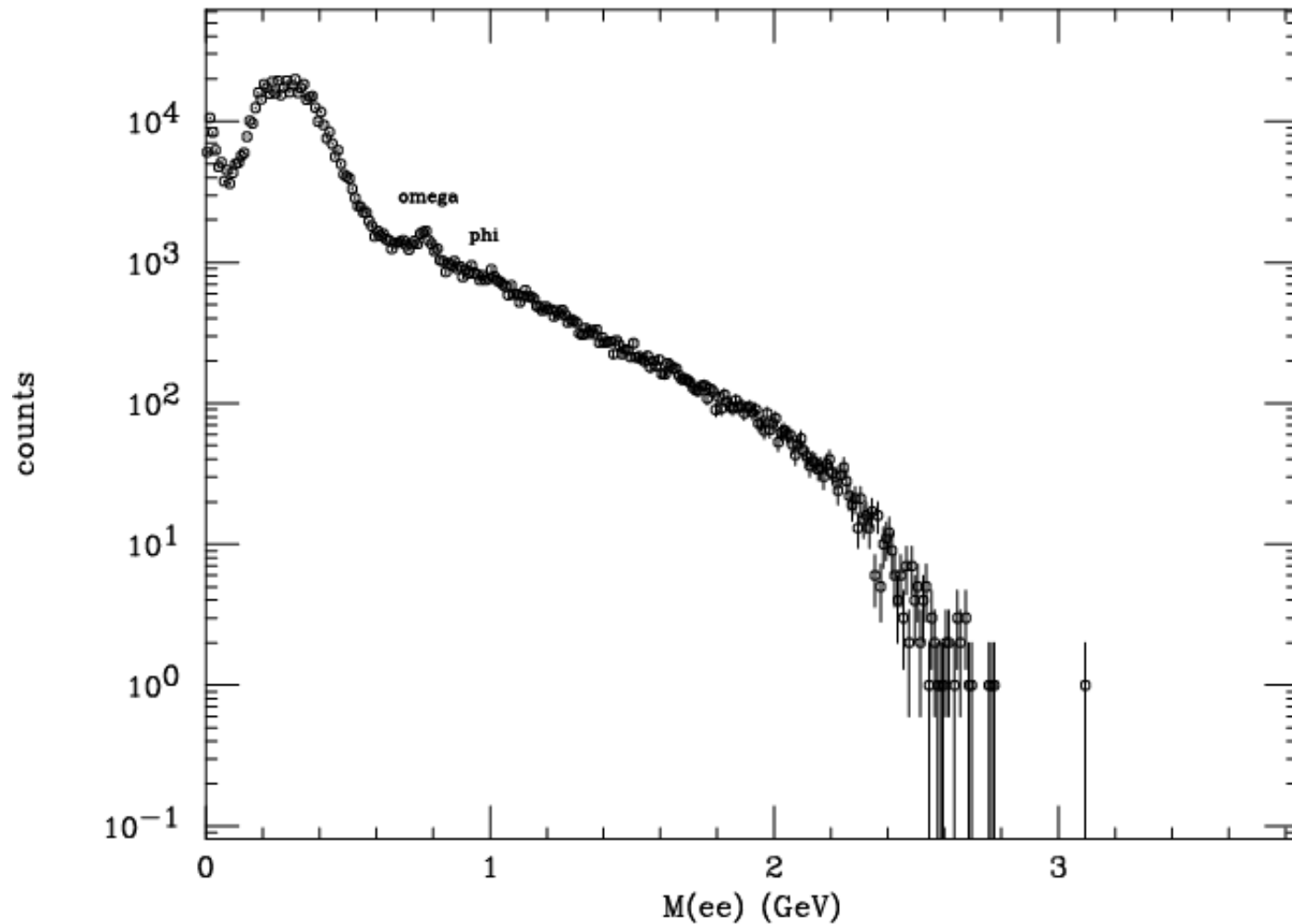


# “Data mining” from Hall B

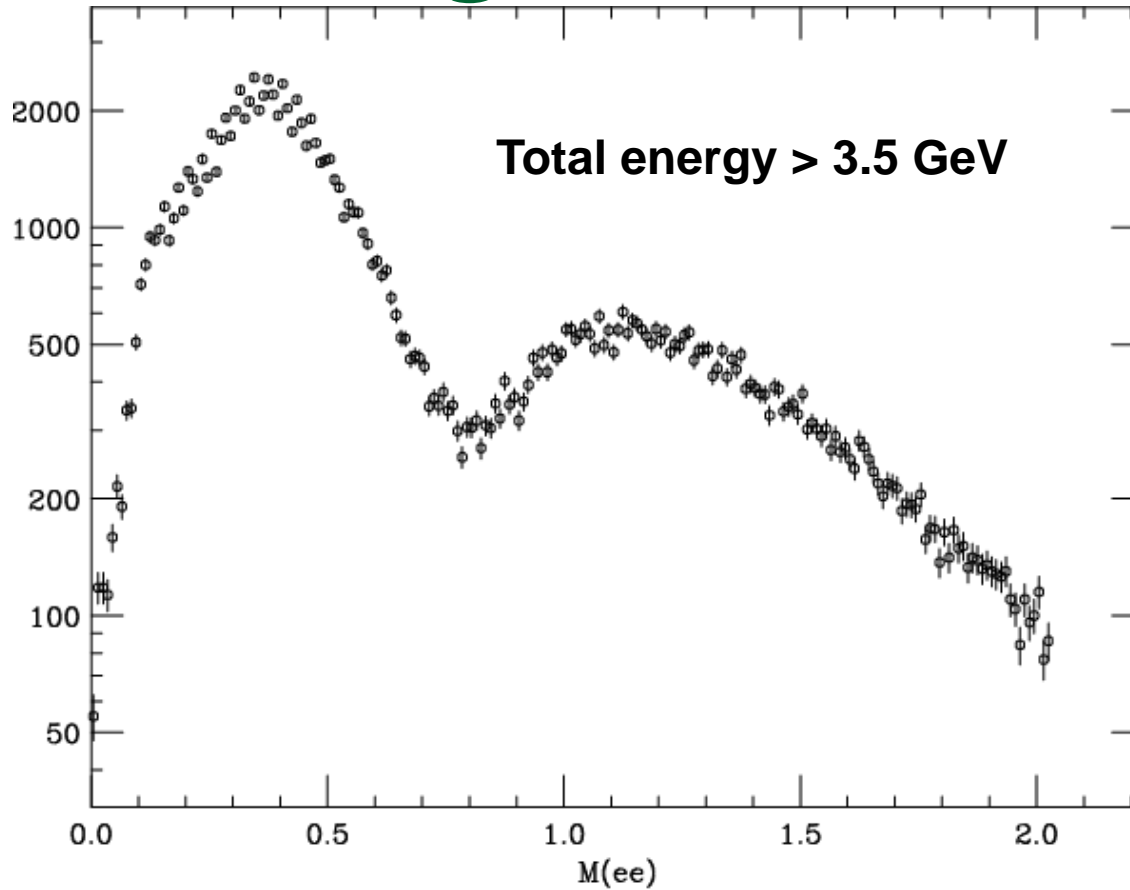
- Used 1/10<sup>th</sup> of data from current eg1-dvcs experiment (8 nA of 6 GeV electrons on 0.03 r.l. of NH<sub>3</sub>)
- Leptons for now only 15 to 50 deg.,  $P > 0.5$  GeV, used Cherenkov, timing, and EM calorimeter for good PID
- Online  $dM/M$  mass resolution only 1-2%: will be improved off-line to  $< 1\%$

# “Data mining” from Hall B

CLAS online 5 days NH3 target E=6 GeV

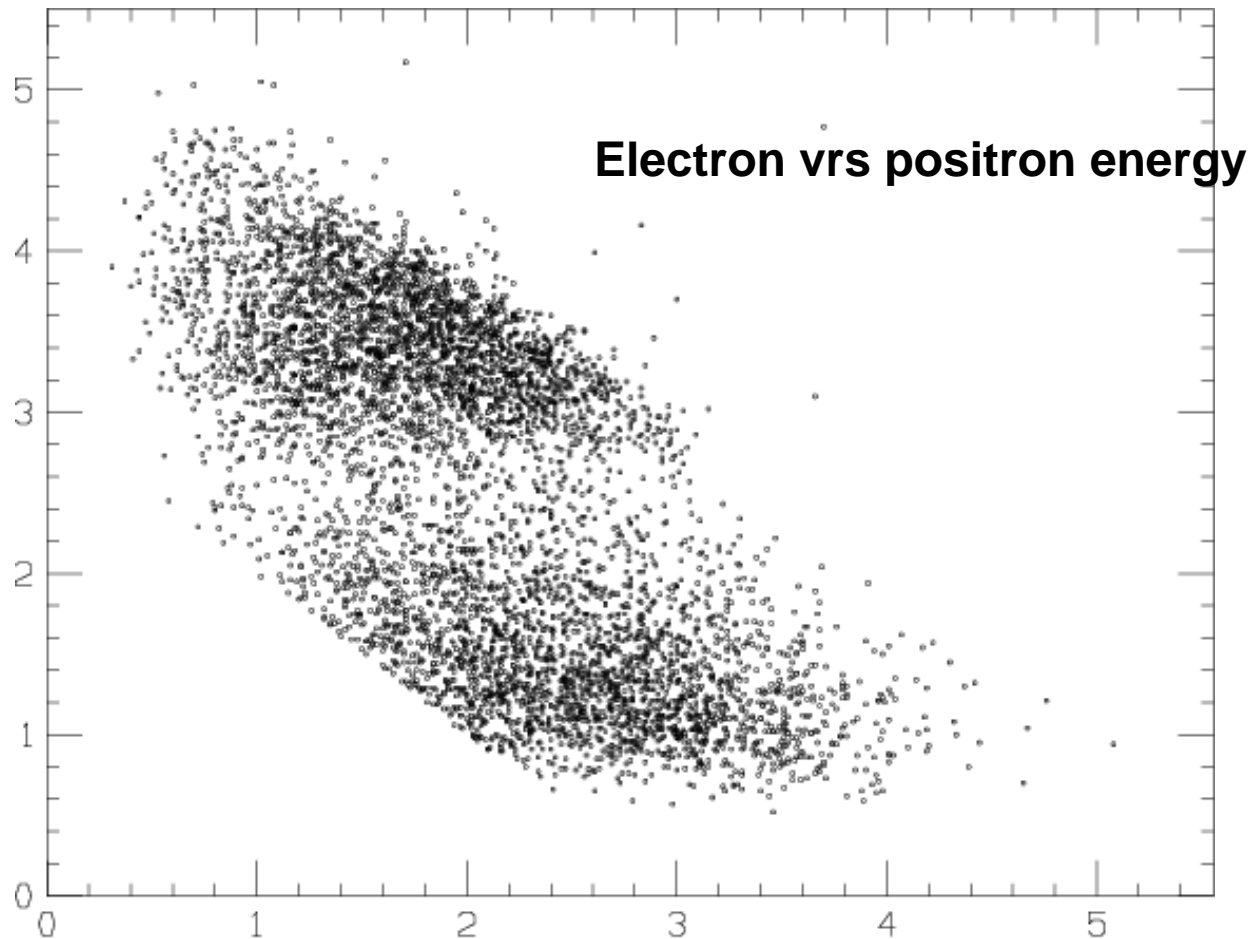


# “Data mining” from Hall B





# “Data mining” from Hall B



## “Data mining” from Hall B

- For  $M > 1$  GeV, most events have  $x > 0.7$  (i.e. sum of  $e^+$  and  $e^-$  energies  $> 4$  GeV)
- For  $M > 1$  GeV, most events in “central region”, i.e. both energies  $> 1$  GeV
- Data might be able to set somewhat interesting limits on  $A'$  coupling epsilon: very preliminary estimates are in ballpark of 0.001

# “Data mining” from Hall B: prospects

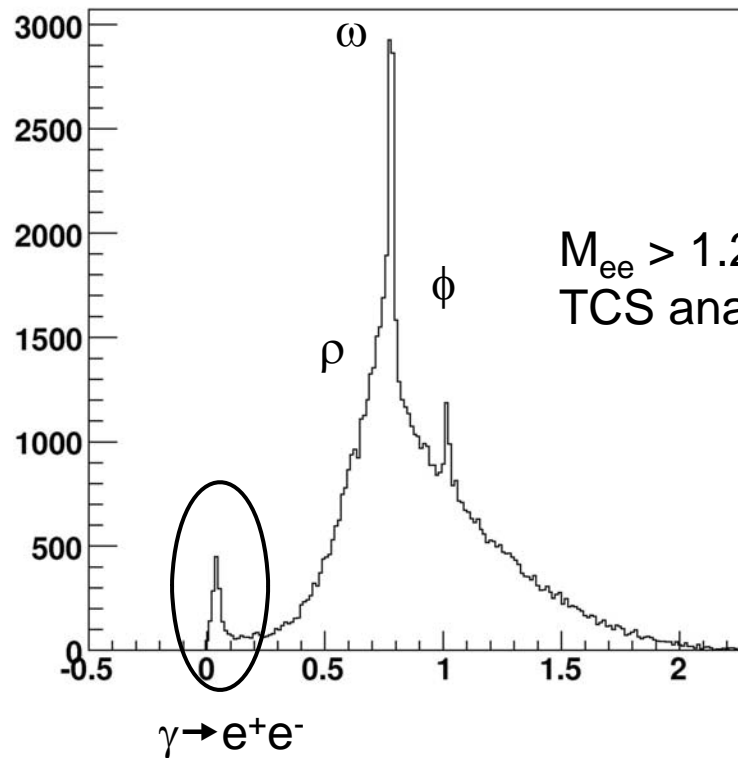
- **10x more data from eg1-dvcs. Use Inner Calorimeter and Hodoscope to go to small mass region?**
- **Also can look at eg1 experiment: same target but goes to smaller positron angles (6 degrees). Beam energies of 1.7, 2.4, 4.2, 5.7 GeV. 1 year**
- **Also several years on LH2 target**



# Lepton pairs in CLAS with recoil proton

## CLAS/E1-6

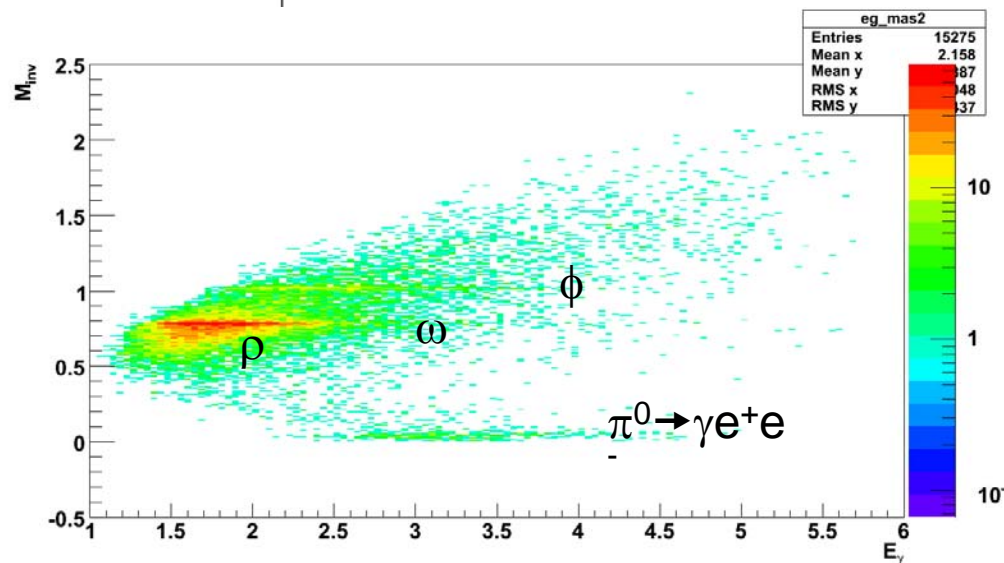
$(e^+, e^-)$  Invariant mass distribution when selected  $(e^-, e^+, p)$



mas3

Entries	72544
Mean	0.899
RMS	0.3507

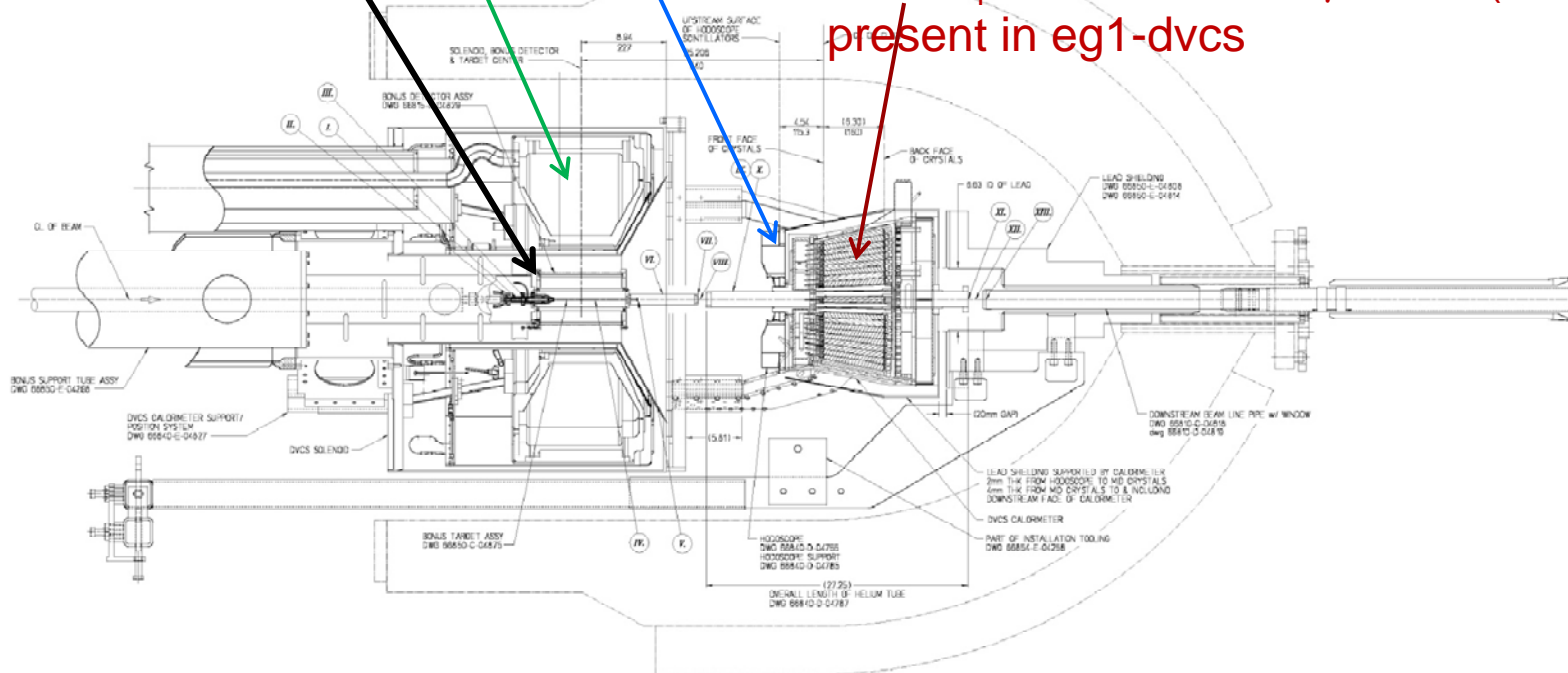
$M_{ee} > 1.2$  GeV for  
TCS analysis



# Next electron run in CLAS

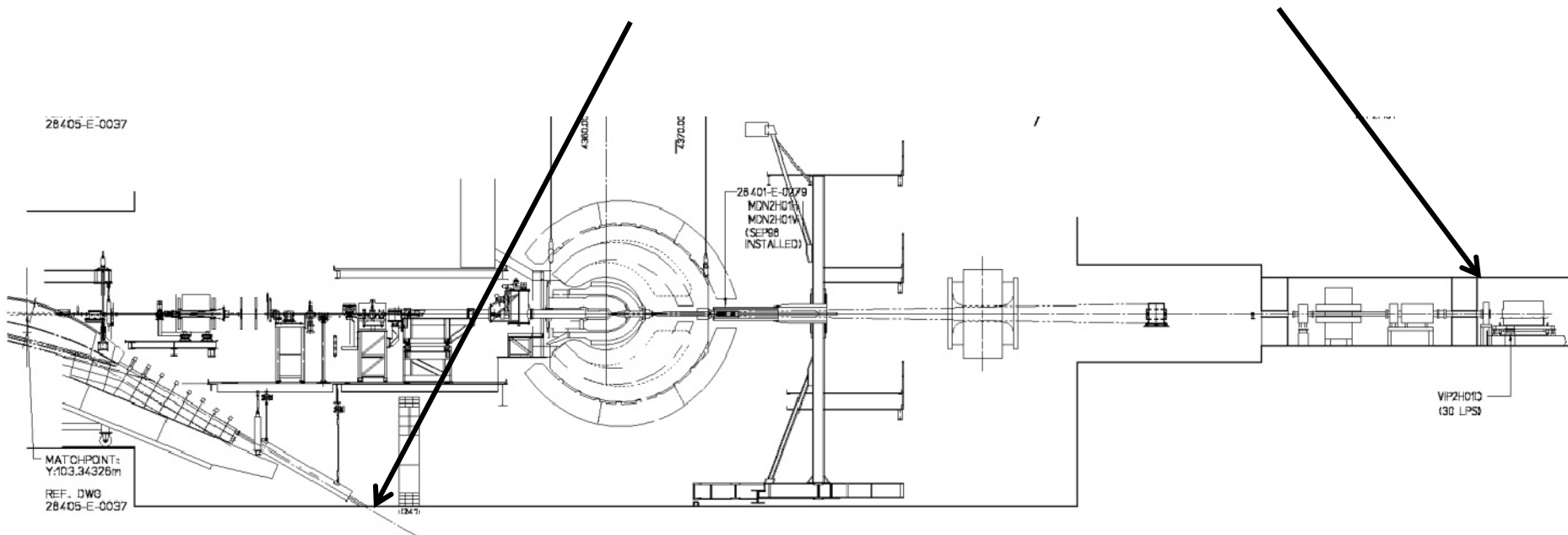
High intensity, 100 nA, 6 GeV electron beam with 6 atm.  $^4\text{He}$  gas target

- RTPC for low energy  $\alpha$ -particle detection
- solenoid magnet for Moller background
- scintillation hodoscope for charge particle tagging
- $\text{PbWO}_4$  calorimeter for  $\gamma$  and  $e$  (also present in eg1-dvcs)



# Possibilities of parasitic experiments in Hall B

- Realistically there are two possible locations for setting up detector and carrying out parallel measurements: (1) before “photon beam dump”, and (2) before “electron beam dump”



## Hall B beam dumps

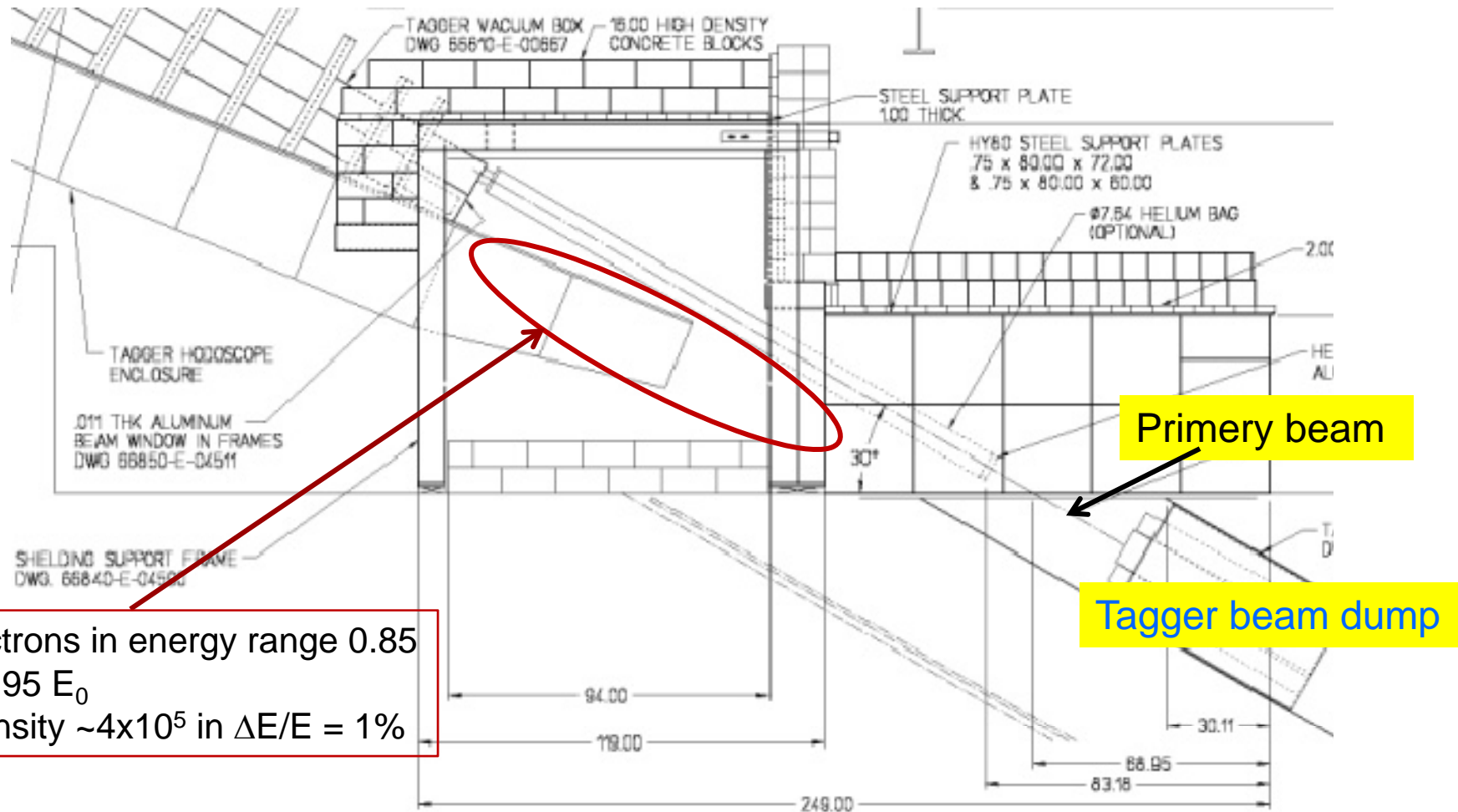
**“Electron beam dump”** – dump for electron and photon beams that pass through the CLAS target

- **Very high electromagnetic background during electron runs**
- **Moderate background during photon runs, helium bag after the CLAS target ends at the photon polarimeter (photon profiler, scintillating fiber hodoscope, seats on the beam all the time)**

**“Photon beam dump”** – dump for electron beam that passes through the tagger radiator ( $\sim \text{few} \times 10^{-4}$  r.l.)

- **Electromagnetic background from high energy electrons passing through tagger vacuum chamber window**

# Possible location of compact detector



Electrons in energy range 0.85 to 0.95  $E_0$   
Intensity  $\sim 4 \times 10^5$  in  $\Delta E/E = 1\%$



# Hall B run schedule

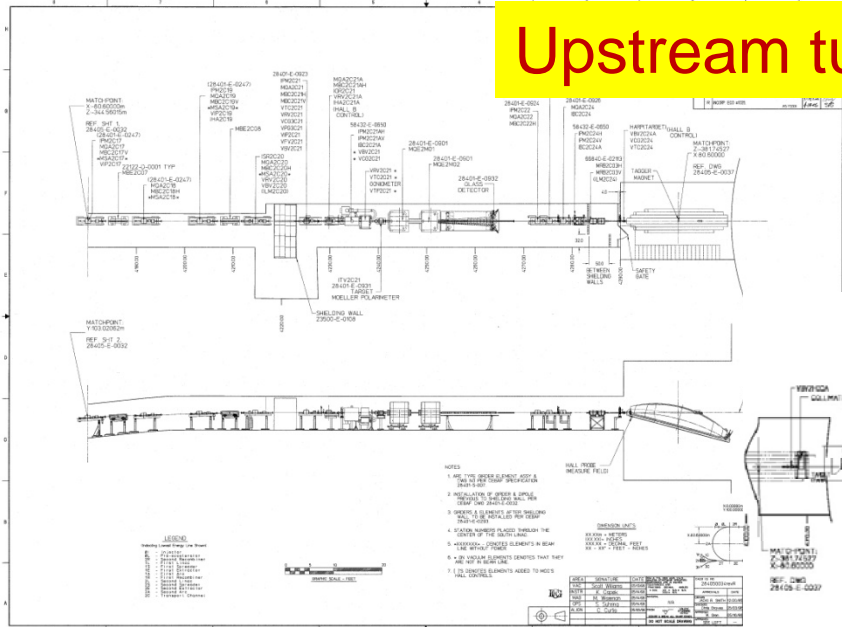
Date	Experiment	PAC days	Energy (GeV)	Beam	Polarization?
Feb-Sep '09	eg1-dvcs (2 exp)	60	5.9/5.7	e-/30 nA	high
Oct-Dec '09	eg6 (2 exp)	45	6.068	e-/100 nA	high
January '10	unscheduled test	--	1.0	---	---
Mar-Jul '10	g9b-Frost ( 5 exp)	60	2.2-5.5	$\gamma$	circ/linear
Sep'10-May '11	g14-HD	85	various	$\gamma$	circ/linear
Nov-Dec '11	ET-HD*( 2 exp)	25	>5.5	e-	high
Jan-Feb '12	PRIMEX II	20	5.5	$\gamma$	--
Mar-May '12	eg5-TPE	35	5.5	$\gamma$ /500 nA	--
<b>SUM</b>	<b>330</b>				

\*) PRIMEX II or TPE or C3 approved experiment g7b may run early if HD is delayed.  
 \*\*) C3 approved experiment g7b may run if ET-HD cannot run (only 25 PAC days)

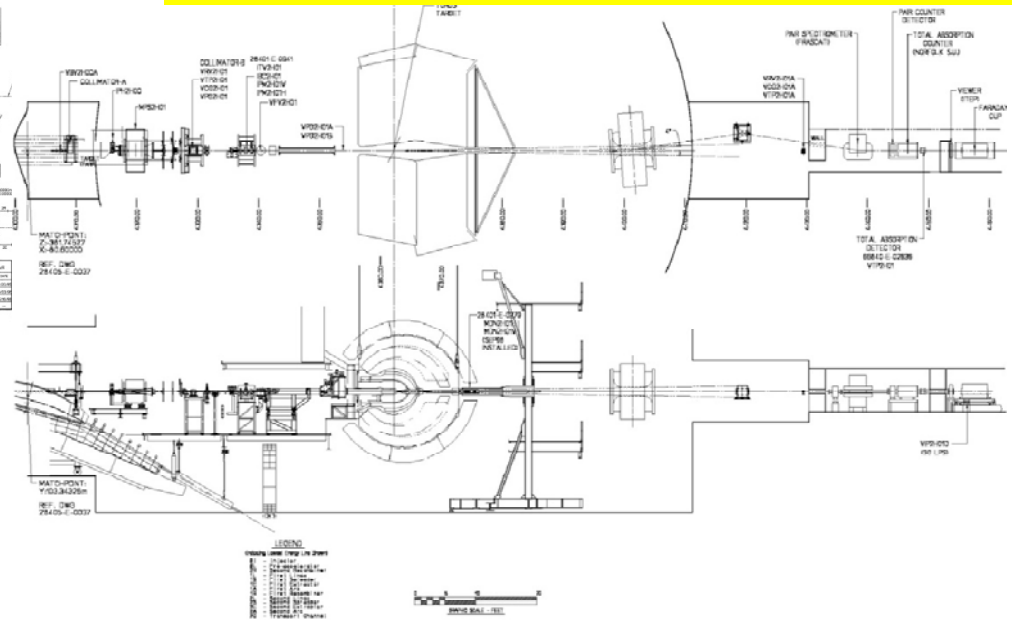


# Hall B

## Upstream tunnel



## Hall and downstream tunnel

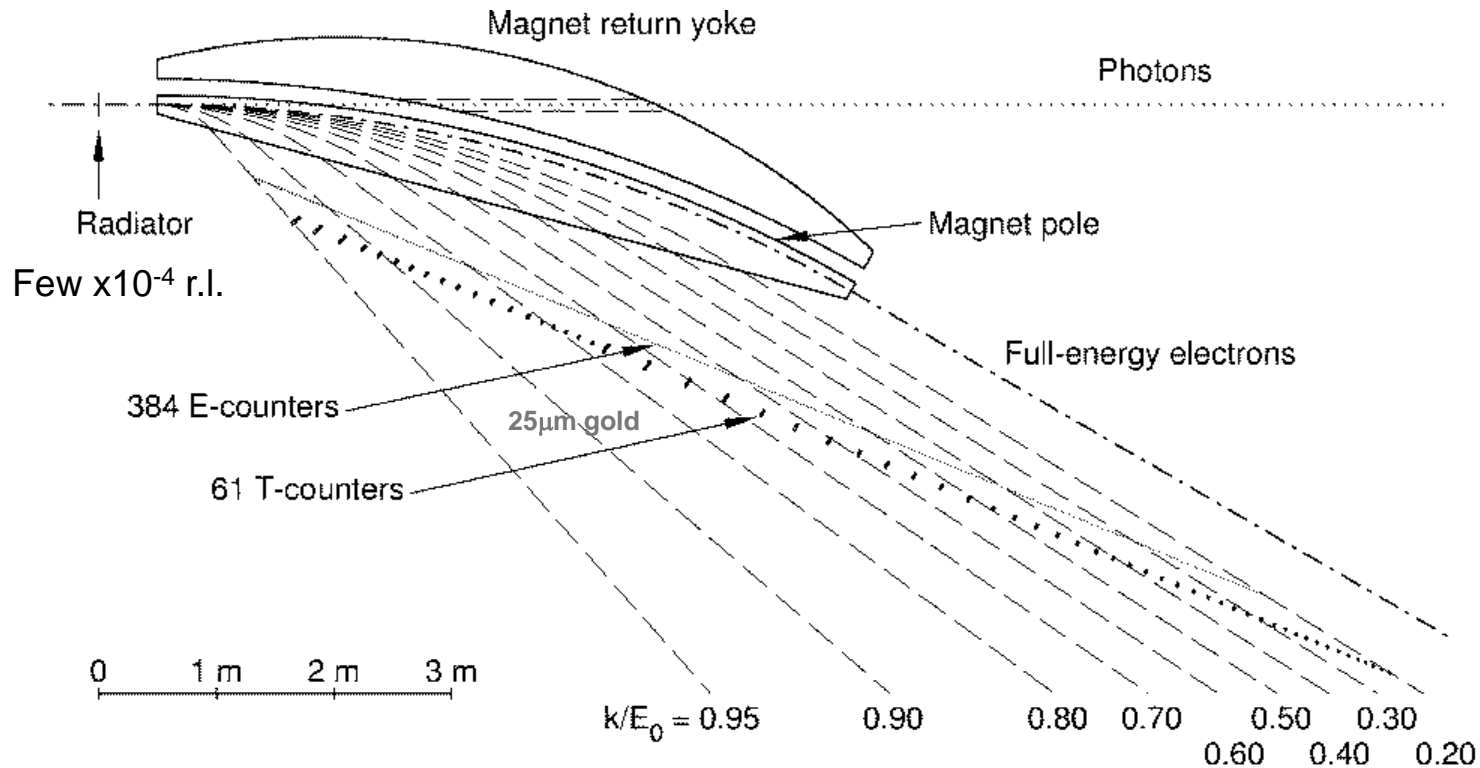


# Hall B Bremsstrahlung tagged photon facility

Dynamic range of focal plane - 5% to 80% of initial beam energy

Tagged photon energy resolution 0.1% of  $E_\gamma$

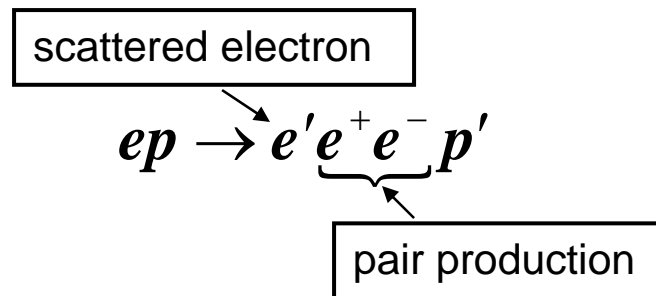
Typical tagging intensity –  $5 \times 10^7$



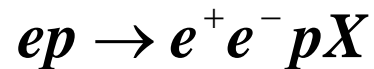
# CLAS data analysis

Analysis of electroproduction data to select events in the quasi-real photoproduction region, when incoming electron scatters at  $\sim 0$  degrees

In the production of  $e^+e^-$  pair, there are two electrons in final state



Final state to analyze



Scattered electron kinematics is deduced from missing momentum analysis