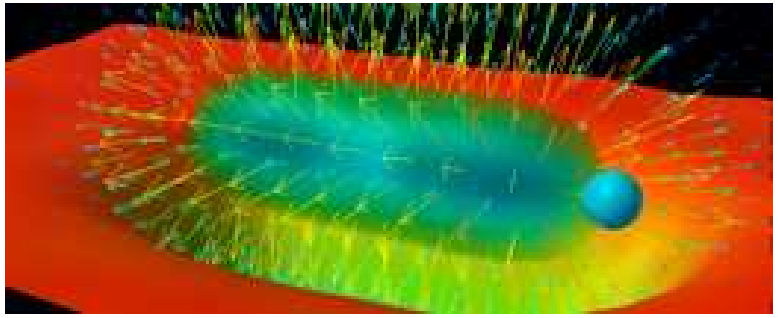
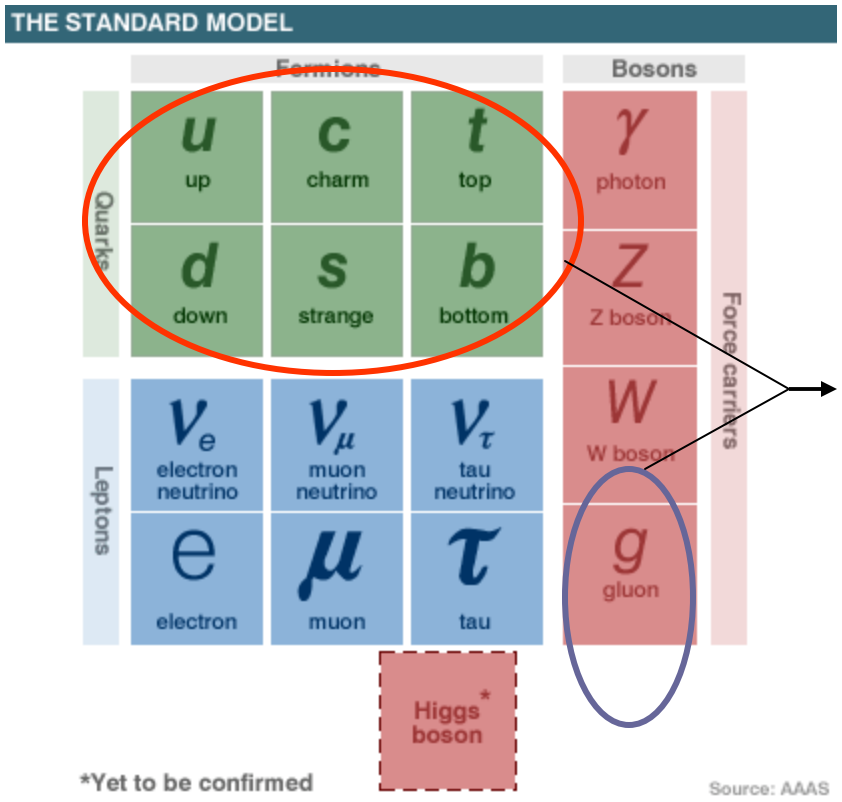
Probing the Force between Quarks with Photons

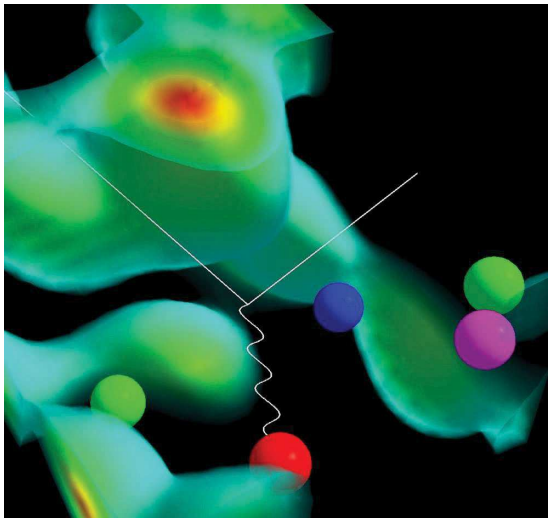
Experimental Nuclear Physics at UConn

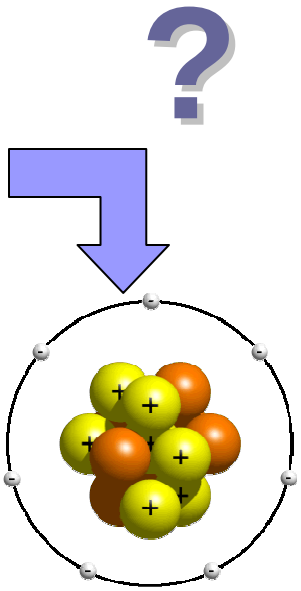
Richard Jones



How do nuclear forces emerge from the Standard Model of quarks and gluons?







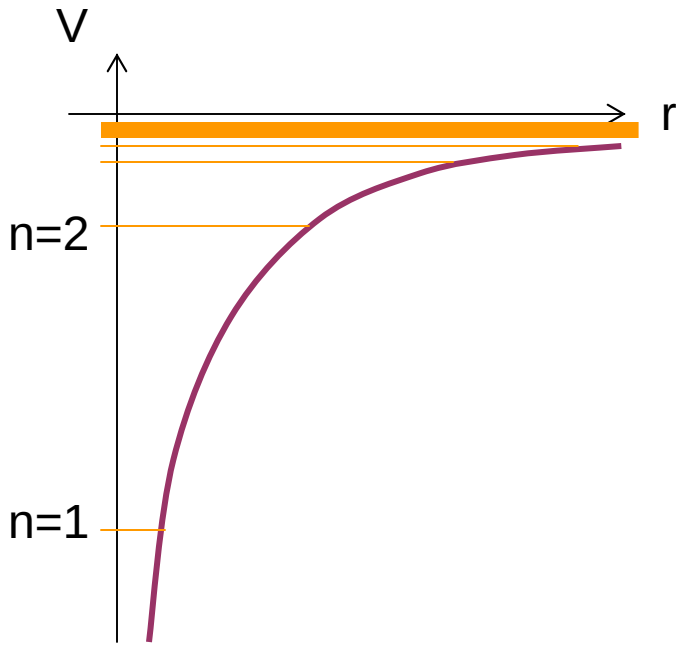
Gauge principle: cornerstone of the SM

- consider the hydrogen atom

$$E_n = -\frac{E_0}{n^2}$$

where

$$E_0 = \alpha^2 \frac{m_e c^2}{2}$$



- α=1/137, weak coupling $\Rightarrow$ ***no confinement***
  - atom can be ionized with energy E0
  - isolated electrons exist as physical states

Gauge theories of different types

QED

1 kind of charge (q)

force mediated by **photons**

photons are *neutral*

α is nearly constant

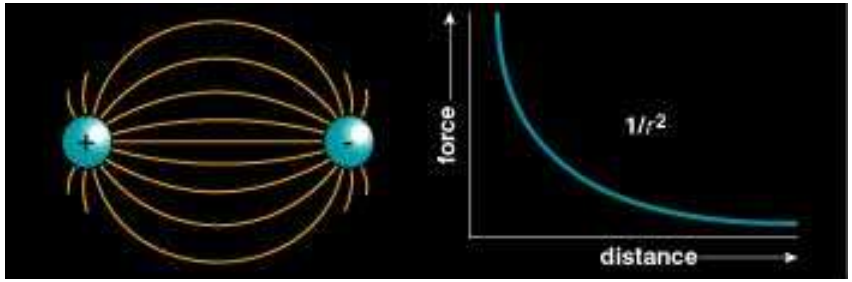
QCD

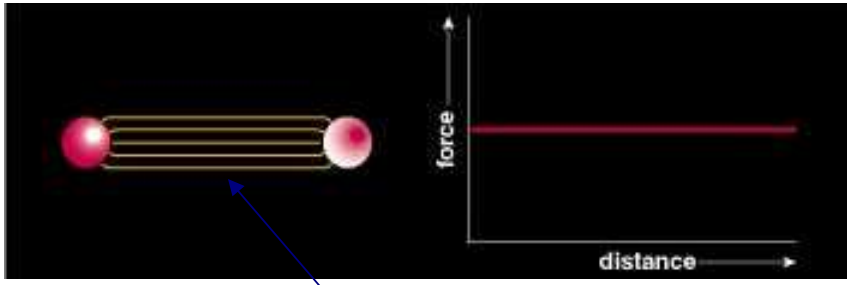
3 kinds of charge (r,g,b)

force mediated by **gluons**

gluons are *charged* (eg. rg, bb, gb)

α_s strongly depends on distance



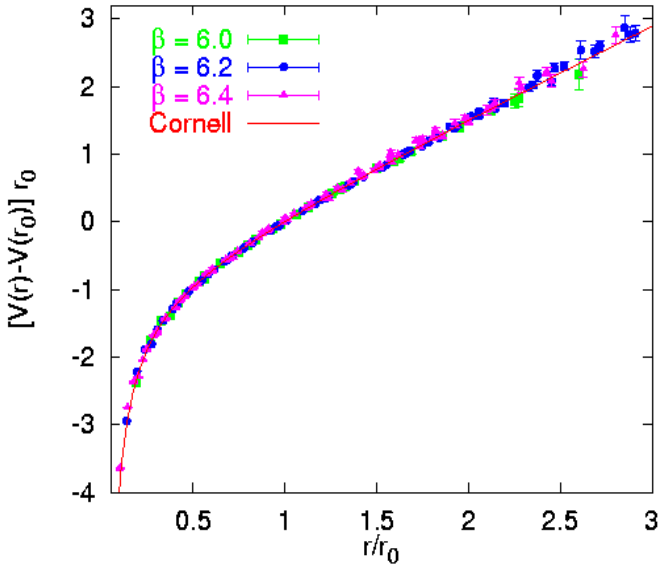


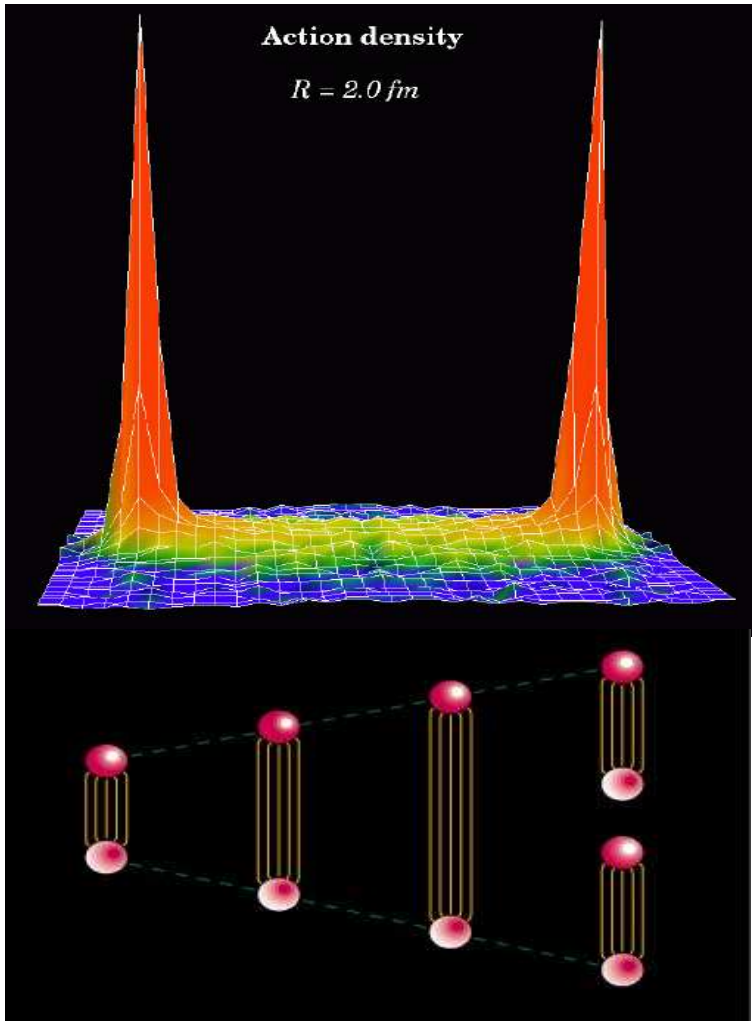
confinement reinterpreted

The underlying theories are formally almost identical – **The Gauge Principle**

Confinement: the “static” quark potential

- $V(r<<r_0) \sim 1/r$
  - 1-gluon exchange
  - ***asymptotic freedom***
- $V(r>>r_0) \sim r$
  - like electrodynamics in 1d
  - ***confinement***

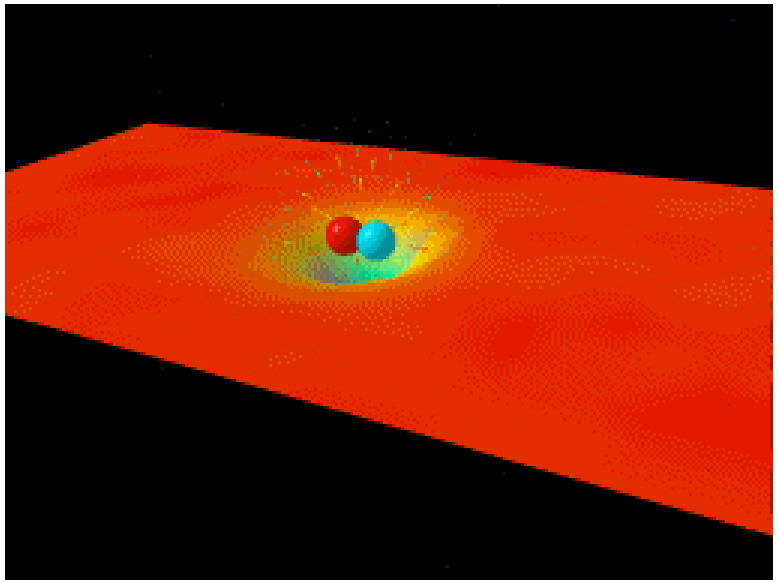




Simple model of a meson: quarks on a string

- So what happens when you pull on a quark inside a proton?

1. ***the quark begins to move***
2. ***a glue string forms***
3. ***the string stretches***
4. ***the quark slows down***
5. ***the quark snaps back – denied!***

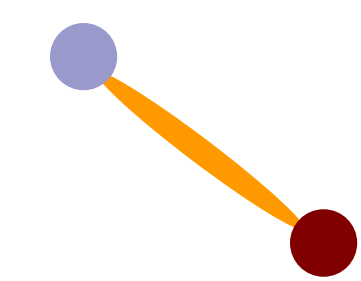


courtesy of D. Leinweber

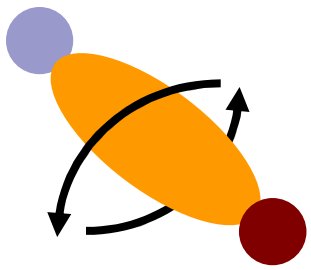
- N. Isgur, 1988:
  What happens if you stretch the string, and then pluck it?

Mesons: the hydrogen atom of QCD

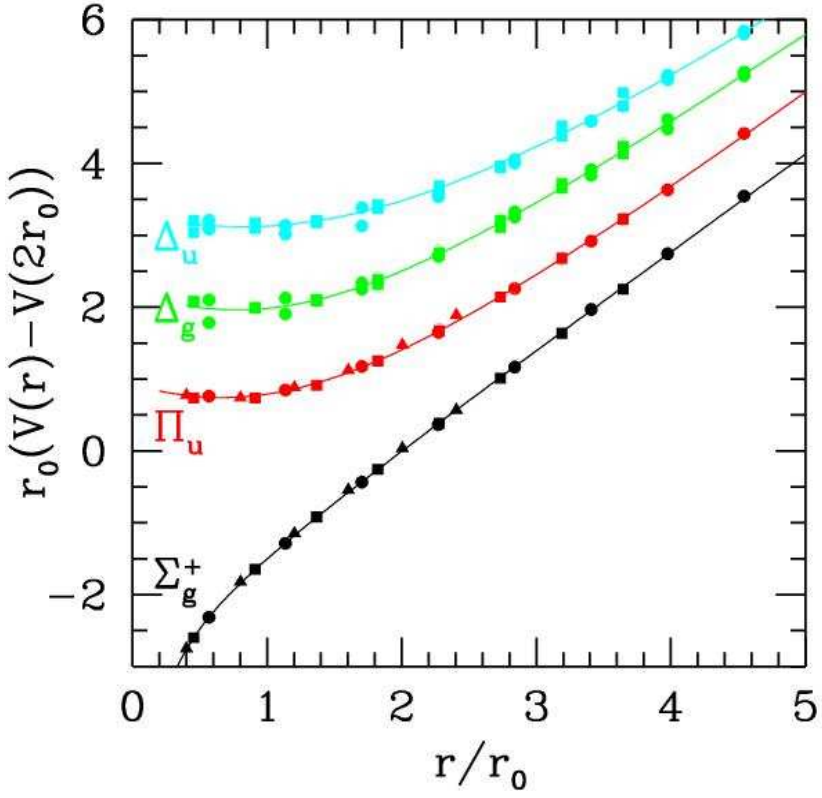
- Intuitive picture within Born-Oppenheimer approximation
  - quarks are massive – slow degrees of freedom
  - gluons are massless – generate effective potential
- Glue can be excited



ground-state flux-tube m=0



excited flux-tube m=1



a new kind of meson (Hybrid) is predicted

Thomas Jefferson National Accelerator

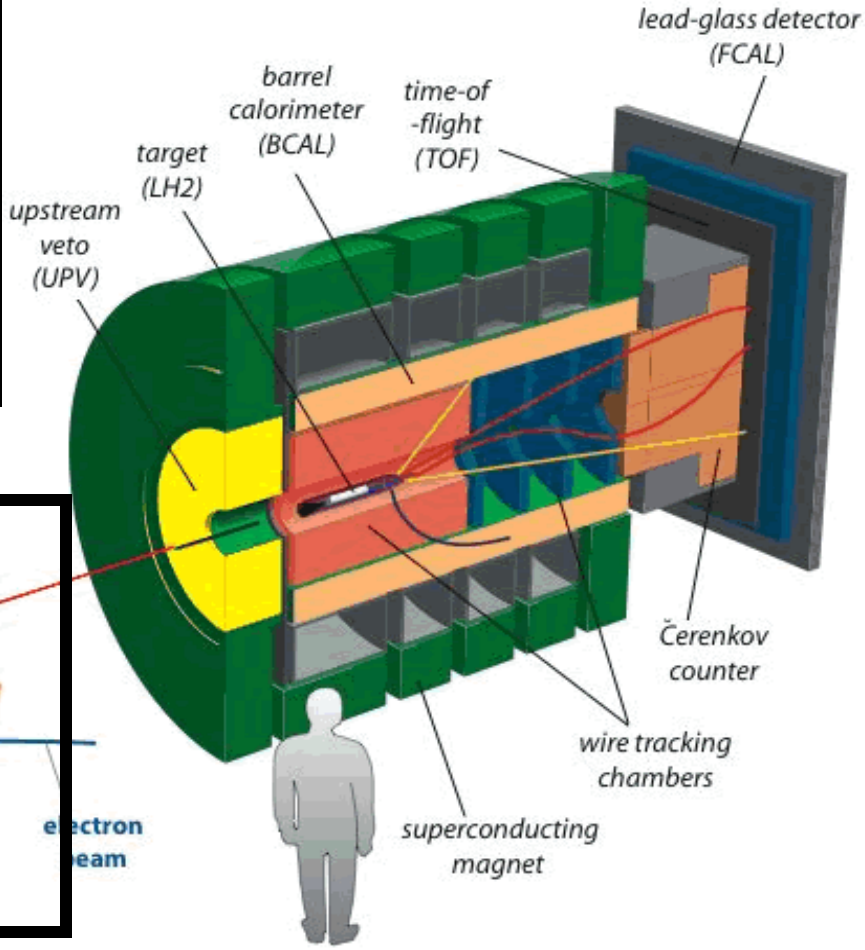
Hall D

- racetrac
  accelera
- accelerates electrons to 6 GeV
- upgrading to 12 GeV
- experiments

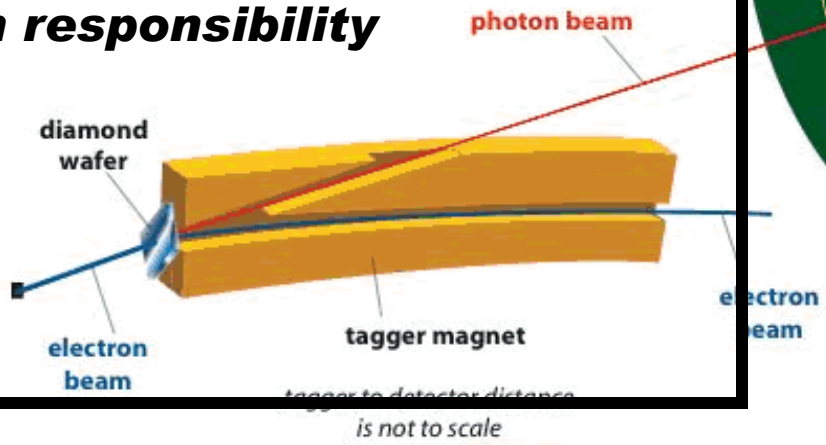
The GlueX experiment

Time line for experiment

- ***1997 – first meeting***
- ***1999 – initial proposal***
- ***2002 – mature proposal***
- ***2003 – project adopted by DOE***
- ***2006 – mature design***
- ***2009 – construction started***
- ***2014 – commissioning***
- ***2015 – first results!***

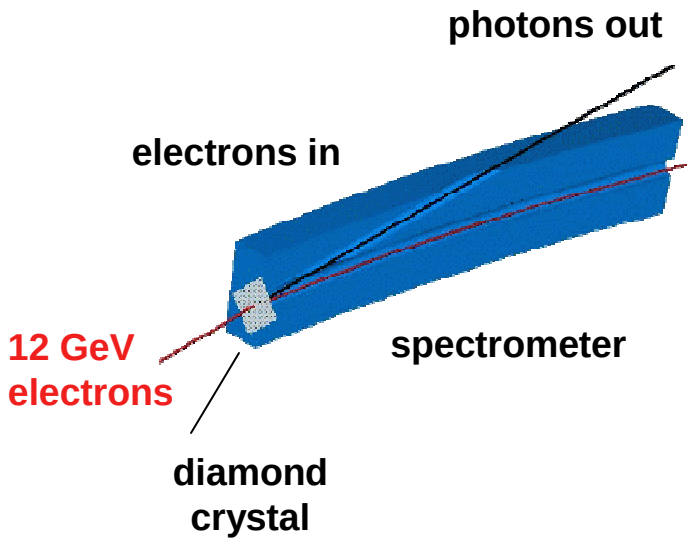


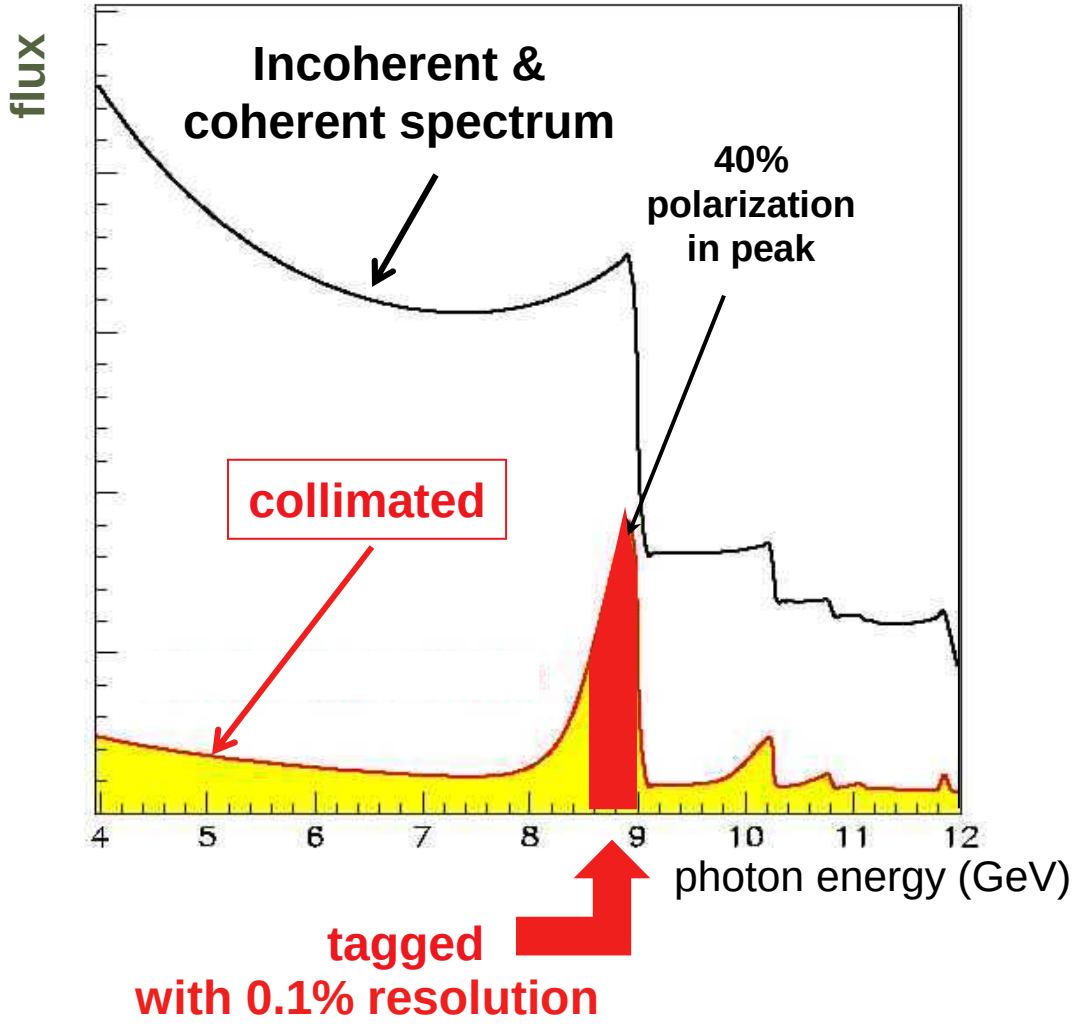
UConn responsibility



The 9 GeV polarized photon beam

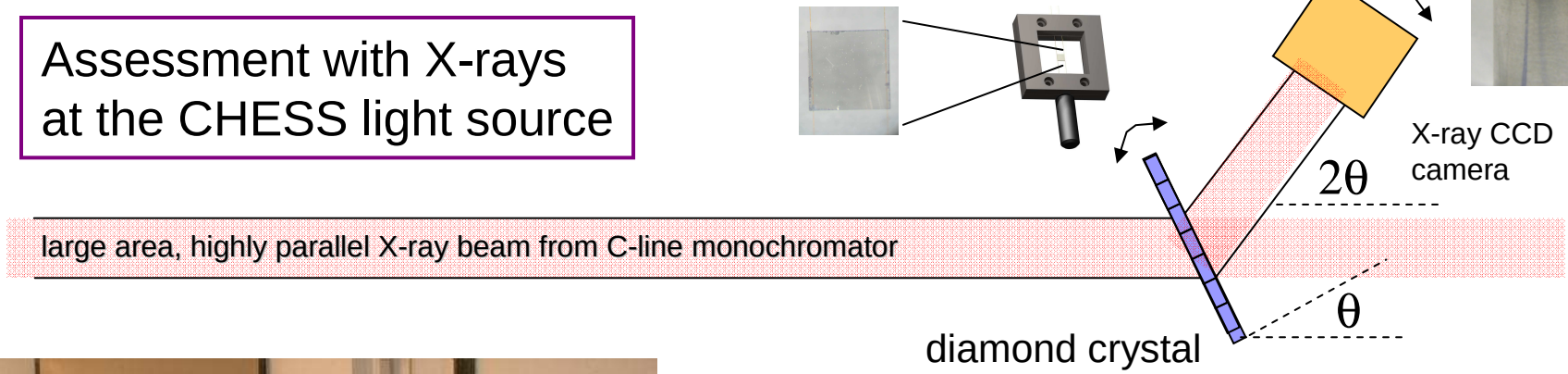
The coherent bremsstrahlung technique provides requisite energy, flux and polarization

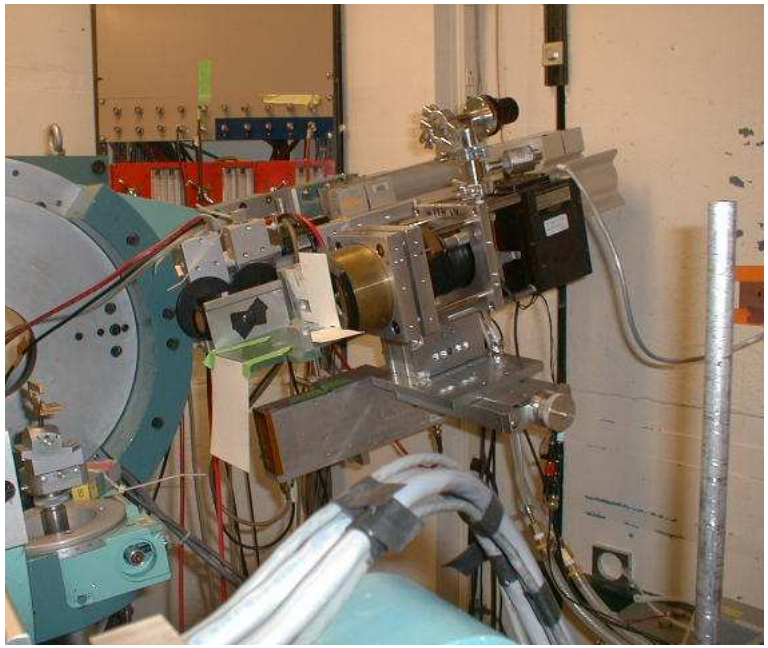


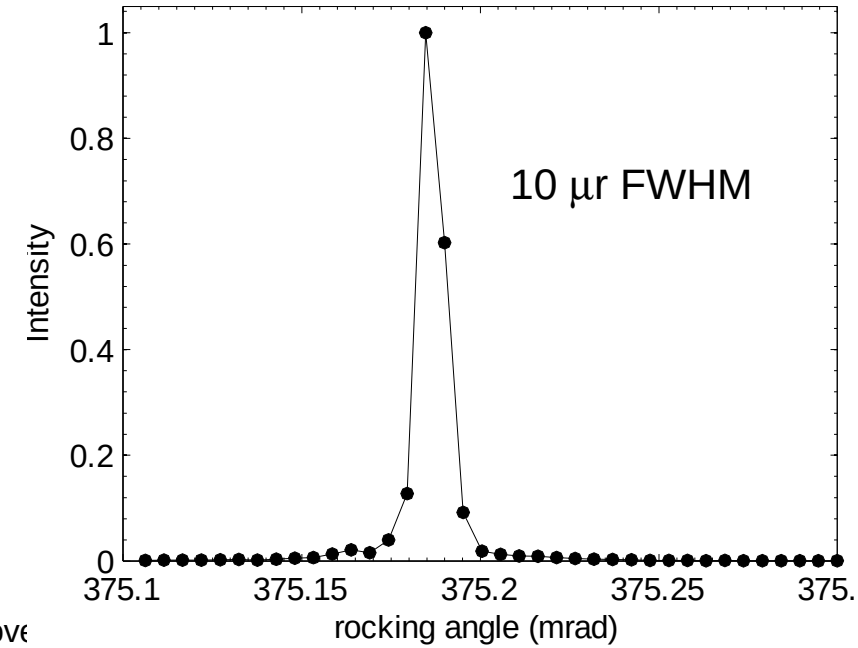


Diamond radiators for GlueX

Assessment with X-rays
at the CHESS light source

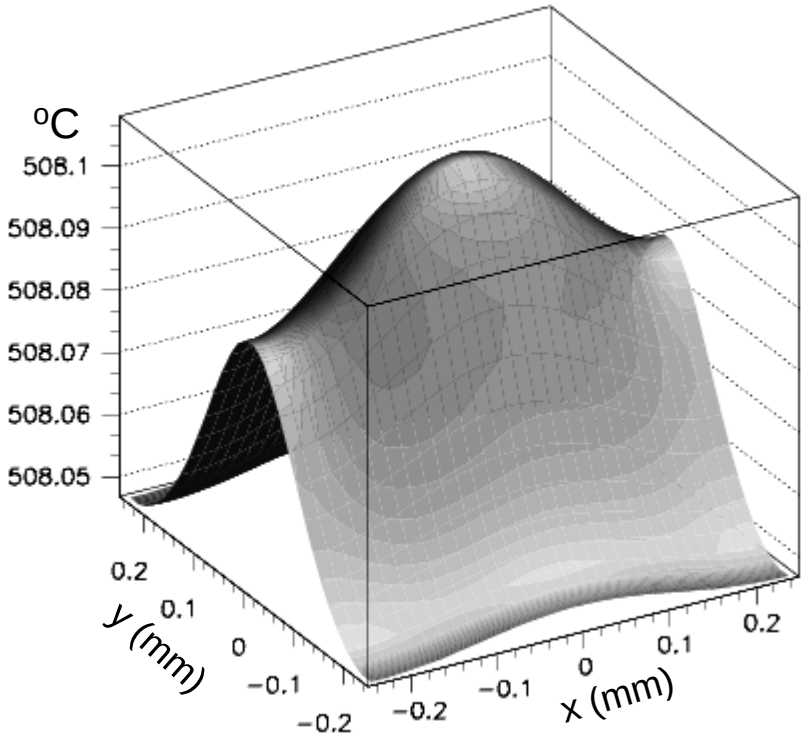






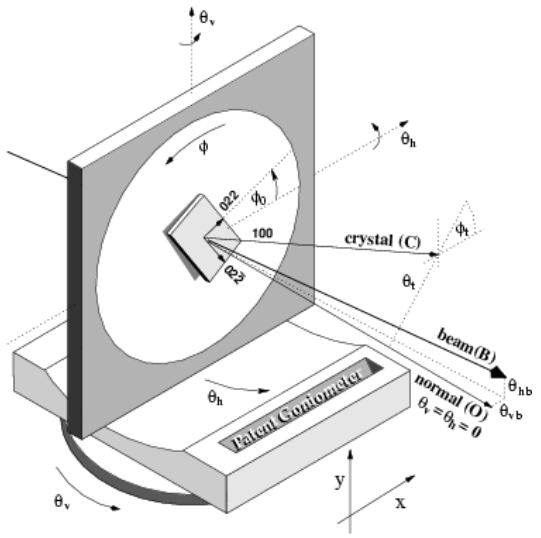
Diamond radiator

temperature profile of crystal
at full intensity, radiation only



diamond-graphite transition sets in ~1200°C

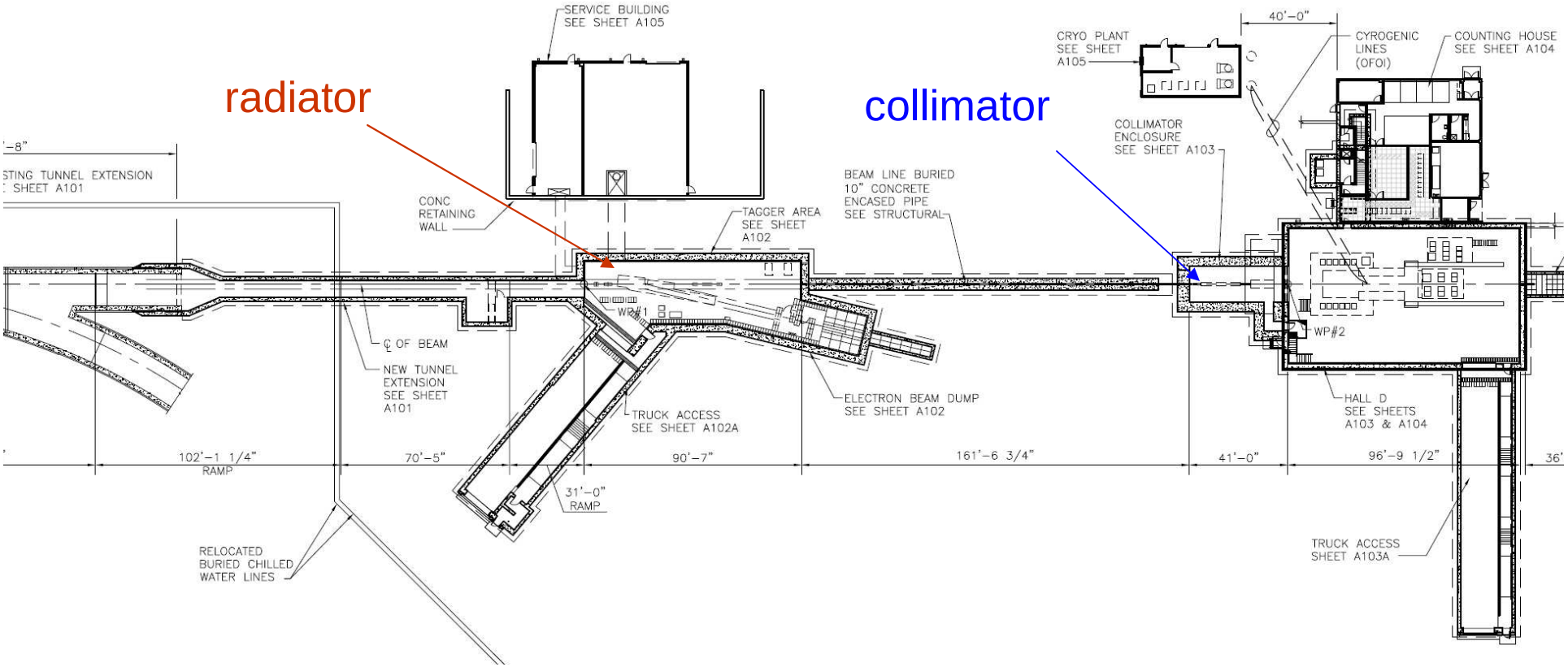
Heat dissipation specification for the mount is not required.



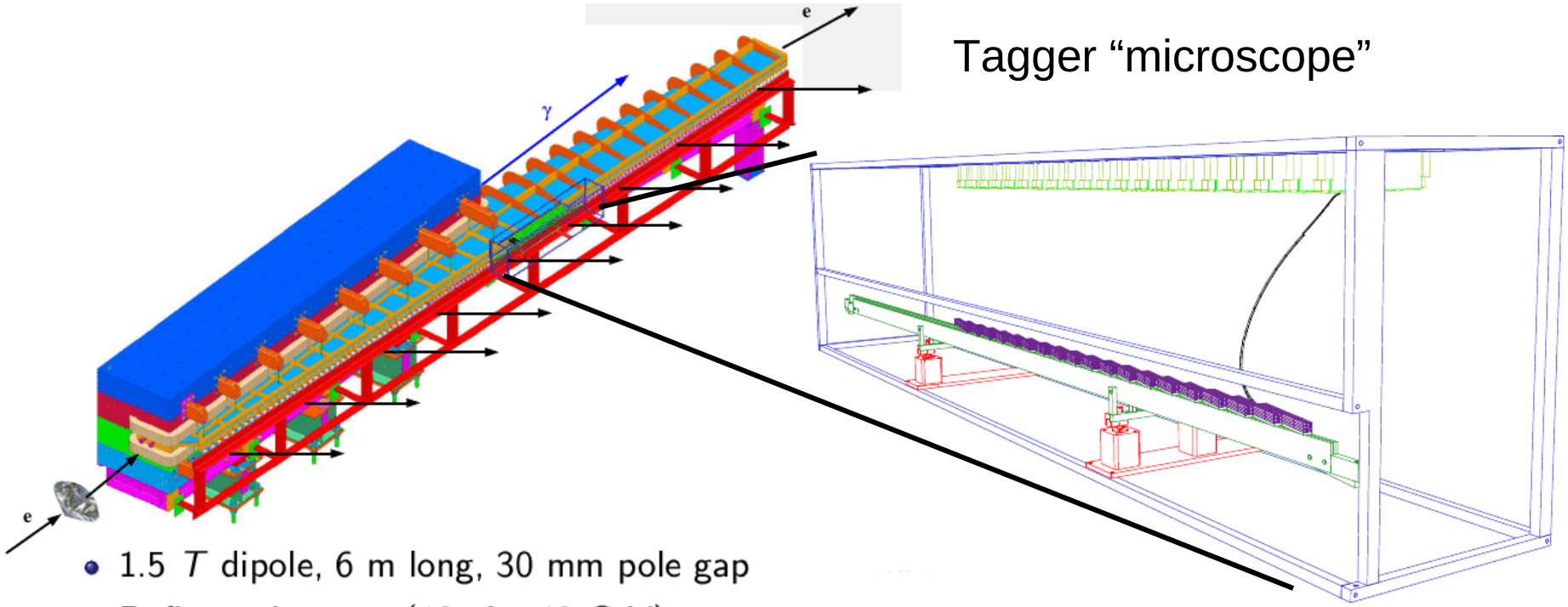
translation step: 200 μm horizontal
25 μm target ladder (fine tuning)

rotational step: 1.5 μrad pitch and yaw
3.0 μrad azimuthal rotation

Hall D Beam Line



Photon tagging detector



Tagger “microscope”

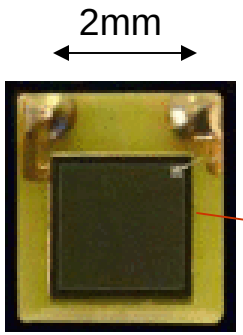
- 1.5 T dipole, 6 m long, 30 mm pole gap
- Deflects electrons (13.4°= 12 GeV)
- 190 Hodoscopes: scintillator + PMTs (12 m long) → 3 - 11.7 GeV

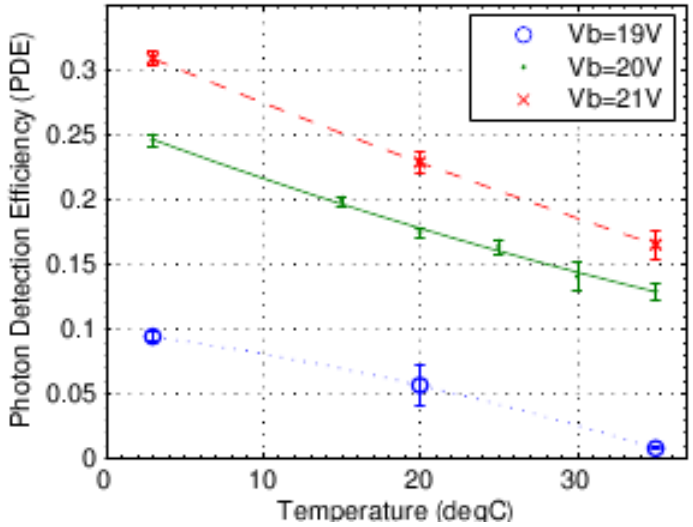
scintillating fibers
read out with SiPM’s

Photon tagging detector

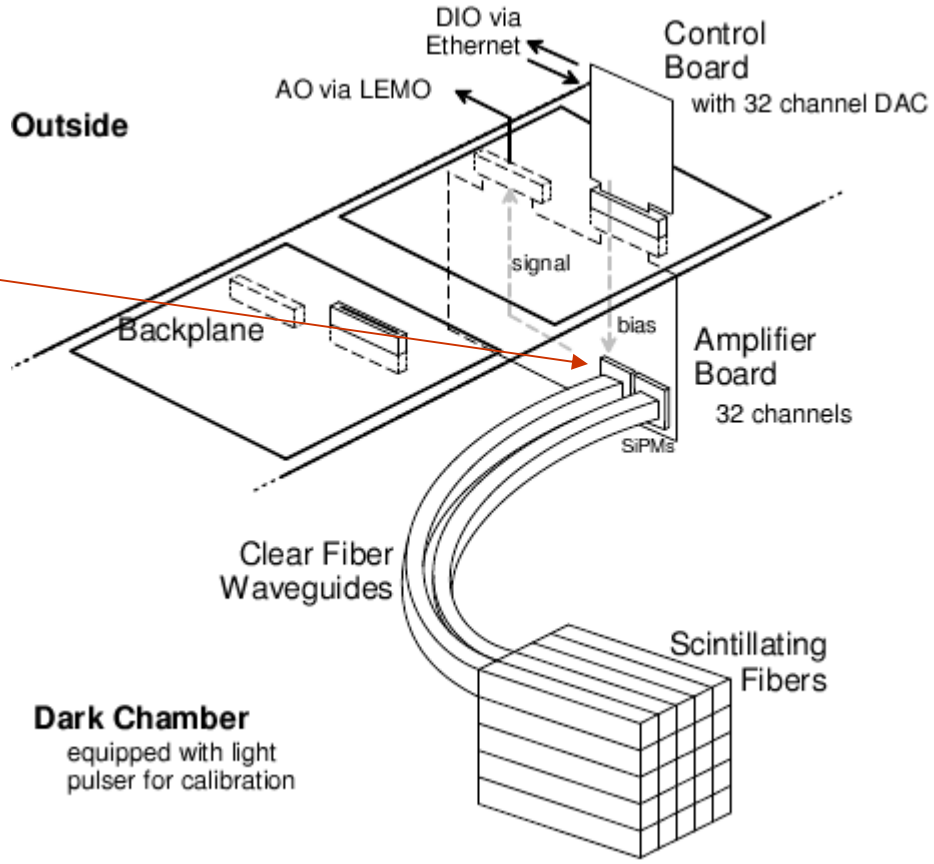
- 8 MeV tagging channel width
- 200 ps time resolution
- 4 MHz/fiber

"Silicon PMT"
(multi-pixel APD
in Geiger mode)



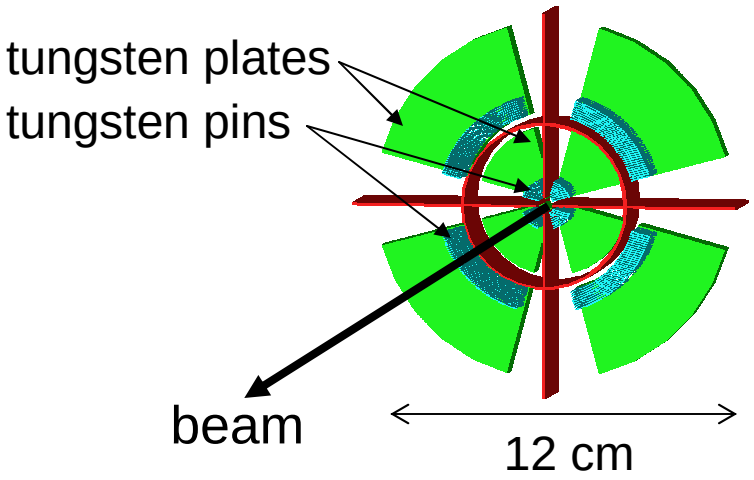


scintillating fiber readout scheme

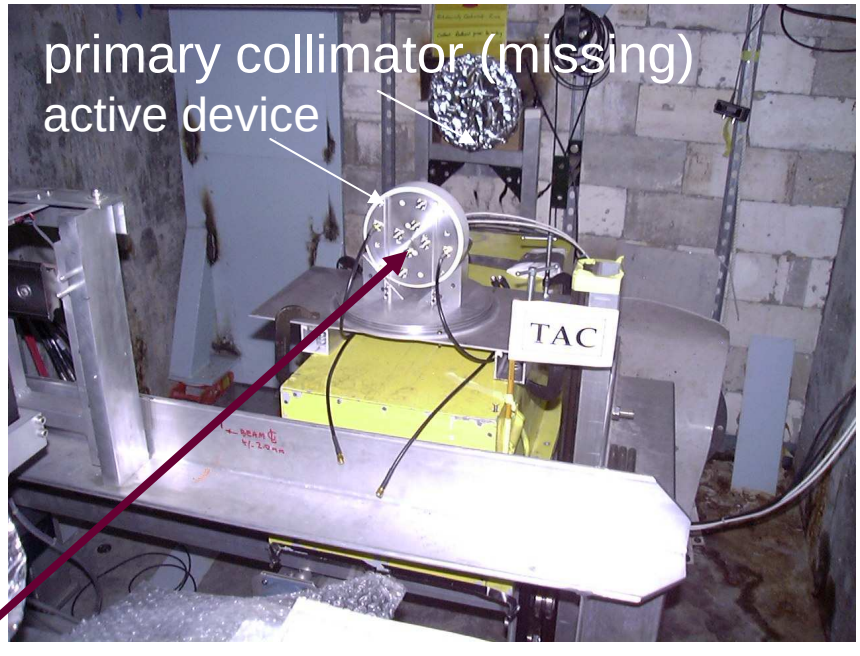


Active Collimator

- Tungsten pin-cushion detector
  - reference: **Miller and Walz, NIM 117 (1974) 33-37**
  - measures current due to knock-ons in EM showers



beam test in Hall B in April 2007



The Competition

- China – Beijing Electron-Positron Collider
  - BES experiment
- Europe – FAIR Antiproton Accelerator
  - PANDA experiment
- Japan – JPARC Proton Accelerator
  - several multi-GeV beam lines

Gluex – computing plan

1. raw data

- ✓ 2 PB/yr for 5 years
- ✓ archives stored on Jlab silo

2. simulation

- ✓ 100 TB/yr for 10 years
- ✓ 2×10^8 SPECint_rate2006 hr/yr
- ✓ limited lifetime, on-demand

3. analysis

- ✓ dataset size ~few TB
- ✓ cpu intensive, massively parallel **(GPU)**
- ✓ advances needed to achieve goals

Gluex– the collaboration

15 institutions + Jlab
~60 members

Collab. Board (6)
Executive Committee
Current spokesperson
Curtis Meyer, CMU

Schedule:

- Sept. 2008: ***CD3***
  start of construction
- Dec. 2012:
  end of 6 GeV Ops.
- 2015: ***CD4***
  start of operations

- University of Athens
- Carnegie Mellon University
- Catholic University
- Christopher Newport University
- University of Connecticut
- Florida International University
- Florida State University
- University of Glasgow
- IHEP Protvino
- Indiana University
- Jefferson Lab
- U. of Massachusetts, Amherst
- North Carolina A&T State
- U. of North Carolina, Wilmington
- Santa Maria University
- University of Regina

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