GlueX and Hall-D

Yves Van Haarlem
for the GlueX collaboration

Carnegie Mellon

Users Group Workshop and Annual Meeting, June 9, 2009

Outline

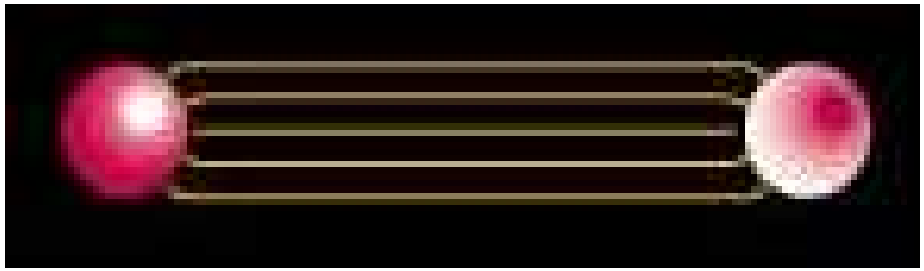
Jefferson Lab
Thomas Jefferson National Accelerator Facility

12 GeV Upgrade
Future Science at Jefferson Lab

GlueXcitations Experiment

1. (Main) Physics motivation
2. Requirements
3. GlueX and Hall-D
4. Status and Future
5. Physics potentials
6. Summary

Confinement



- Quantum Chromodynamics
  - Gluons have color-charge $\longrightarrow$ are self interacting
  - Gives rise to flux tubes (Bernard *et al.* - 2004)
  - $V(r) = \kappa r$
  - Non-perturbative

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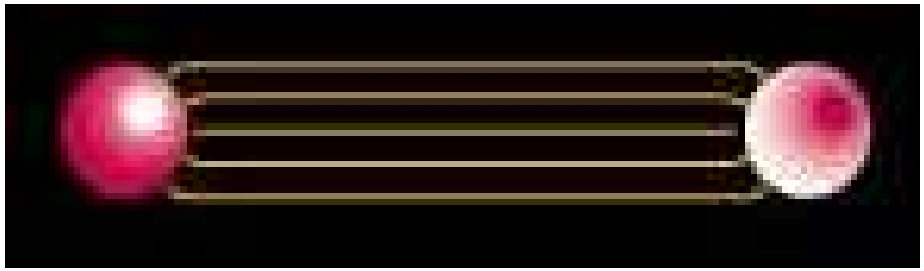

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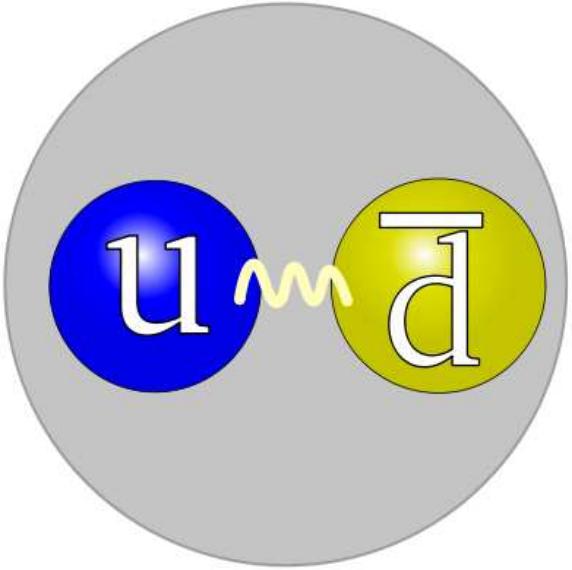
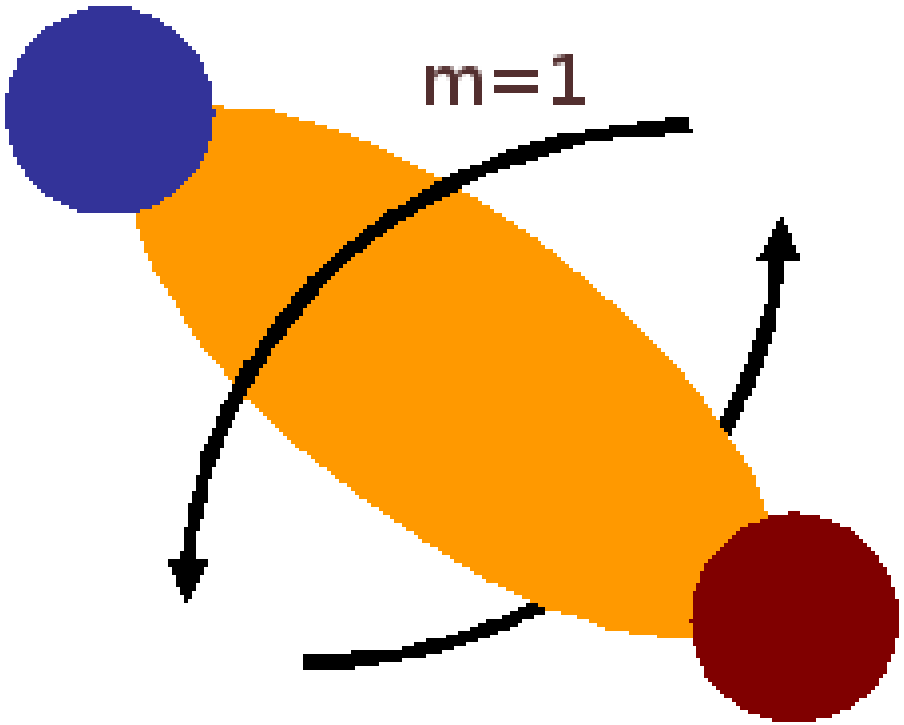


$0^{-+}: \pi^+$

$1^{--}: \rho^+$

- Mesons
  - 2 quarks ($q\bar{q}$)
  - Studied/mapped in spectroscopy
  - Characterized by J^{PC} quantum numbers
  - Some J^{PC} are not allowed ($q\bar{q}$) (e.g. 0^{+-}): $\longrightarrow$ Exotic mesons

Can the glue be excited?



- Mesons with excited flux tube
  - Hybrids: L in flux tube
    - $J^{PC} = 1^{+-}$ and 1^{-+}
  - About 1 GeV/c^2 above ground state meson spectrum
  - Exotic quantum numbers possible

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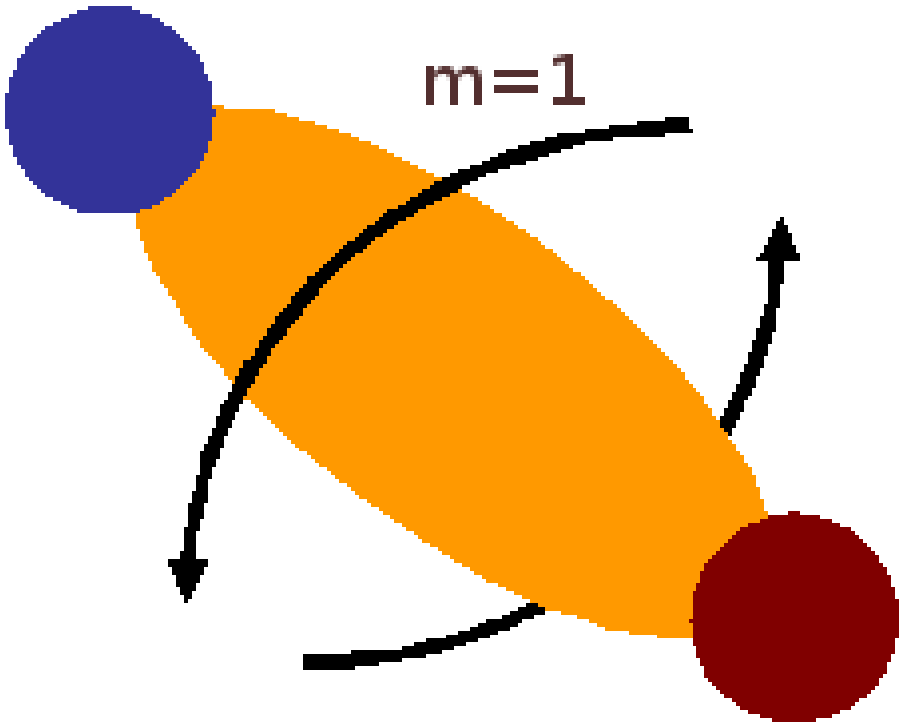

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- Lattice calculations predict:

  (Phys. Rev. D56 (1997) 7039)
  - 1^{-+}: $\sim 1.9\ GeV/c^2$ (lightest nonet)
  - 2^{+-}: $\sim 2.1\ GeV/c^2$
  - 0^{+-}: $\sim 2.3\ GeV/c^2$

    $\rightarrow$ **Exotic quantum numbers!**

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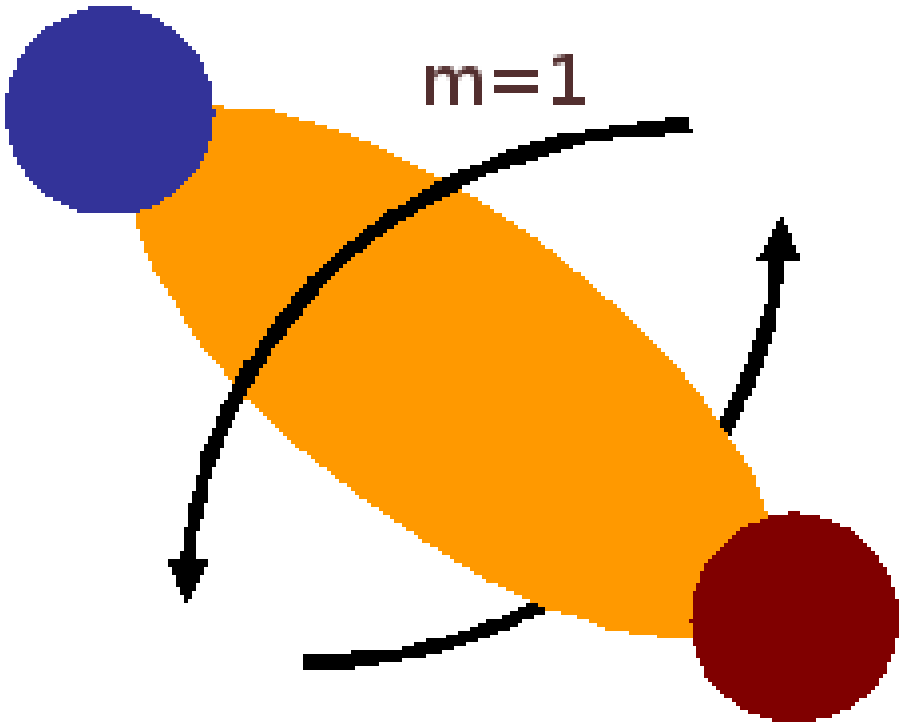

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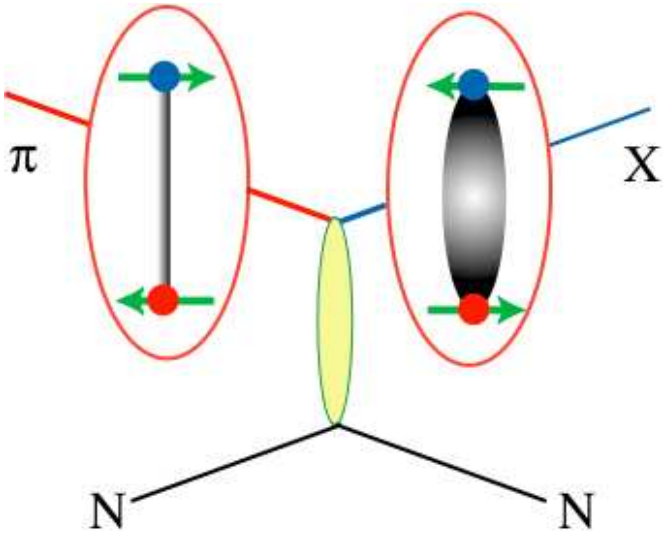
$\rightarrow$ **GlueX wants to map out the hybrid mesons** $\leftarrow$ Measurement of the excited QCD potential

π/γ BEAM?



π beam

- π with excited flux tube:
  - m=1, S=0, L=0, J=1 $\rightarrow 1^{++}\ 1^{--}$
- Quark spin flip $\rightarrow$ exotic hybrids
  BUT $\sigma_{exotic-meson}$ reduced ($\ll \sigma_{meson}$)
- A lot of data but little evidence for hybrids

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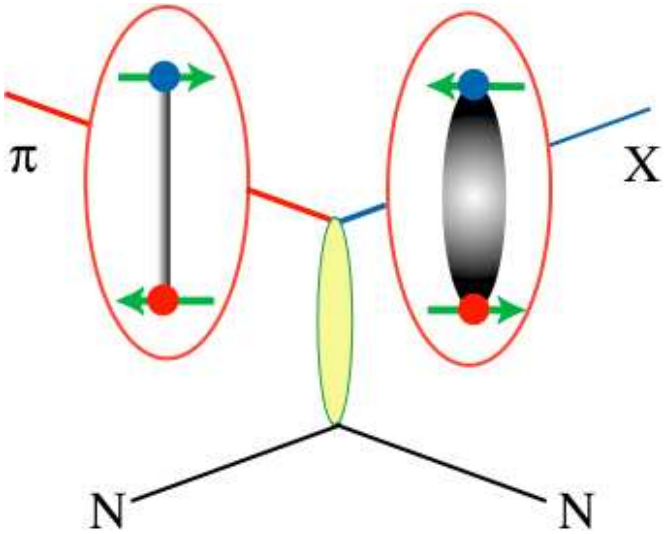

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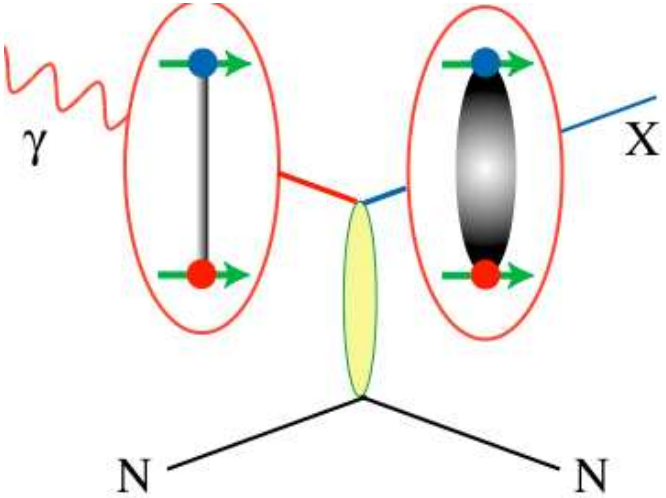
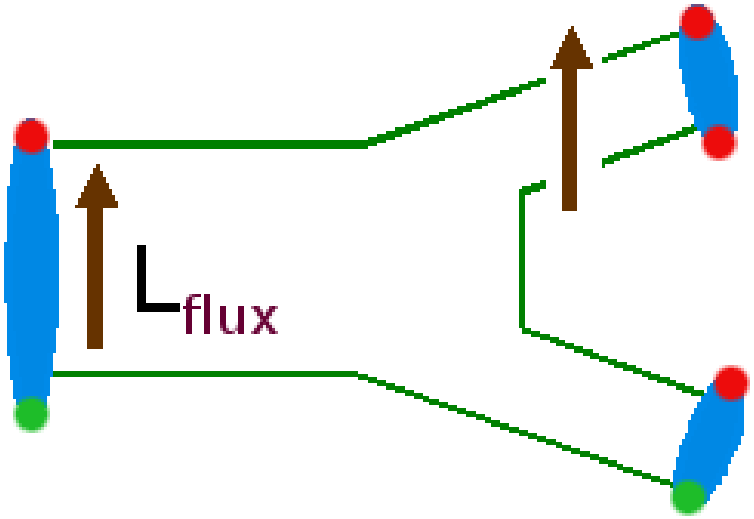


γ beam

- $q\bar{q}$ with excited flux tube:
  - m=1, S=1, L=0, J=0,1,2
    $\rightarrow 0^{-+}\ 0^{+-}\ 1^{-+}\ 1^{+-}\ 2^{-+}\ 2^{+-}$
  - Exotic hybrids!
- $\sigma_{exotic-meson} \approx \sigma_{meson}$
- Almost no data available
- Linear polarized $\gamma \rightarrow$ parity measurement

Hybrid decays in the fluxtube model



One decay meson gets L_{flux}:
$\rightarrow$ L=0 meson + L=1 meson
(most models)

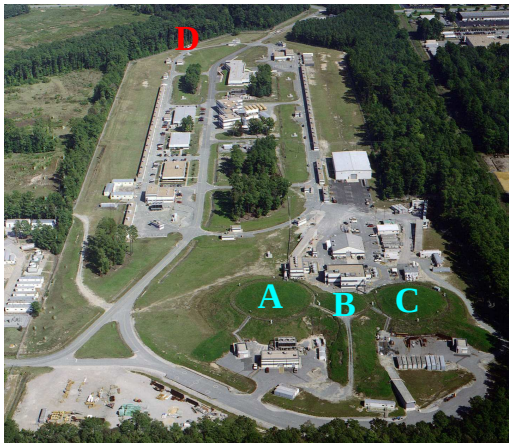
- Examples of final states:
  - $\eta_1 \rightarrow a_1^+\pi^- \rightarrow ... \rightarrow \pi^+\pi^-\pi^+\pi^-$
  - $h_0 \rightarrow b_1^0\pi^0 \rightarrow ... \rightarrow \pi^+\pi^-\gamma\gamma\gamma\gamma\gamma\gamma$
  - $h_2' \rightarrow K_1^+K^- \rightarrow ... \rightarrow \pi^+\pi^-K^+K^-$
- GlueX needs to detect:
  - Charged particles
  - Multiple γs
    - 70% involved at least one π^0
    - 50% more than one π^0
  - Strange particles

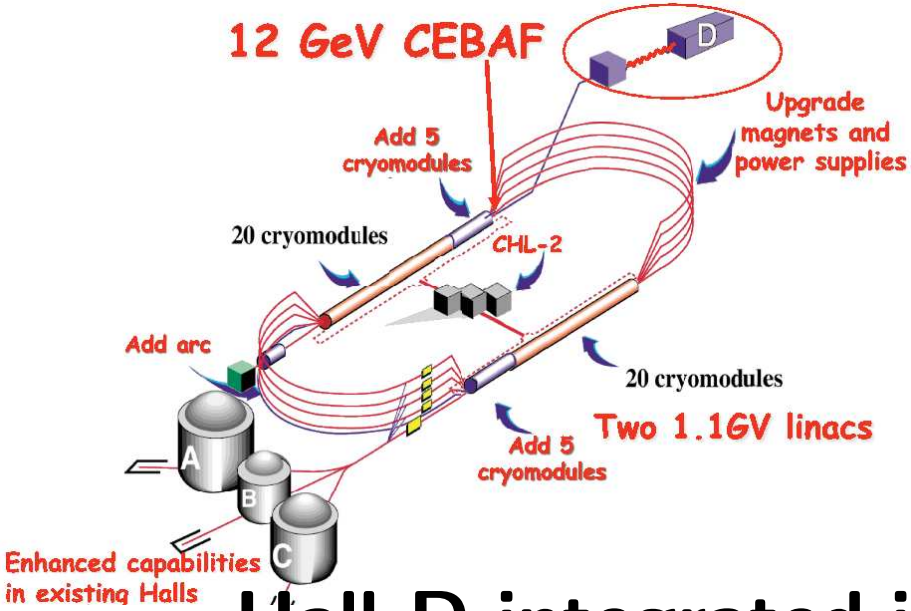
Exotic Meson	J^{PC}	I	G	Possible Modes
b_0	0^{+-}	1	+	
h_0	0^{+-}	0	−	$b_1\pi$
π_1	1^{-+}	1	−	$\rho\pi$, $b_1\pi$
η_1	1^{-+}	0	+	$a_2\pi$
b_2	2^{+-}	1	+	$a_2\pi$
h_2	2^{+-}	0	−	$\rho\pi$, $b_1\pi$

Requirements for hybrid spectroscopy

- γ - beam ($\sigma_{exotic-meson}$)
  - Linearly polarized (parity)
  - High enough in energy (to produce hybrids)
  - High luminosity
- Detector
  - Large & uniform acceptance
  - Good calorimetry (multiple γ_s)
  - Good momentum resolution
  - Charged particle ID
  - Handle high luminosity

Requirements for hybrid spectroscopy





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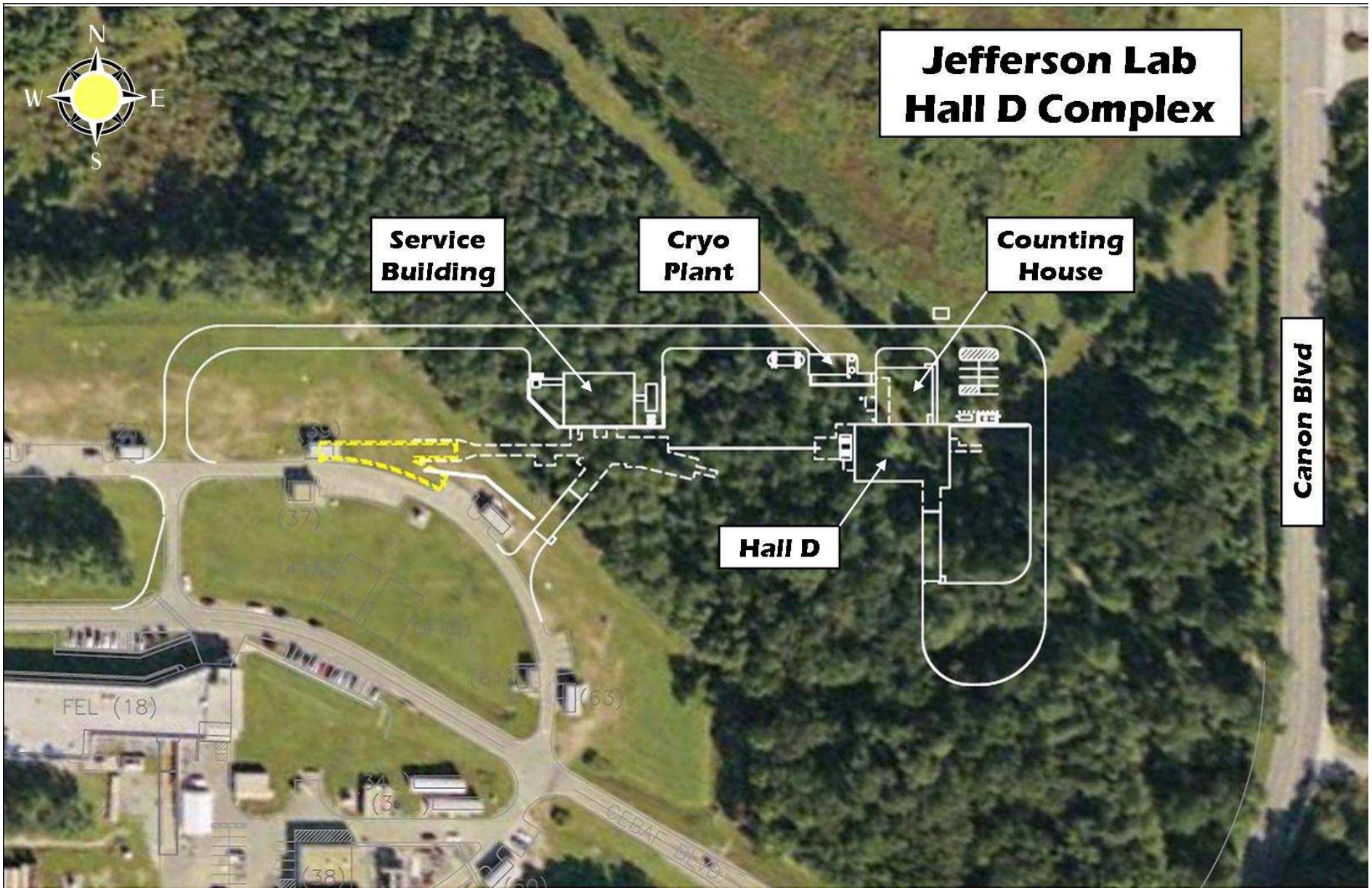
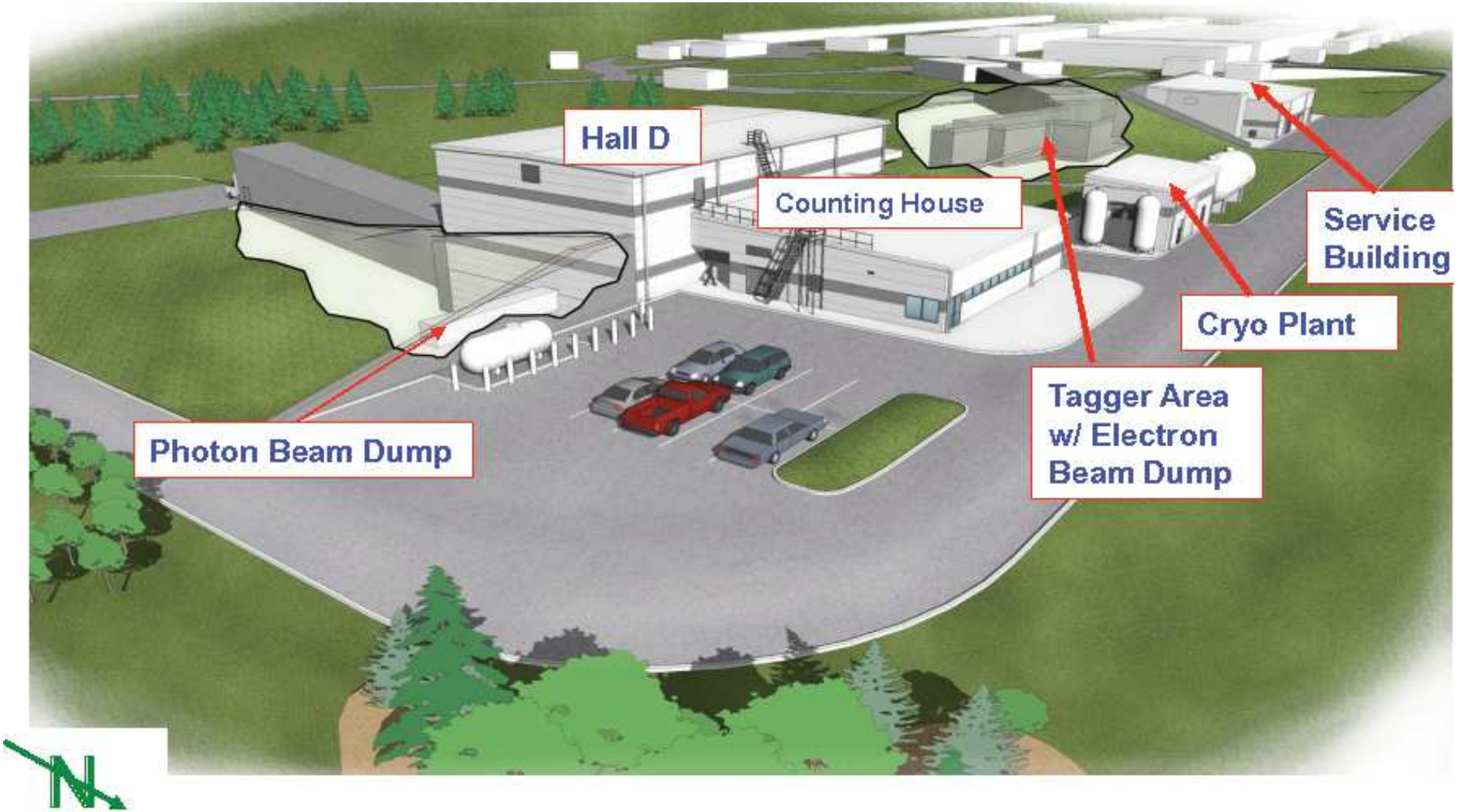
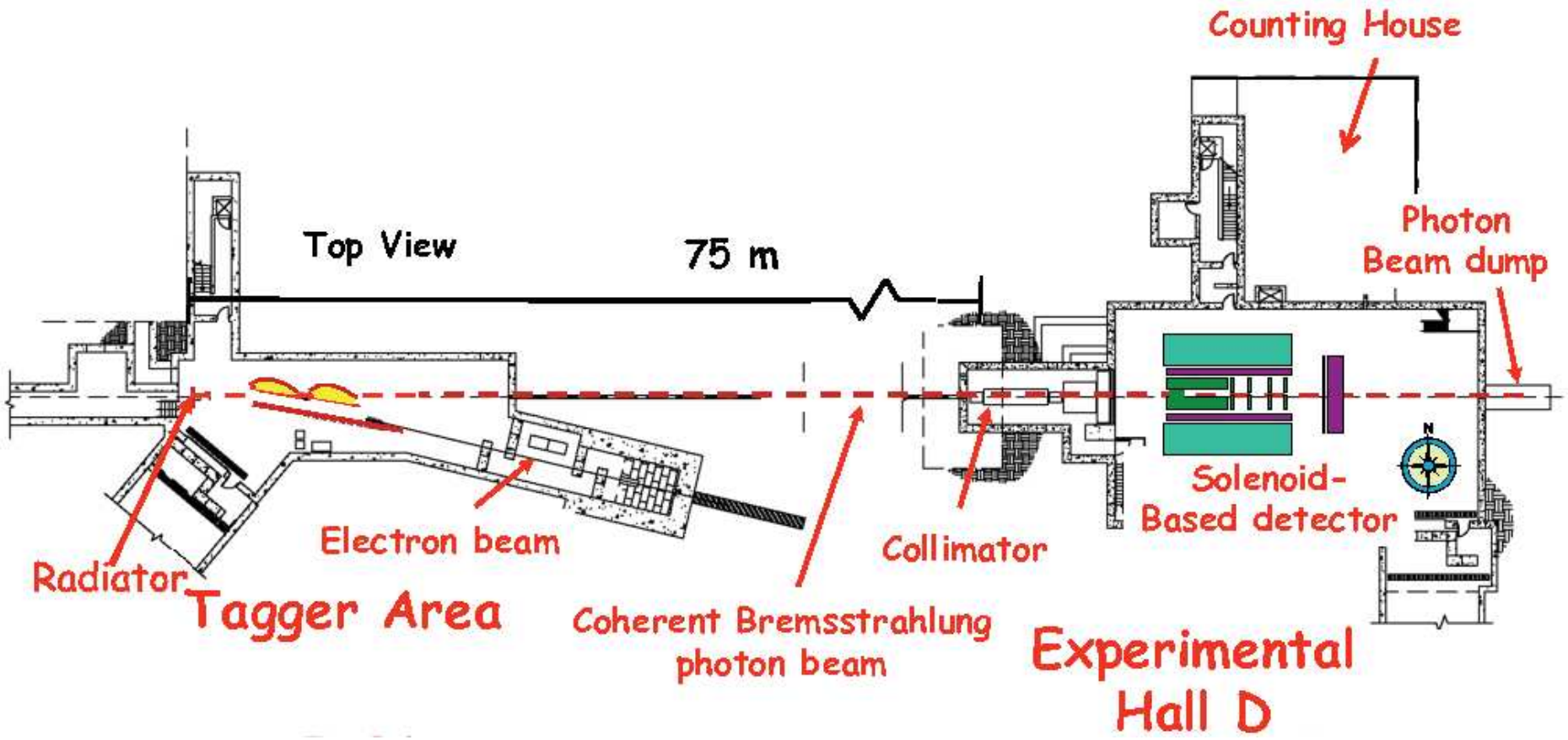
Hall-D integrated in 12 GeV upgrade of JLab


N
W
E
S
Jefferson Lab
Hall D Complex
Service Building
Cryo Plant
Counting House
Hall D
Canon Blvd
FEL (18)

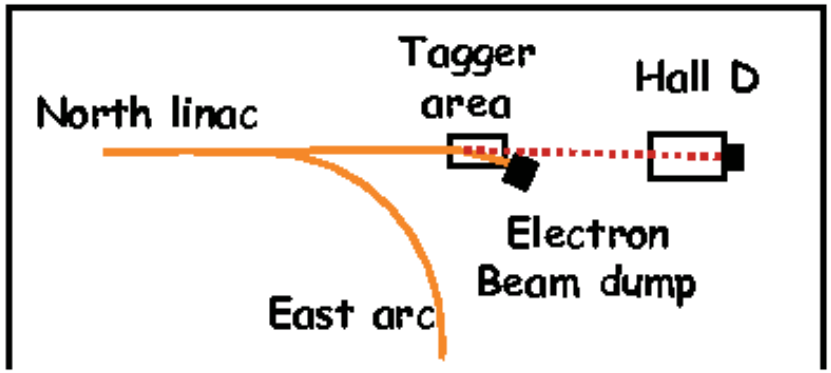
Ground Breaking Ceremony - Apr. 14, 2009



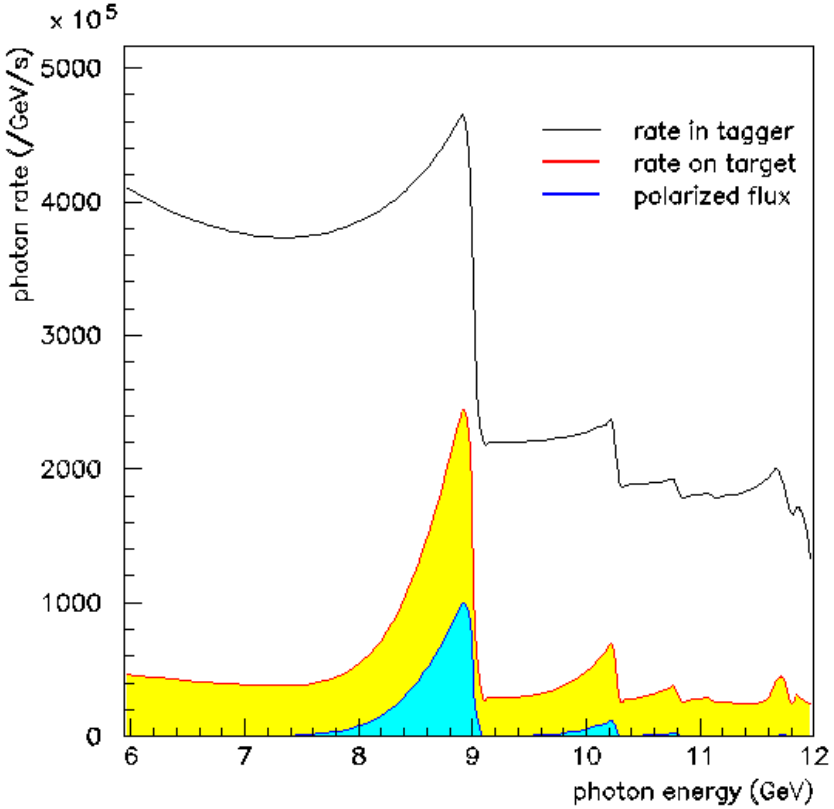
(Construction started in May 2009)



- $e^-(12\ GeV/c)$ on 20 μm diamond
- Coherent bremsstrahlung -γ-beam
- 8.4-9 GeV $\vec{\gamma}_s$ (tagged)
- 10^8 $\vec{\gamma}/s$ on p target (collimated)
- Solenoid based detector

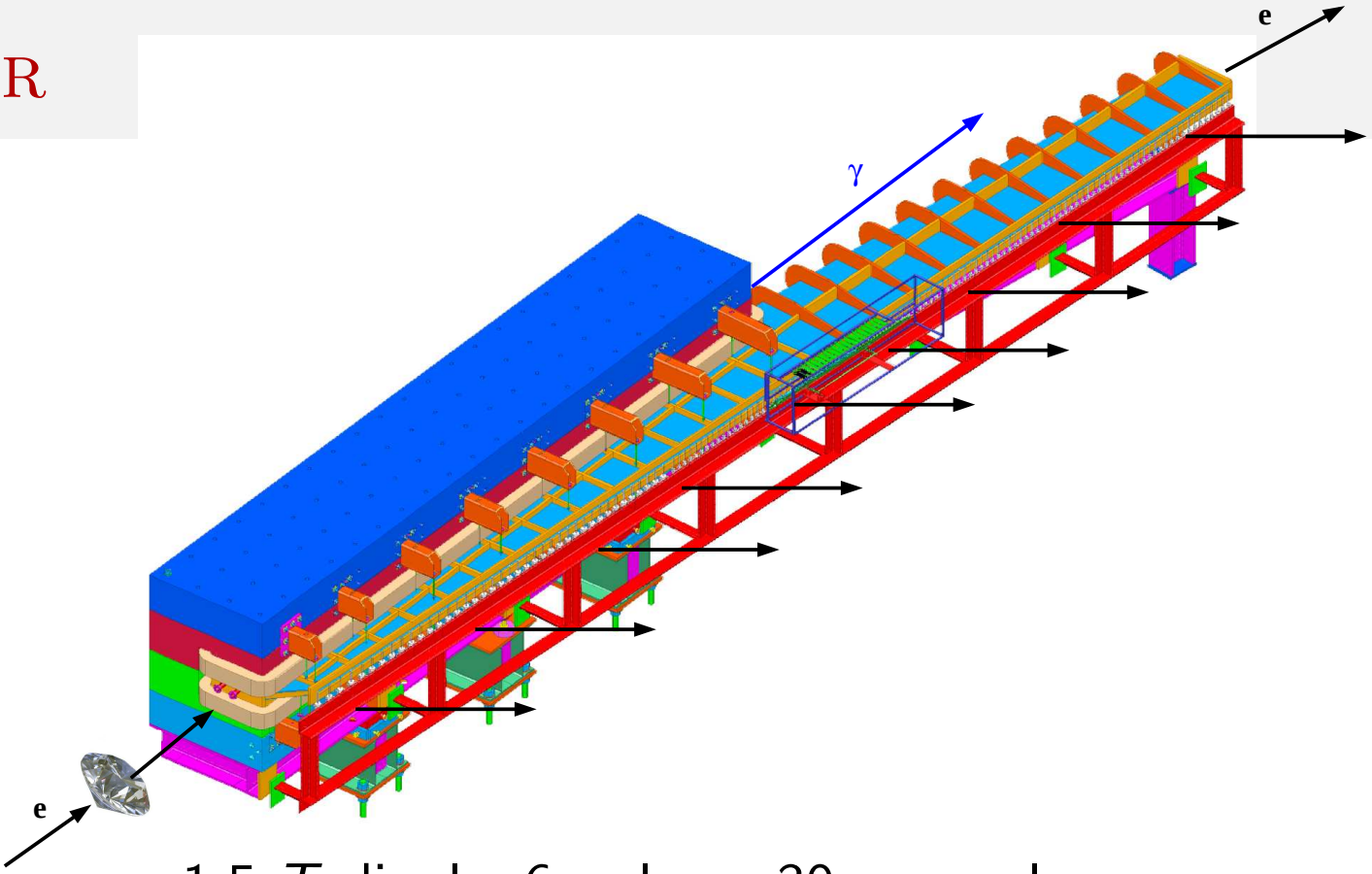


Linearly Polarized γ-beam



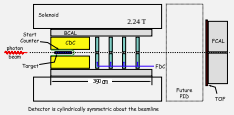
- $10^8 \gamma$/s on target:
  - 12 GeV/c e-momentum
  - 2.2 μA e-beam
  - 20 μm diamond crystal
  - 75 m diamond-collimator
  - Active collimator aperture: 3.5 mm
- Peak linear polarization: 40%
- Electron pair spectrometer
  - Measures post-collimated γ-beam spectrum
  - Essential for determination of the beam polarization

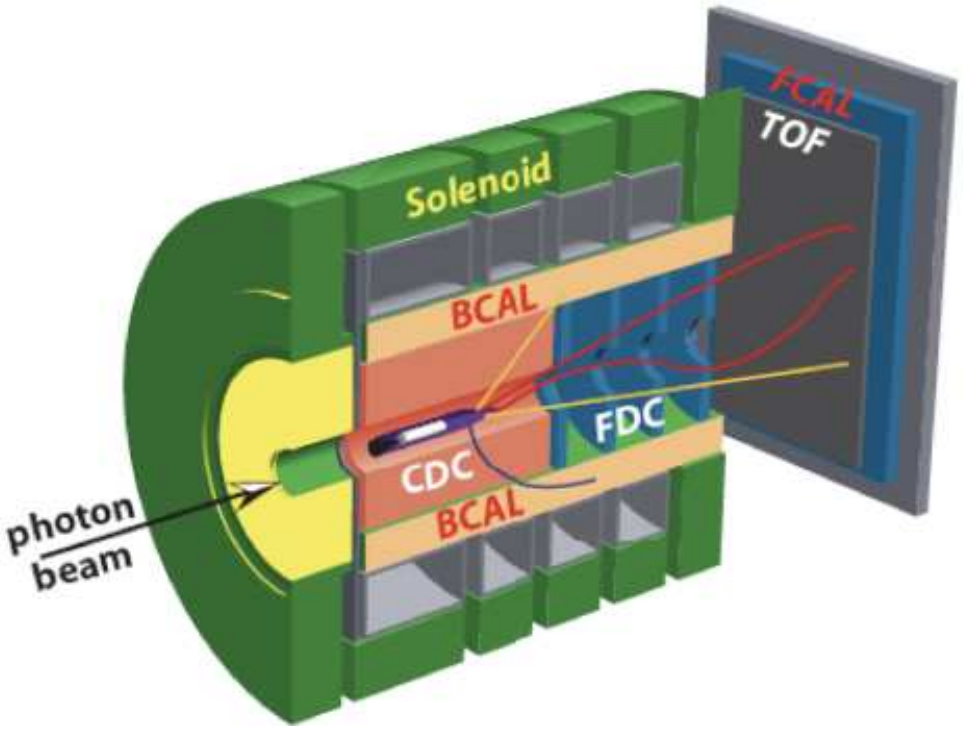
Tagger



- 1.5 T dipole, 6 m long, 30 mm pole gap
- Deflects electrons (13.4°= 12 GeV)
- 190 Hodoscopes: scintillator + PMTs (12 m long) $\rightarrow$ 3 - 11.7 GeV
- Microscope: 124 scintillating fibers (movable) + SiPMs $\rightarrow$ 8.3 - 9.1 GeV $\pm$ 8 MeV

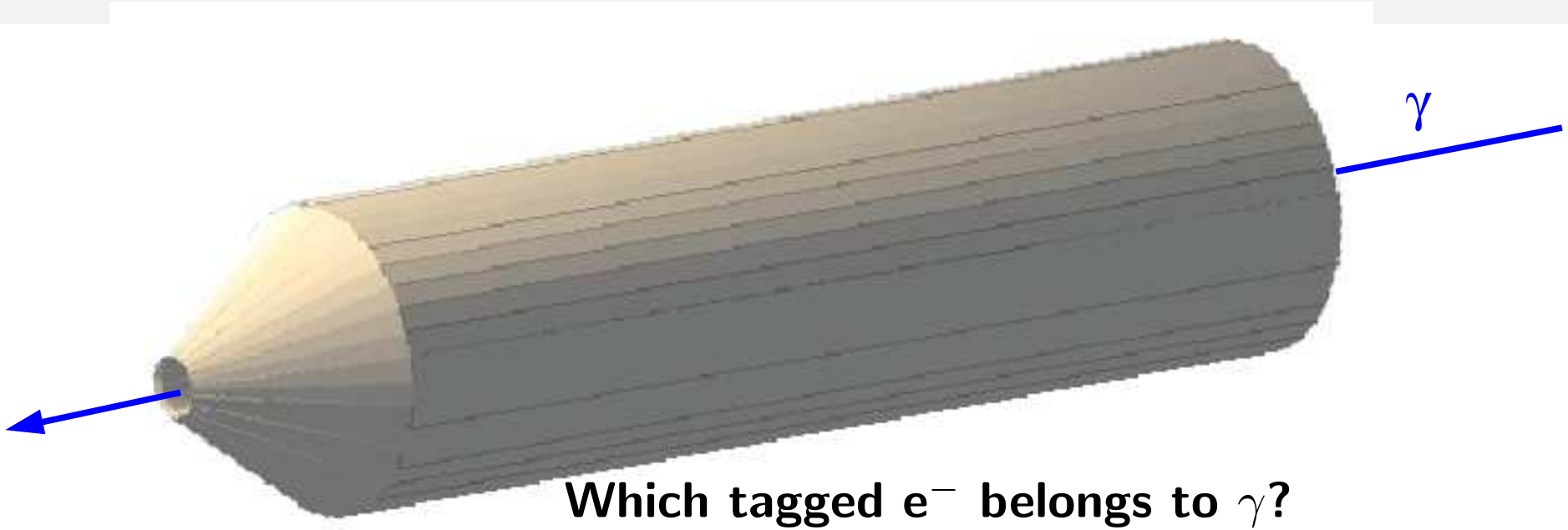
Spectrometer





- Liquid H target - 30 cm long
- Solenoid: 2.24 T
- Tracking (inside solenoid):
  - Start counter
  - Central Drift Chamber (CDC)
  - Forward Drift Chamber (FDC)
- Calorimetry
  - Barrel Calorimeter (BCAL)
  - Forward Calorimeter (FCAL)
- Time-of-flight wall (ToF)
- Custom read-out & trigger

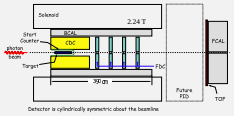
Start counter

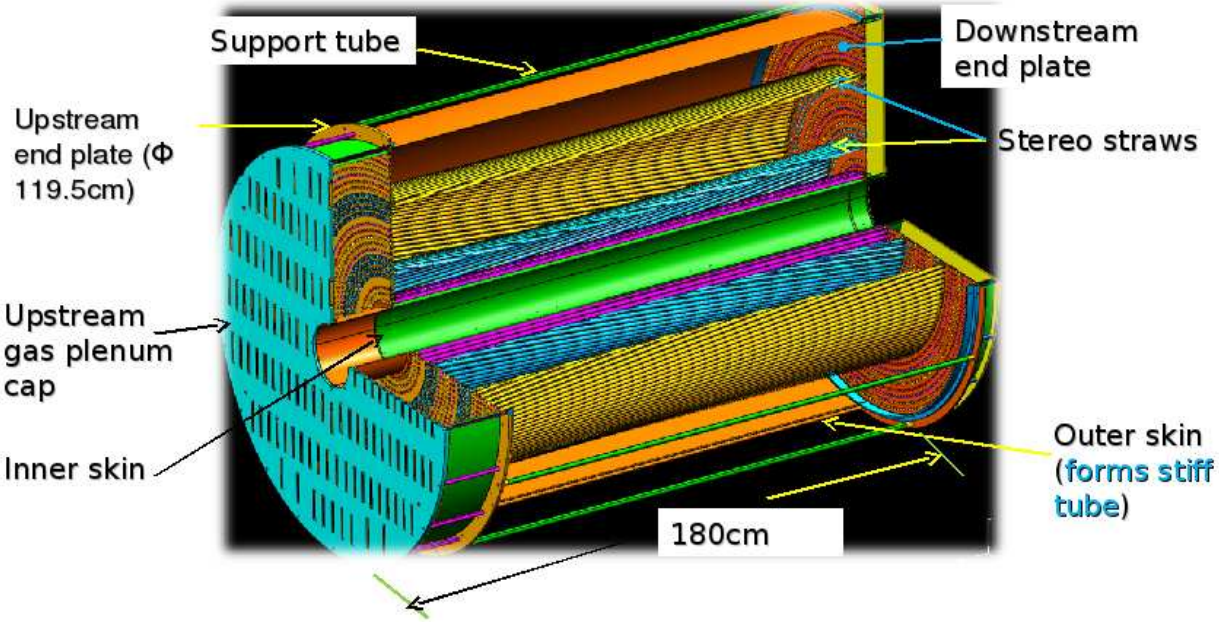


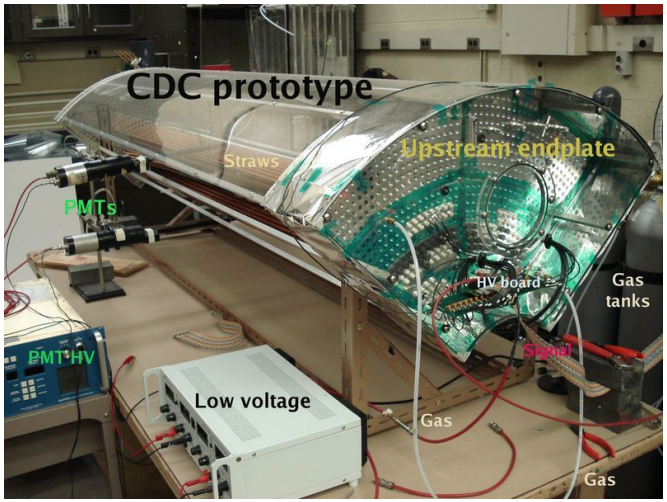
Which tagged e⁻ belongs to γ?

- Together with tagger
- 40 scintillators (+PMTs or SiPMs)
- $r = 8\ cm$
- 50 cm Straight + 10 cm bended (35°)
- Only used in initial phase (lower rate)
- Energy and timing measurements

Central Drift Chamber

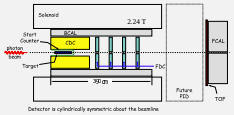


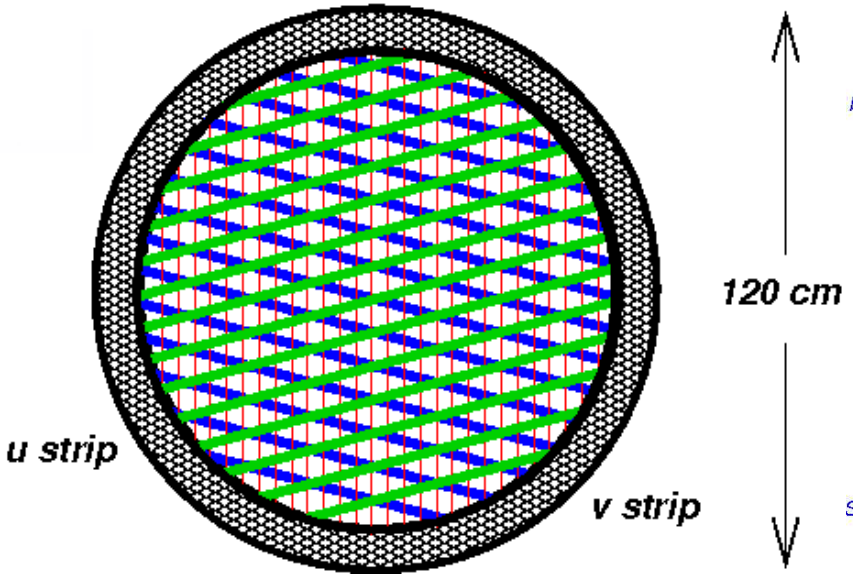


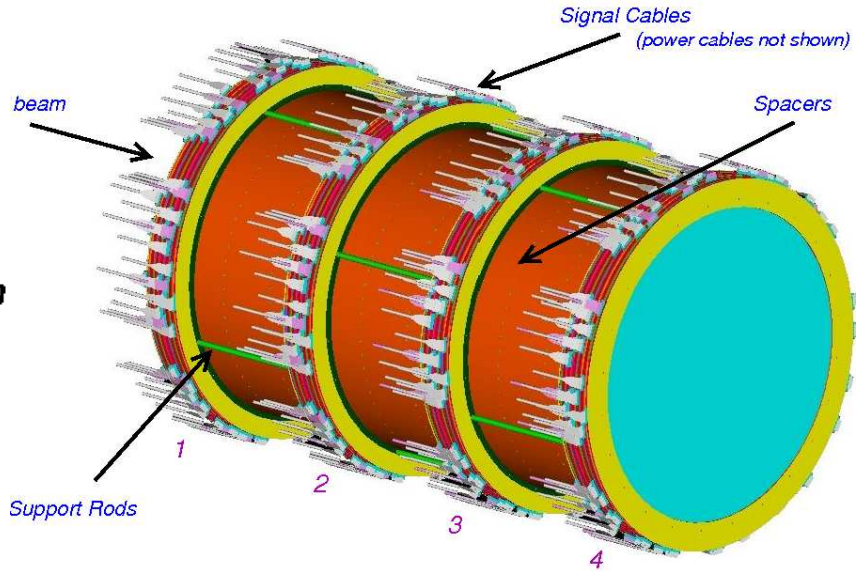


- 3500 Straws (r=8 mm): 28 layers
- 6 - 150° optimal angular coverage
- Resolution: $\sigma_{r\phi} = 150\ \mu m$, $\sigma_z = 1.5\ mm$
- $\frac{dE}{dx}$ for π/proton ID ($p < 450\ MeV/c$)

Forward Drift Chamber

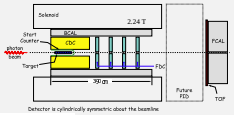


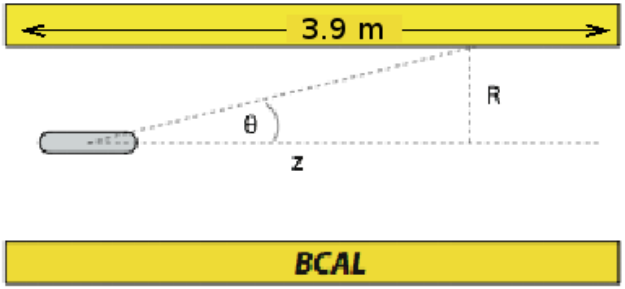


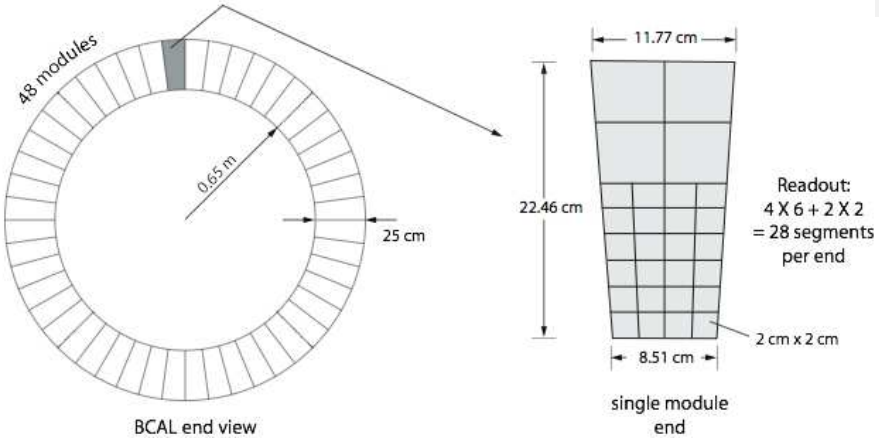


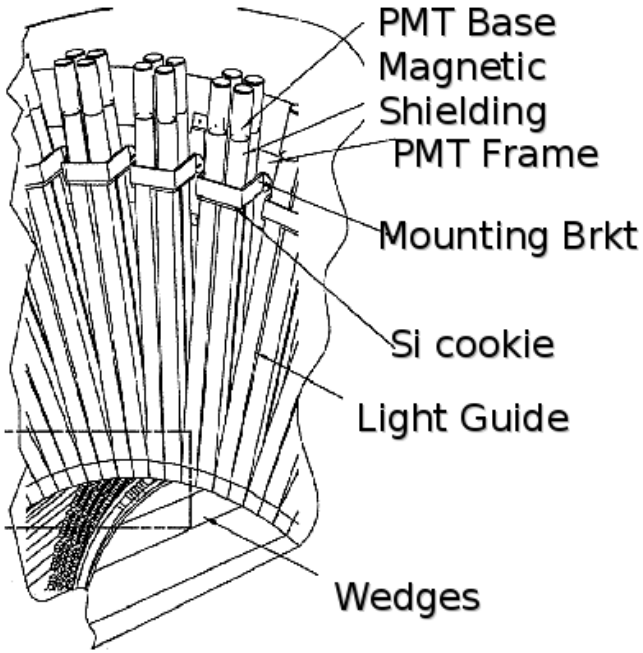
- 4 packages: ground - cathode(75°) - wire(0°) - spacer - cathode plane(-75°)
  $\longrightarrow$ suppression of ambiguities
- 1 - 30° angular coverage
- $\sigma_{xy} = 200\ \mu m$

Barrel Calorimeter



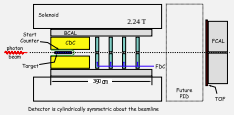


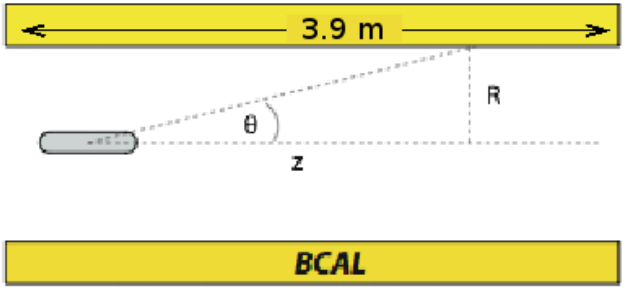


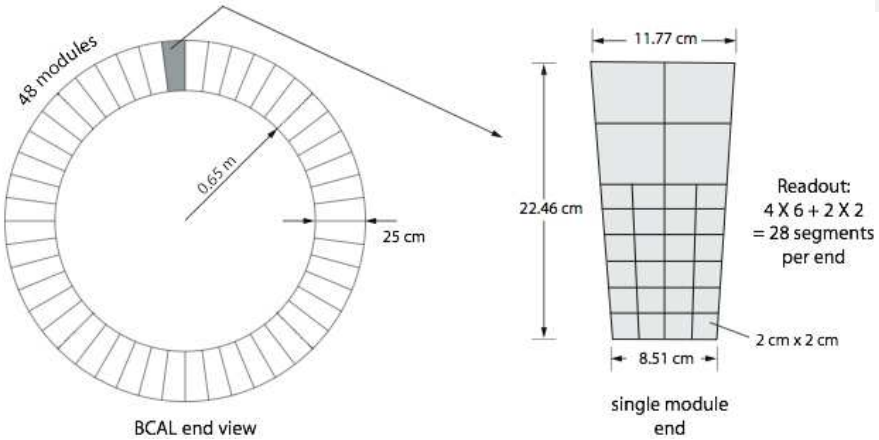


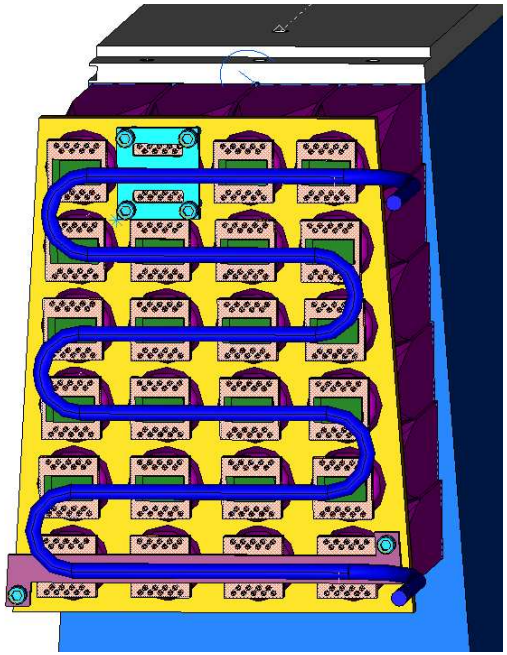
- Module: 191 layers Pb:SciFi:Glue (37:49:14)
  - 28 segments
  - inner segment → SiPMs
  - Outer segment → PMTs
- $\sigma_E/E\ (\%) = 5.54/\sqrt{(E)} + 1.6$ (testbeam)
- Charged particle PID (ToF: TDC)

Barrel Calorimeter









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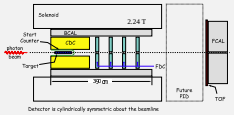
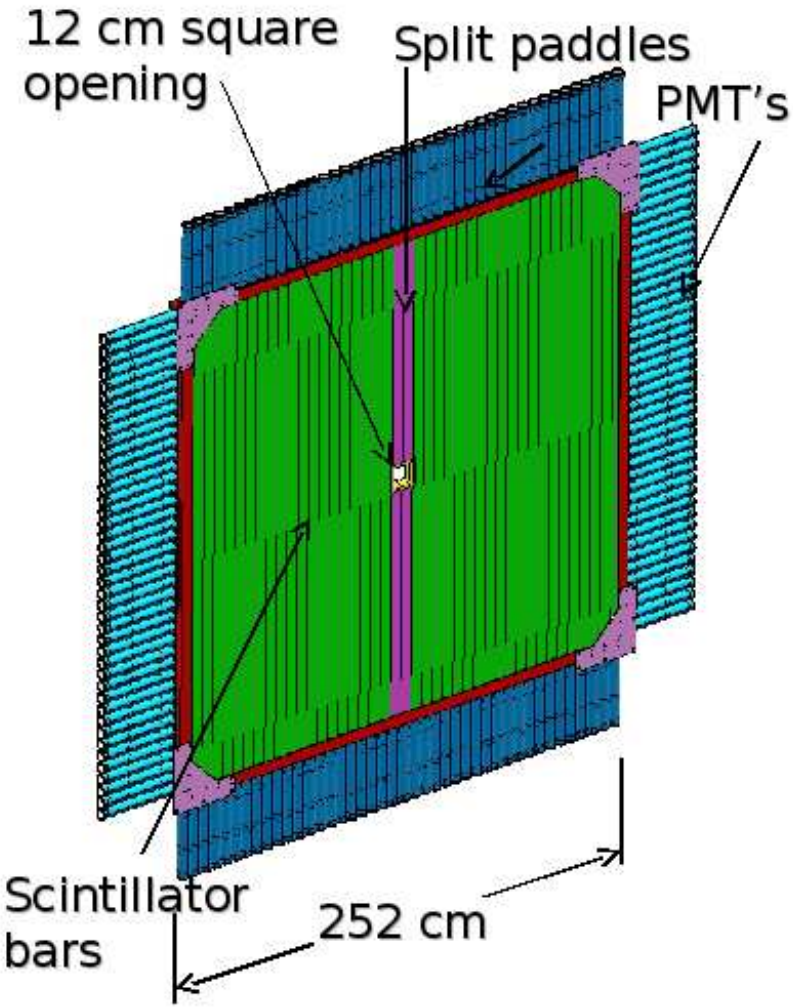
  - 28 segments
  - inner segment → SiPMs
  - Outer segment → PMTs
- $\sigma_E/E\ (\%) = 5.54/\sqrt{(E)} + 1.6$ (testbeam)
- Charged particle PID (ToF: 62 *ps* TDC)

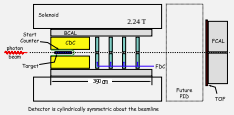
Time-of-Flight Scintillator Wall

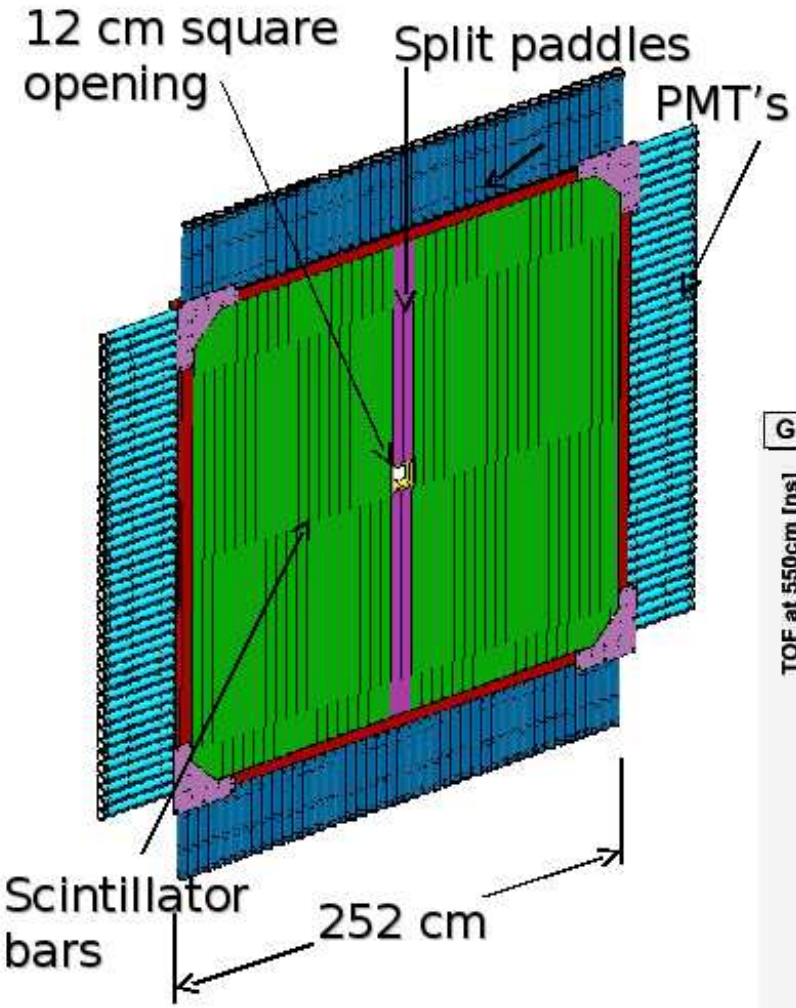




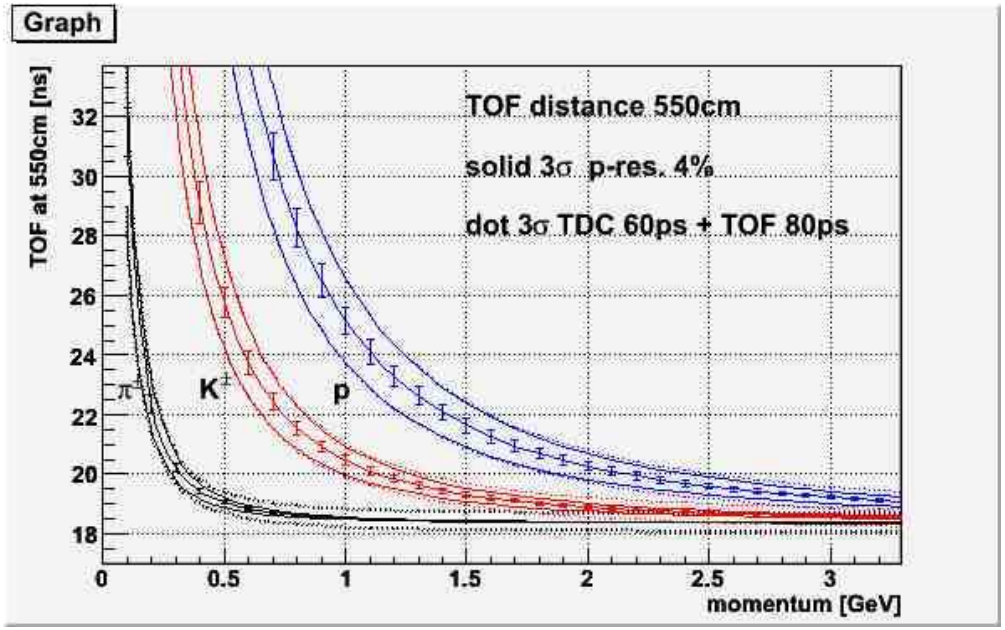
- 5.5 *m* downstream the target
- 2 layers of 42 scintillator bars/each
- Time resolution/plane: 80 *ps*

Time-of-Flight Scintillator Wall

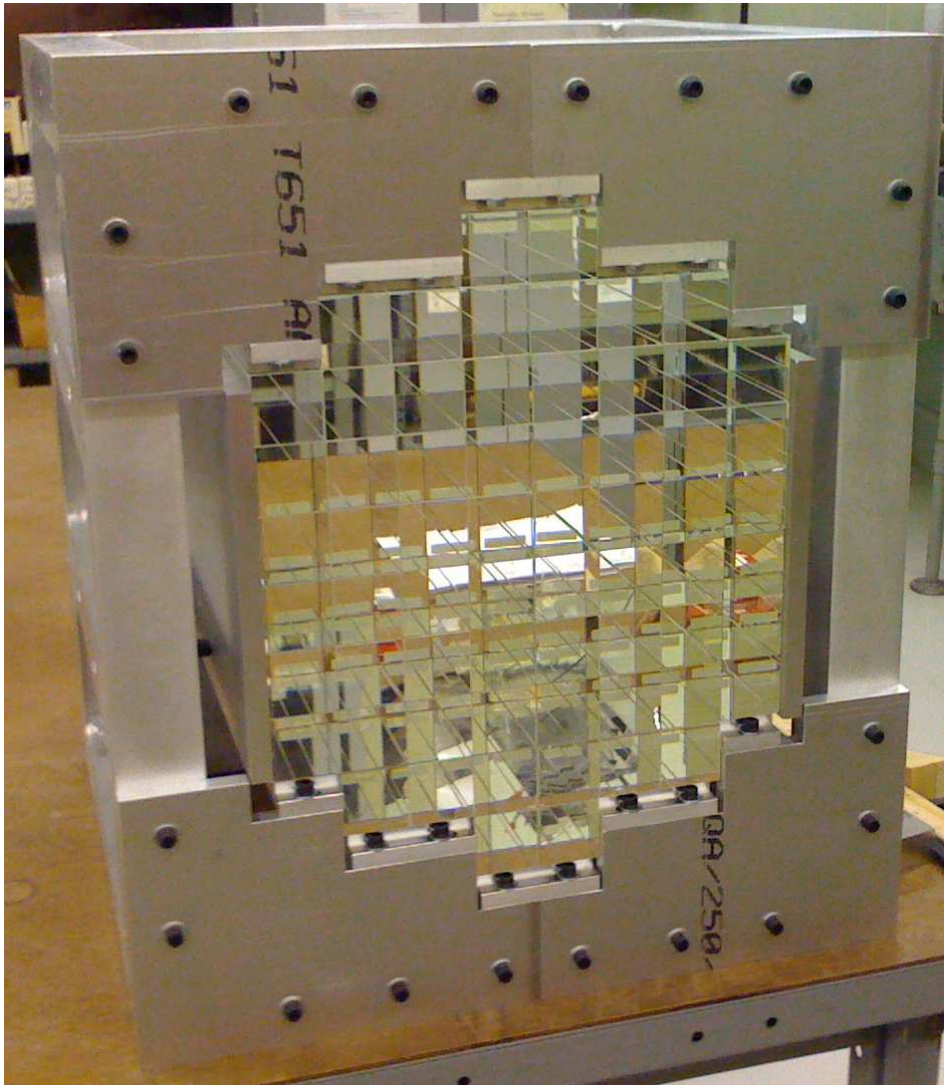




- 5.5 *m* downstream the target
- 2 layers of 42 scintillator bars/each
- Time resolution/plane: 80 *ps*
- Good charged PID up to 2 GeV/c

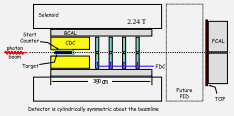


Forward Calorimeter



- 5.6 m away from target
- 2800 lead glass blocks (used before in E852 and RadPhi)
- Stacked in circular shape: 2.4 m diameter
- $\sigma/E\ (\%) = 5.6/\sqrt{E} + 2.0$
- $\sigma_{xy} \approx 0.64\ cm/\sqrt{E}$

Forward Calorimeter



As used in E852 at BNL

Trigger

$3{\cdot}10^8$ tagged γs/s:

- EM background
  - Pair production
  - Compton scattering
  - Dominant background
- Hadronic photoproduction
  - 360 kHz

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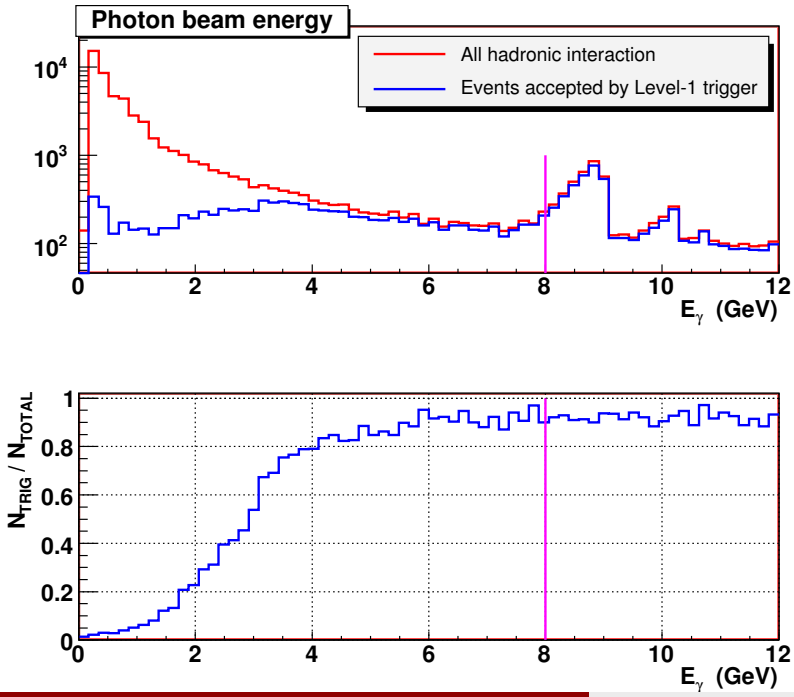

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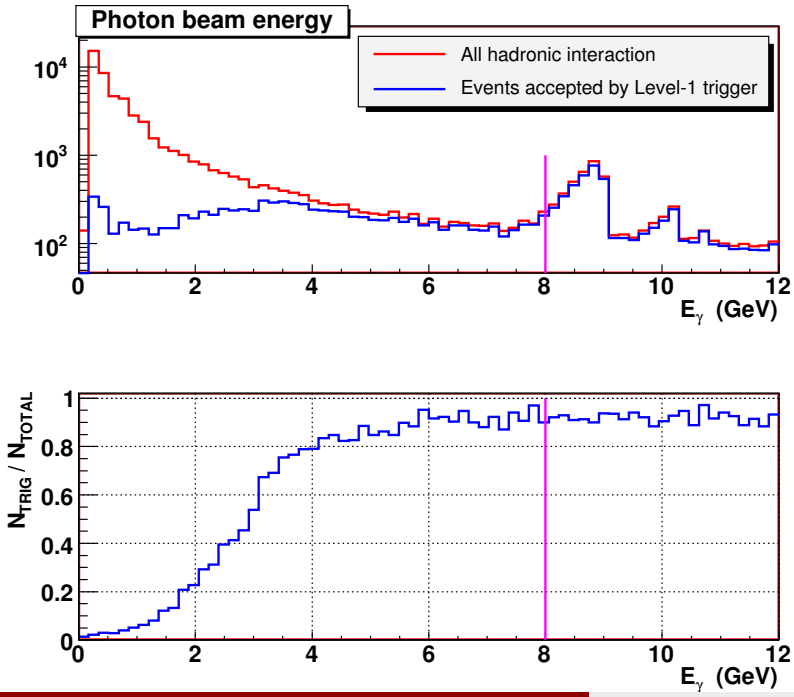

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    - hadronic + em (pile up)
  - Energy deposition in FCAL and BCAL
  - # hits in Tagger, ToF wall, and start-counter
  - Trigger efficiency for exotic decays: >98%
- **Level-3 trigger**: $\rightarrow \sim$ 20 kHz
  - Computer farm
  - Only for high lumi runs

Status

- (DOE) CD-3 granted in September 2008
- HALL-D civil construction started May 2009
- BCal is being built
- Procurement for other detectors is in progress
- Beam on target: **2014**

Physics potentials with Hall-D

Photon-hadron physics workshop (PHP) (March 2008)

$\Rightarrow$ **http://conferences.jlab.org/php2008/index.html**

- Primakoff effect
  - Good forward calorimetry needed
- Photo-production on nuclear targets
  - Medium effects on hadron production
- Charm photo-production (near threshold)
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New collaborators are welcome!

The Gluex collaboration

- Carnegie Mellon (CDC)
- Catholic University
- Christopher Newport
- Florida International (start-counter)
- Florida State (ToF wall)
- Glasgow (γ-beam)
- Indiana University (FCal)
- IUCF (CDC, FDC)
- Jefferson Lab (CDC, FDC, BCal,γ-beam)
- Langzou University
- University of Connecticut (γ-beam)
- University of Alberta (BCal)
- University of Athens (BCal)
- University of Pennsylvania (CDC, FDC)
- University of Regina (BCal)
- Yerevan (γ-beam)

Summary

The GlueX collaboration

- Will map out the hybrid mesons ($< 2.5\ GeV/c$) and will do other interesting physics
  - High intensity 9 GeV linear polarized photons
  - Large acceptance spectrometer
    - In the **new** experimental Hall-D at JLab
- Procurement and construction in progress
- We welcome new participants