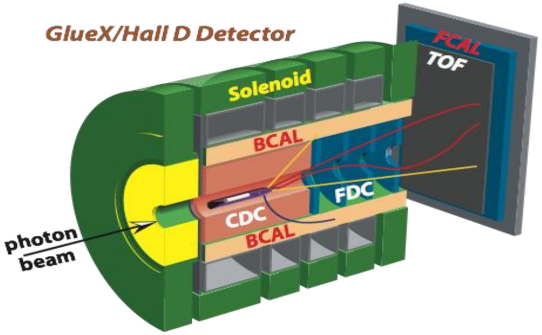


Beamline Commissioning and Radiation

A. Somov, Jefferson Lab

E12-19-003
Experiment Readiness Review
March 31, 2020

Outline

- Beam Commissiong (charge 7)

Are the beam commissioning procedures and machine protection systems sufficiently defined for this stage?

- Radiation level (charge 4)

What is the impact of the expected neutron radiation on GlueX detector components such as the SiPMs? Is any local shielding required? Are the radiation levels expected to be generated in the hall acceptable?

Photon Beam Requirements

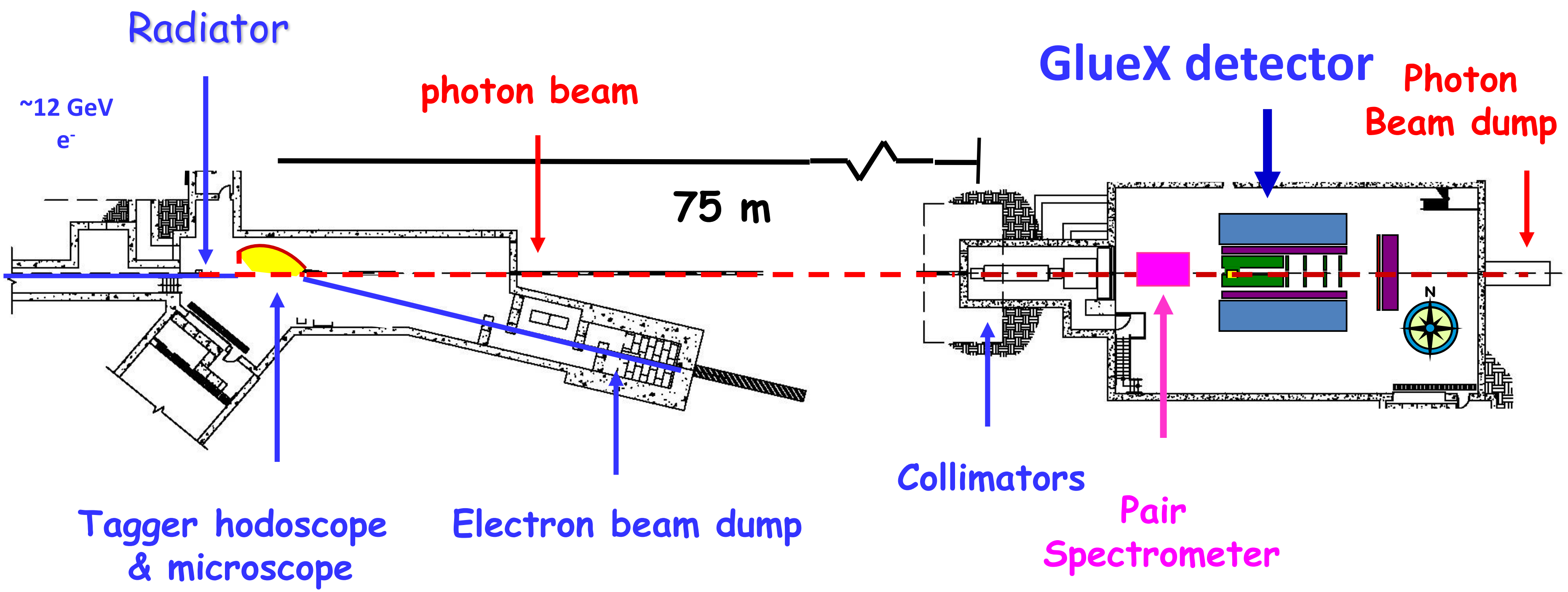
Experiment	Energy Range (GeV)	Polarization	Flux in the energy range of interest γ/ sec	Flux on target (0.012 – 11.7 GeV) γ/ sec
GlueX Design	**8.4 - 9.1**	**40 %**	10^8	$1.8 \cdot 10^9$
GlueX II	**8.4 - 9.1**	**40 %**	$5 \cdot 10^7$	$9 \cdot 10^8$
This experiment	**8.4 - 9.1**	**40 %**	$2 \cdot 10^7$	$3.6 \cdot 10^8$

	This experiment	*GlueX II*
Electron beam current:	140 nA	350 nA
Radiator thickness:	$2 \cdot 10^{-4}\ X_0$	$2 \cdot 10^{-4}\ X_0$
Collimator diameter:	5 mm	5 mm

Photon flux on target is about 2.5 smaller than GlueX II flux
(5 times smaller than GlueX designed flux)

Hall D Photon Beam Line

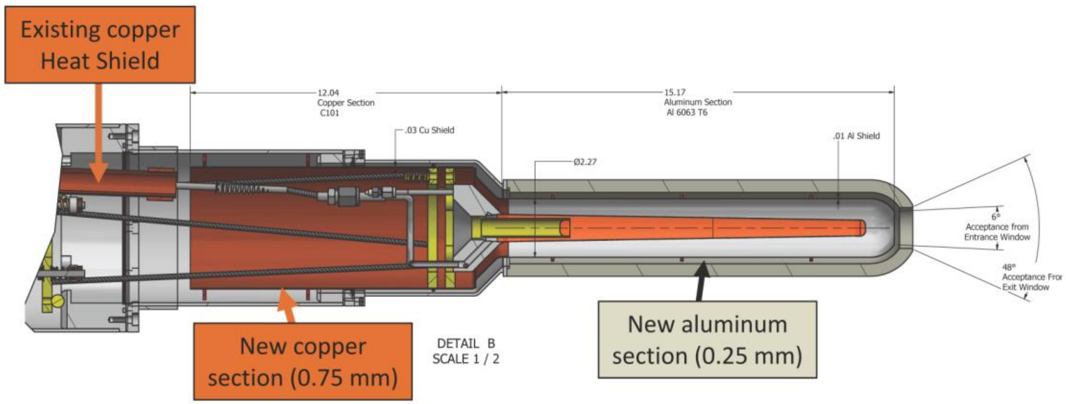
Use standard Hall D beam line equipment for SRC / CT !



Targets

See C. Keith talk

- LD (LHe) target. Standard GlueX target cell and cryogenic system
  - LHe targer was used by Hall D PrimEx expeiment
- Carbon target
  - Similar to PrimEx Be target



SRC/CT Beamline Summary

- 12 GeV polarized photon beam has been successfully used by the GlueX experiment in 2016 - 2019

- Typical GlueX beam configurations:
  - electron beam current 100 – 350 nA (data production)
  < 5 nA (PS calibration)

- Beamline equipment installed in Hall D is ready to use by the SRC/CT experiment

- Photon beam conditions used for the GlueX data production satisfied specifications of the RC/CT experiment

- Beam delivery/monitoring procedures and machine protection systems are the same as for the GlueX experiment

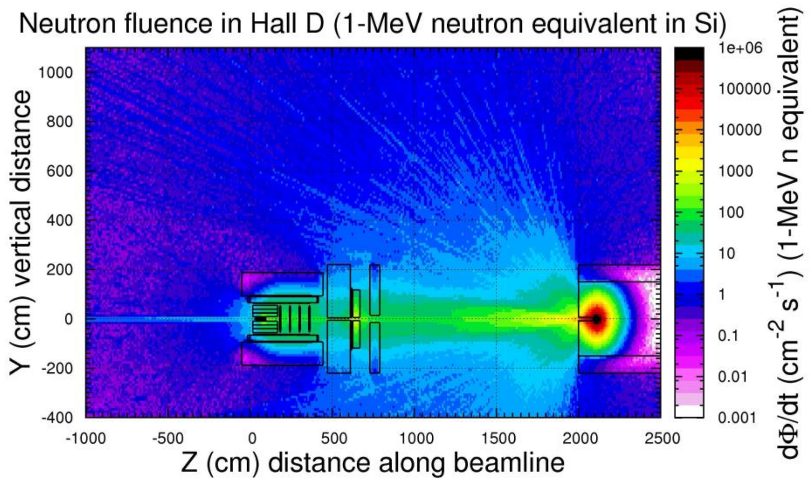
Radiation Level

Charge 4

JLAB-TN-11-005
GlueX-doc-1660
Version 0.3
February 23, 2011

Calculation of Radiation Damage to Silicon Photomultipliers in GlueX Experiment

P. Degtiarenko, A. Fassò, G. Kharashvili, A. Somov



- Estimated background for the LH/LHe/LD target using Fluka and Geant simulations provided by the JLab Radiation Control group
- Neutron background is critical for SiPM operation

SRC Targets and Run Period

Target	Thicknes [cm] / % X_0	Atoms	Run Time (days)
LH	30 / 3.4	$1.28 \cdot 10^{24}$	GlueX
D	30 / 4.1	$1.51 \cdot 10^{24}$	5
4He	30 / 4.0	$5.68 \cdot 10^{23}$	1
12C	1.9 / 7	$1.45 \cdot 10^{23}$	7

SRC/CT photon flux 5 times smaller than GlueX designed

Radiation Damage to SiPM

Damage effects to Silicon detectors (SiPM) caused by different particle types

- largest damage by neutrons with $E_{kin} > 1$ MeV

- **increase of the SiPM dark noise**

In simulation, convert particle fluence to the to equivalent fluence of 1 MeV neutrons

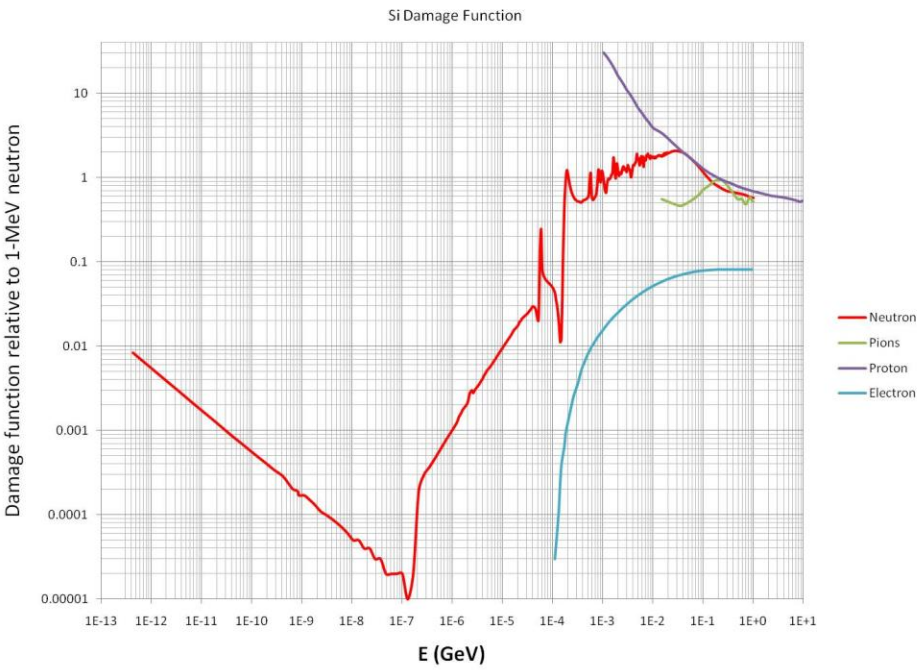
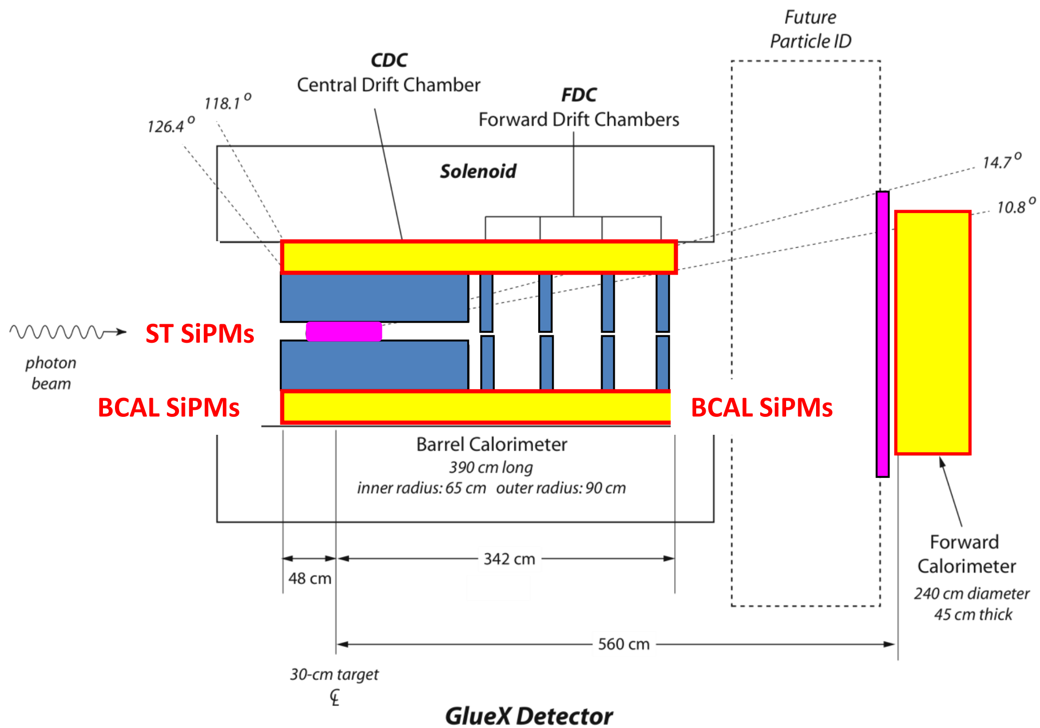


Photo Detectors Sensitive to Neutron Radiation



Barrel Calorimeter SiPMs (4 x 4 array of 3 mm x 3 mm)

- calorimeter design allows a factor of 5 increase of the dark noise
- about 6 years of GlueX operation at high luminosity (10^8 γ / sec)

Start Counter SiPMs (3 mm x 3 mm)

- Neutron dose larger than in BCAL
- less sensitive to dark current, large readout threshold

Neutron Background Induced by LH and LHe Targets

FLUKA, Liquid Hydrogen target

Position of control volume	n	p	π	e^-	e^+	Total
Start Counter	20.9	1.4	18.4	0.1	0.1	40.9 ± 3.1
BCAL upstream SiPM	2.0	0.1	0.3	0.0	0.0	2.4 ± 0.2
BCAL downstream SiPM	18.2	1.7	1.8	1.1	0.3	23.2 ± 0.6
75 cm downstream from BCAL	16.7	2.2	2.3	18.2	5.6	45.1 ± 1.0

GEANT, Liquid Hydrogen target

75 cm downstream from BCAL	30.5					

FLUKA, Liquid Helium target

Start Counter	112.1	34.8	14.7	0.2	0.1	162.9 ± 5.9
BCAL upstream SiPM	8.0	0.2	0.3	0.04	0.03	8.6 ± 2.2
BCAL downstream SiPM	23.0	2.1	2.2	1.0	0.3	28.7 ± 0.3
75 cm downstream from BCAL	21.1	2.7	2.5	20.1	6.8	53.7 ± 0.9

Table 1: 1-MeV neutron equivalent fluence in units of $n_{eq} \cdot s^{-1} \cdot cm^{-2}$ estimated with FLUKA and GEANT simulations. The fluences were computed in the Start Counter and BCAL SiPM regions. See definitions of the regions in the text.

Neutron background was evaluated for the GlueX proposed luminosity

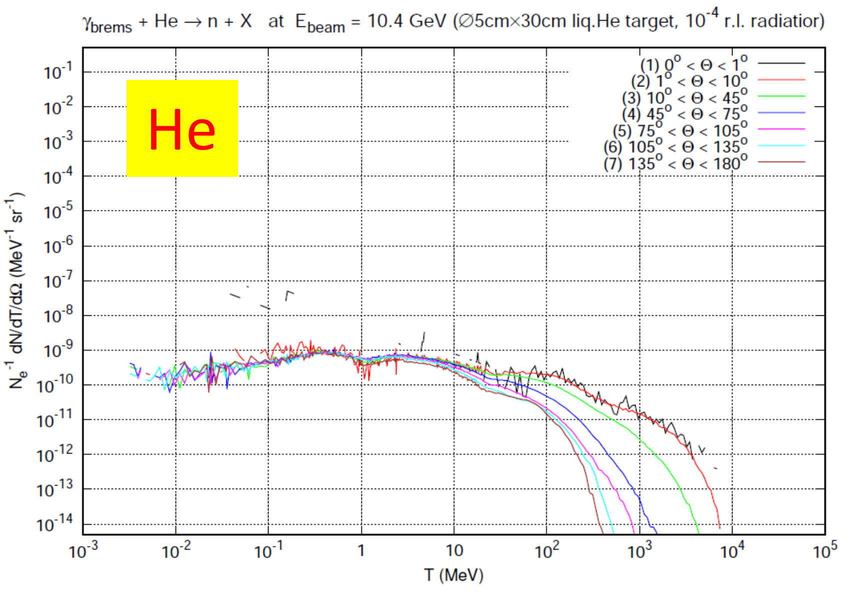
Neutron background induced by the LHe target is about a factor of 4 – 5 larger that for LH_2

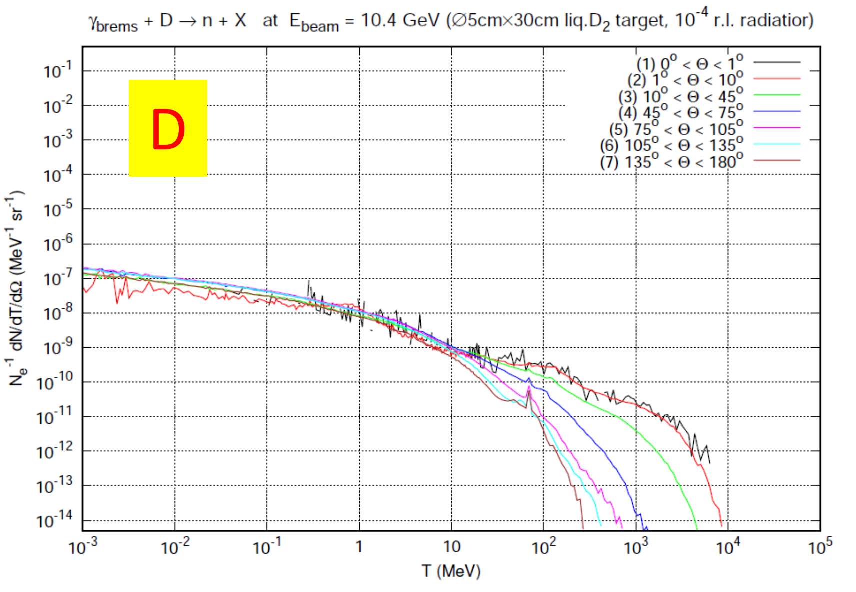
- SRC/CT beam flux on target is 5 times smaller than that for GlueX

Background induced by the LHe target will not exceed the GlueX level

(RSAD for SRC/CT will be similar to GlueX . It will be coordinated with the RadCon group)

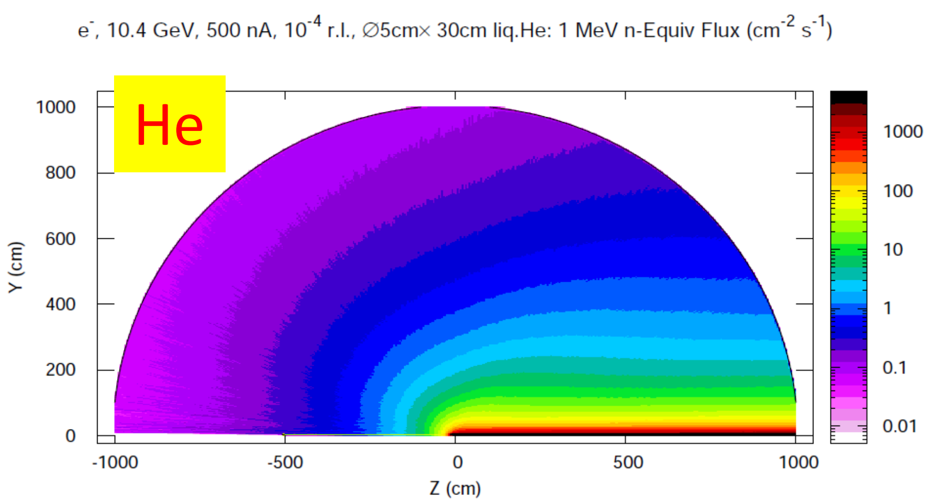
Neutron Flux: He and D Targets

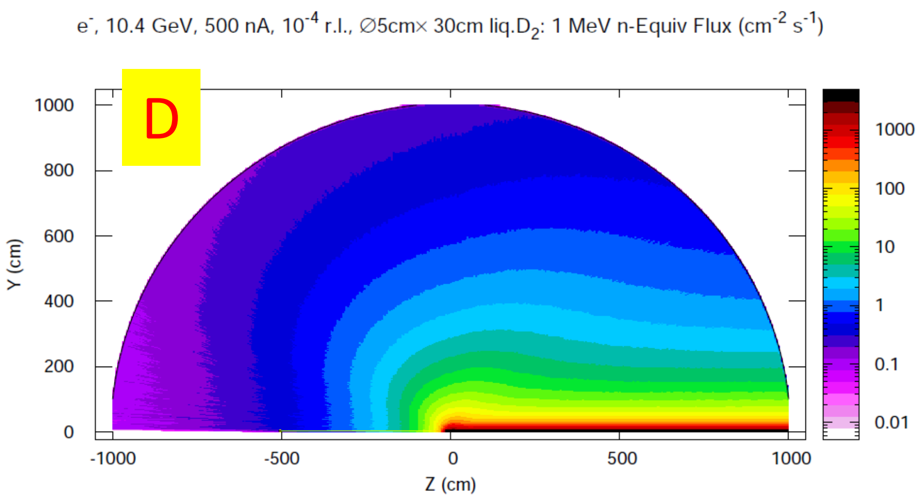




- Recent calculations by Pavel Degtyareko
- Computed using RadCon Geant and Fluka
  - relatively good agreement between Geant and Fluka

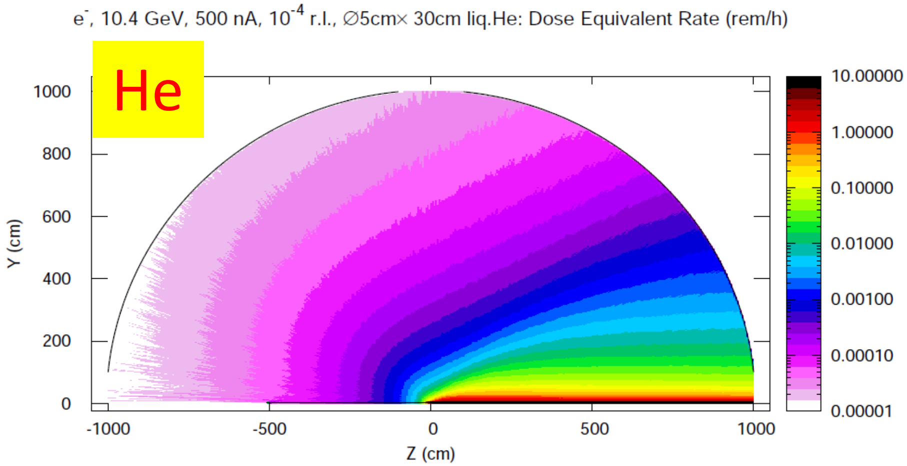
1 MeV Equivalent Flux: He and D Targets

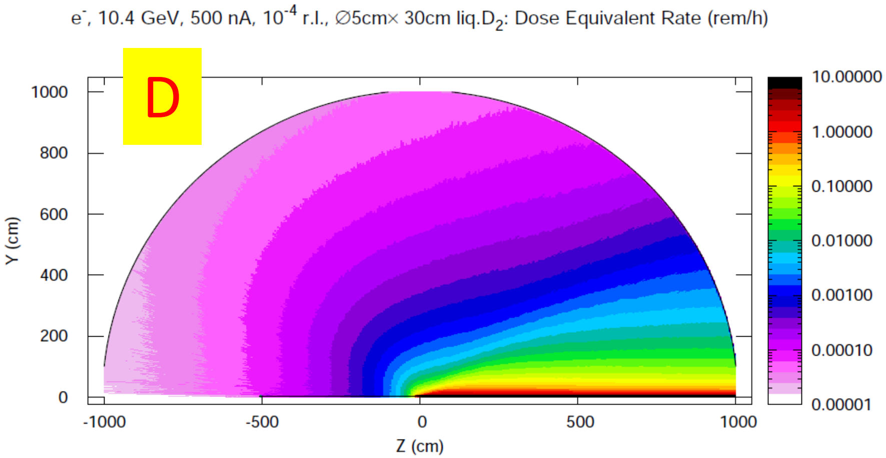




- 1 MeV neutron equivalent fluence for the Deuterium target is about 4 times larger than that for the He target

Dose Equivalent Rate: He and D Targets





- Estimated neutron dose equivalent rate in Hall D(ceiling) induced by the Deuterium target is smaller than 0.1 mreh / h, which is acceptable by RadCon

Monitoring Radiation Level in Hall D

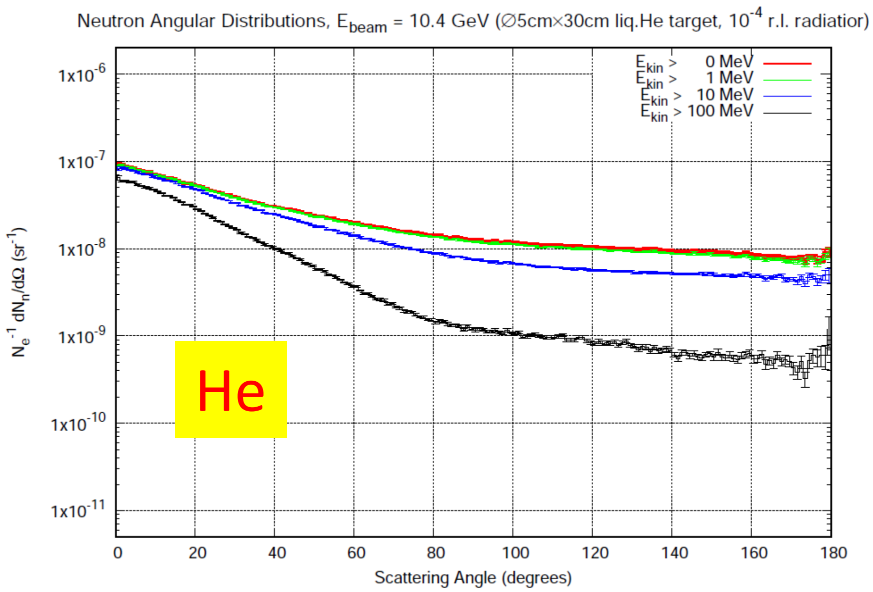
- Installed quick access ionization chambers (show locations)
- Install thermoluminescent dosimeters (**TLD)** close to the target
- Install **Bonner spheres** (determine the energy spectrum of neutons) close to the target (coordinate with RadCon group)

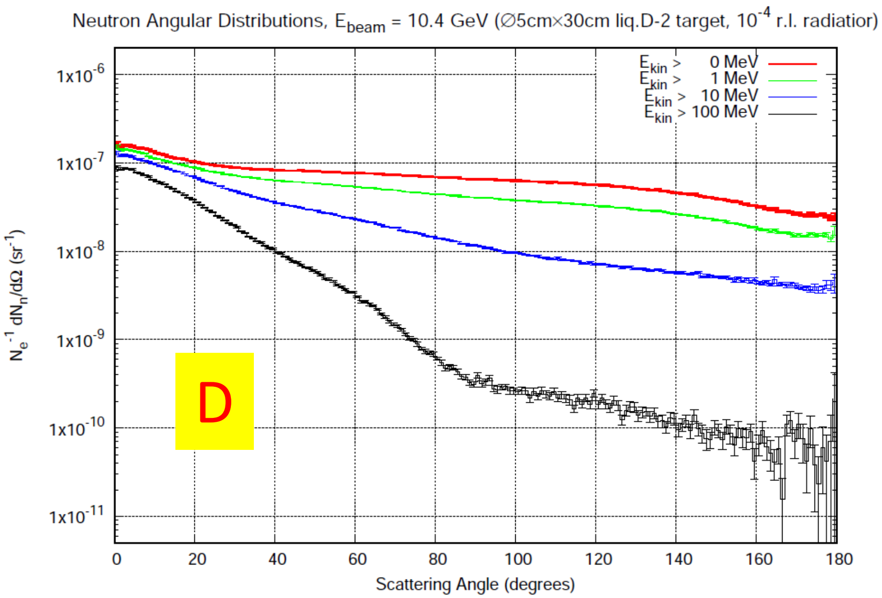
Monitoring SiPM Dark Current

Summary: Radiation Level

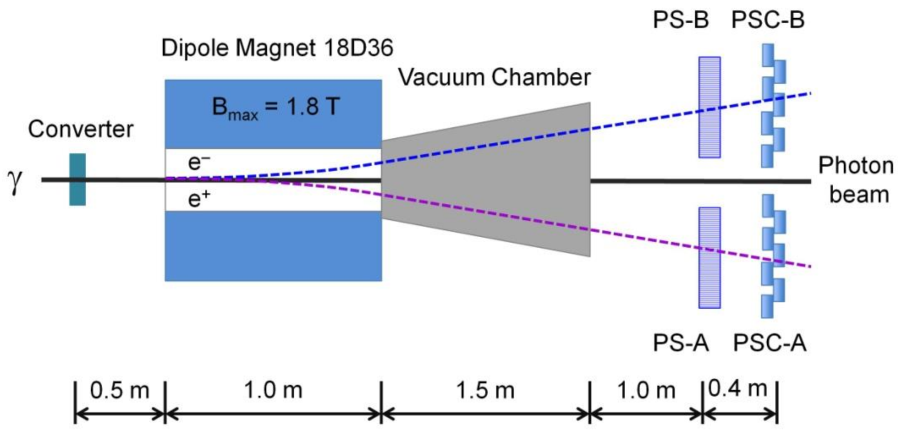
Backup Slides

Neutron Flux: Liquid He and D Targets





Photon Flux Measurements with Pair Spectrometer

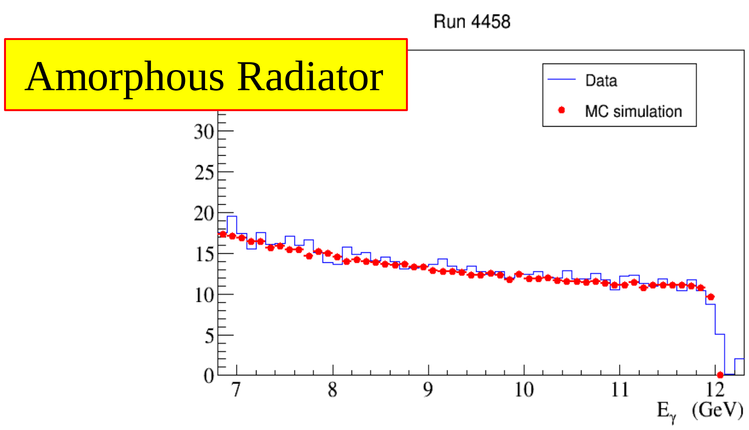


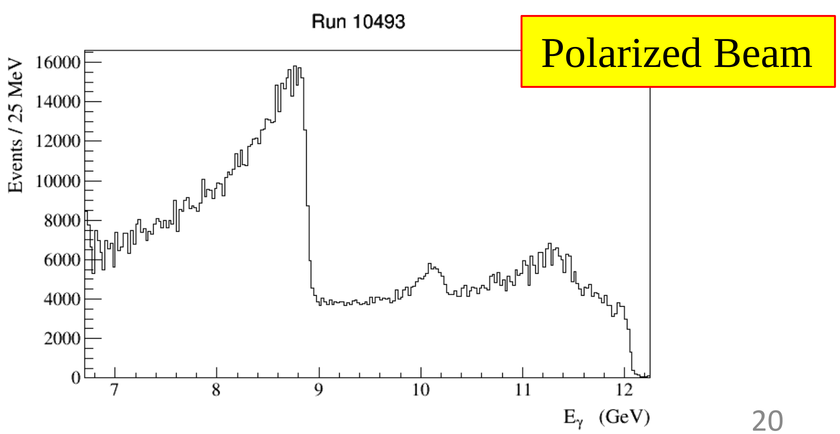
Two layers of scintillator detectors:

High-granularity hodoscope (measure photon energy in the range 6 – 12 GeV)

Low-granularity counters (use in trigger)

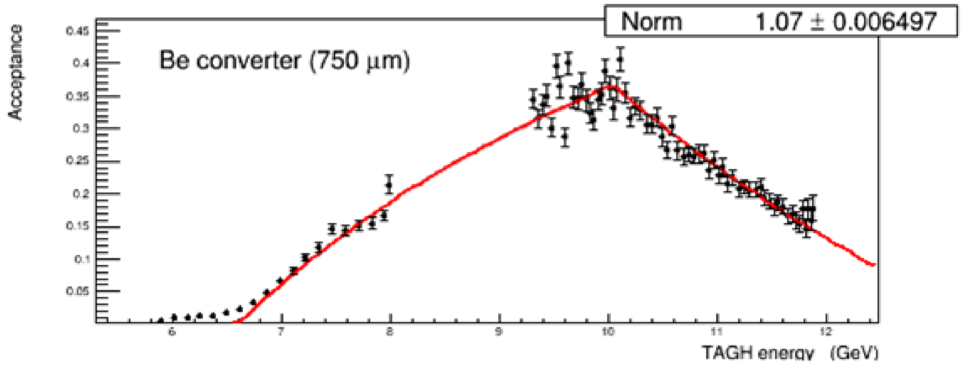
- Reconstruct the energy of a beam photon by detecting $e^{\pm}$ pairs
  - measure the photon beam flux and spectrum of the collimated photon beam





Photon Flux Measurements with Pair Spectrometer

- PS acceptance and energy determination
  - Ray tracing (measure magnetic field map)
  - Calibrate using total-absorption-counters (TAC) at low luminosity



- 3.4 mm collimator ,
  $2 \cdot 10^{-5}$ X_0 radiator,
  2 nA beam current

Calibration is performed regularly; takes 2-6 hours
- will be performed during PrimEx-D run (Recommendation 1.5)

- Special trigger type – continuous flux monitor (typical rate 1 – 3 kHz)
  - fadc / CTP scalers inserted to the data stream and EPICS

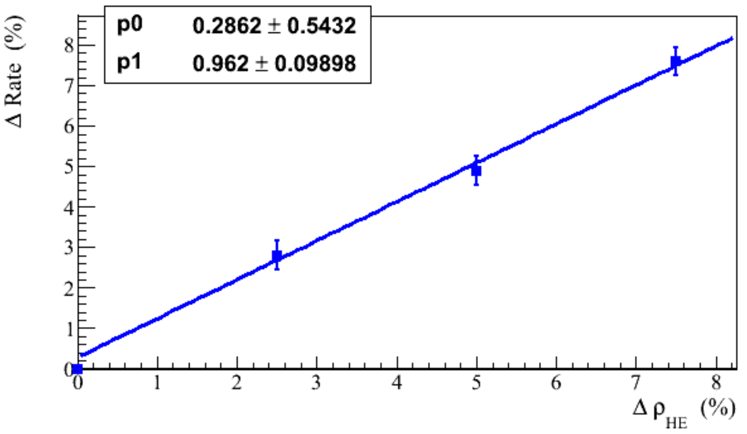
Monitor the photon flux with the precision < 1 %

Target Density Monitor

- Short term stability control:

  - photon beam flux provided by the PS
  - rates in the Start Counter (ST) and Time-of-Fight (TOF) wall

ST rate dependence on the target density



ST consists of 30 paddles surrounding the target

ST rate for production runs: 250 kHz / paddle

Coincidence of hits between the ST and TOF
(2 x 2 bars in TOF at R = 30 cm & one ST paddle)
1.5 kHz

- Long term stability control:

  - monitor using Compton process; expected rate in the photon range of interest is about 30 Hz

Pair Spectrometer Acceptance Calibration

- Calibrate PS acceptance using total-absorption counter (TAC)

- Data samples were acquired for three converters

  - 5.7×10^{-3} R.L. Al (508 μm foil)
  - 2.1×10^{-3} R.L. Be (750 μm foil)
  - 0.21×10^{-3} R.L. Be (75 μm foil)

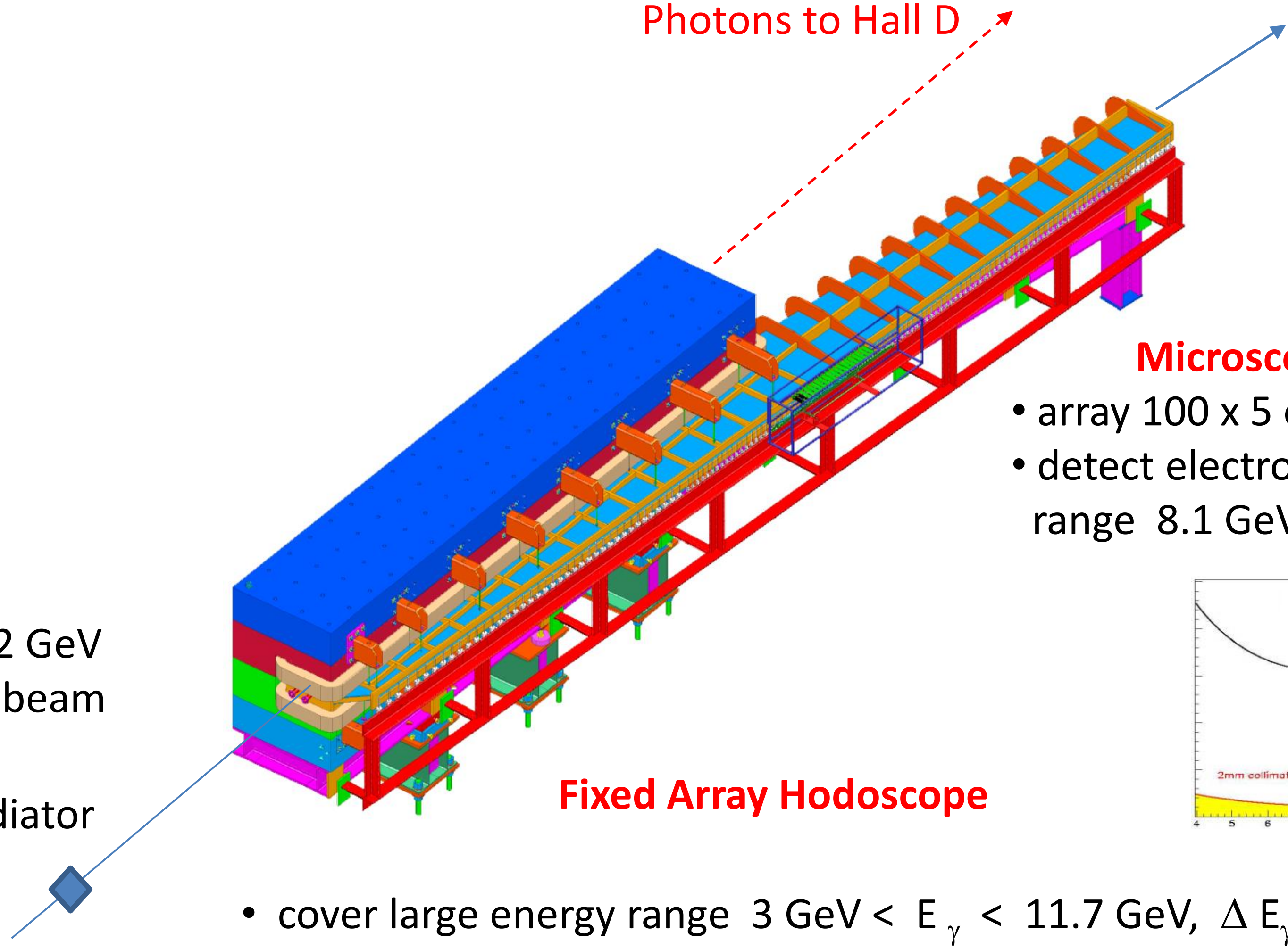
- Run conditions

  - 3.4 mm collimator , $2 \cdot 10^{-5}$ radiator, 2 nA beam current

- Trigger

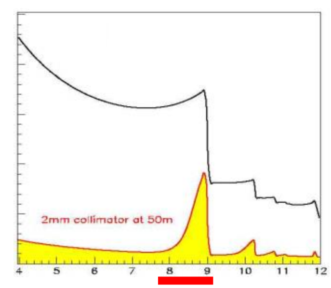
  - run two triggers in parallel: PS and TAC (energy sum)
  - PS rate: 10 Hz 750 μm Be
  - TAC rate: 200 – 300 kHz (trigger prescaling factor 129)

Tagged Photon Beam



Microscope

- array 100 x 5 of thin scintillators
- detect electrons in the energy range 8.1 GeV < E_γ < 9.2 GeV



- cover large energy range 3 GeV < E_γ < 11.7 GeV, $\Delta E_\gamma / E_\gamma < 0.002$
- 233 counters installed
- detect tagged ellectrons with E_γ > 9.2 GeV during data runs
- accidental background for PrimEx-D < 4 %