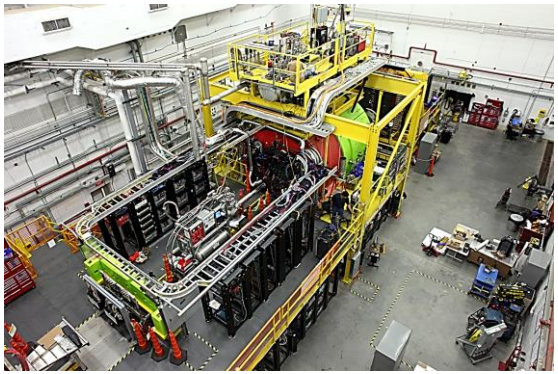
Be-Target Assembly Conceptual Design: Progress & Plans

Igor Strakovsky

The George Washington University

(for KLF Collaboration)

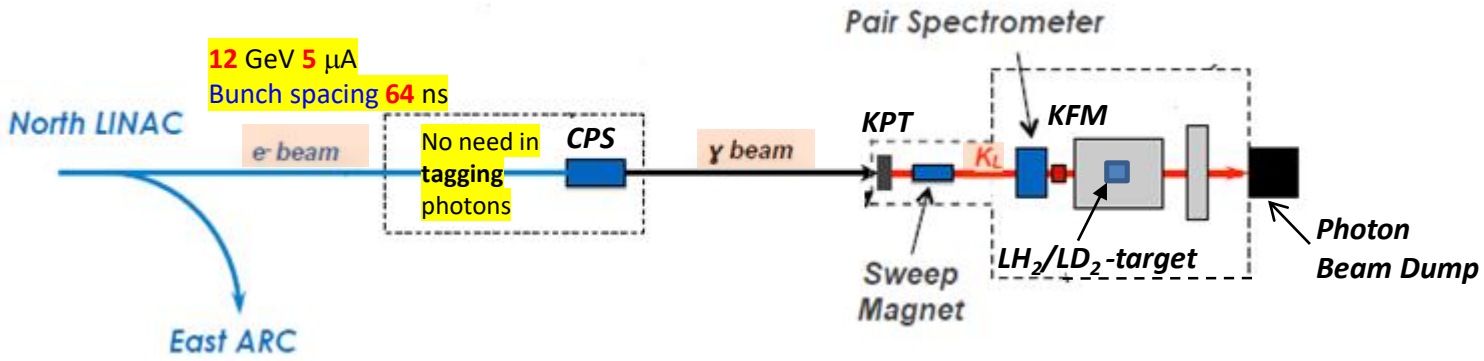


- Hall D beam line for KLF.
- Hall D setting.
- MCNP6 radiation transport code.
- KPT & Plug materials.
- Be-target assembly.
- Biological dose rate for n & γ.
- Muon background.
- Where we are now & where to go.

*Supported by DE-SC0016583

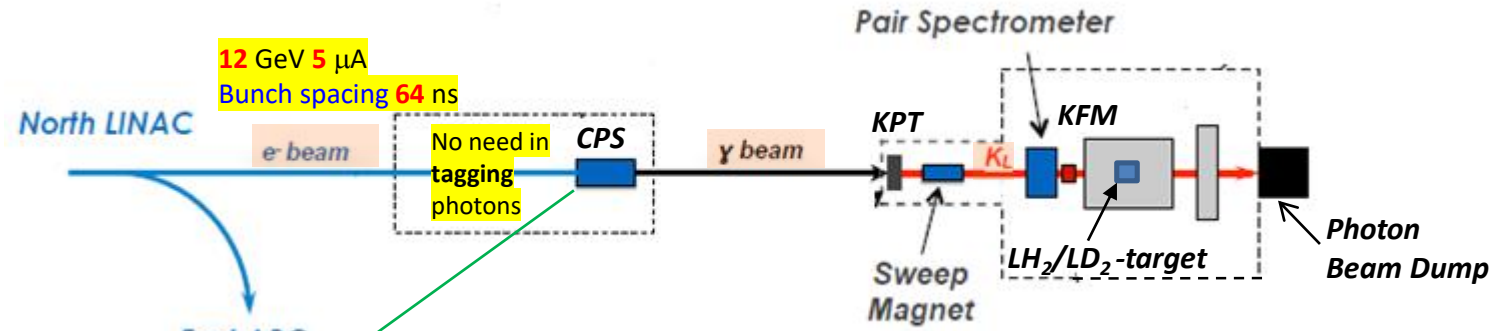
Hall D Beam Line for K-long

- Electrons (**3.1 x 10^{13}** e/sec) are hitting Cu-radiator @ CPS located in Tagger alcove.

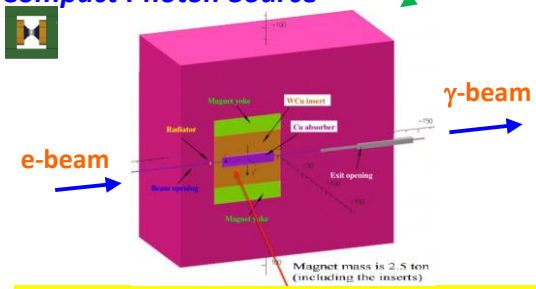


Hall D Beam Line for K-long

- Electrons (**3.1 x 10^{13}** e/sec) are hitting Cu-radiator @ CPS located in Tagger alcove.
- Photons (**4.7 x 10^{12}** γ/sec @ E > 1.5 GeV) are hitting Be-target located in collimator alcove.



Compact Photon Source

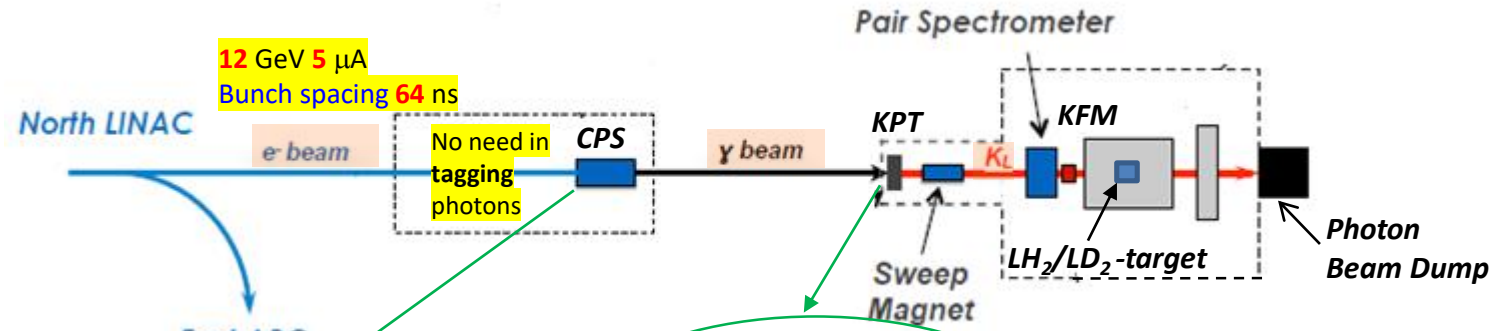


D. Day *et al*, Nucl Ins Meth, A **957**, 163429 (2020)

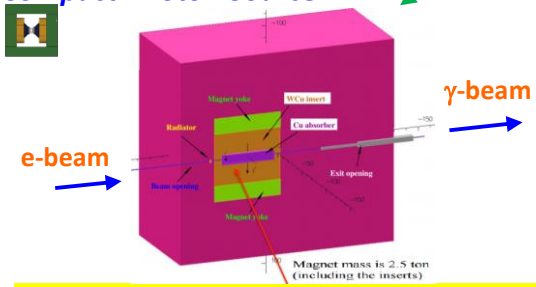
Sean Dobb's Talk

Hall D Beam Line for K-long

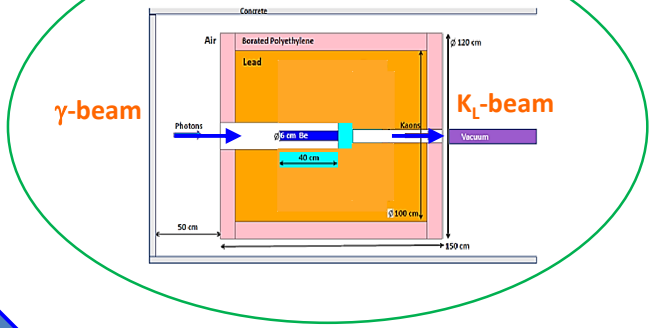
- Electrons (**3.1 x 10^{13}** e/sec) are hitting Cu-radiator @ CPS located in Tagger alcove.
- Photons (**4.7 x 10^{12}** γ/sec @ E > 1.5 GeV) are hitting Be-target located in collimator alcove.
- K_Ls (**1 x 10^4** K_L/sec) are hitting LH_2/LD_2 target within GLueX setting.



Compact Photon Source



Kaon Production Target

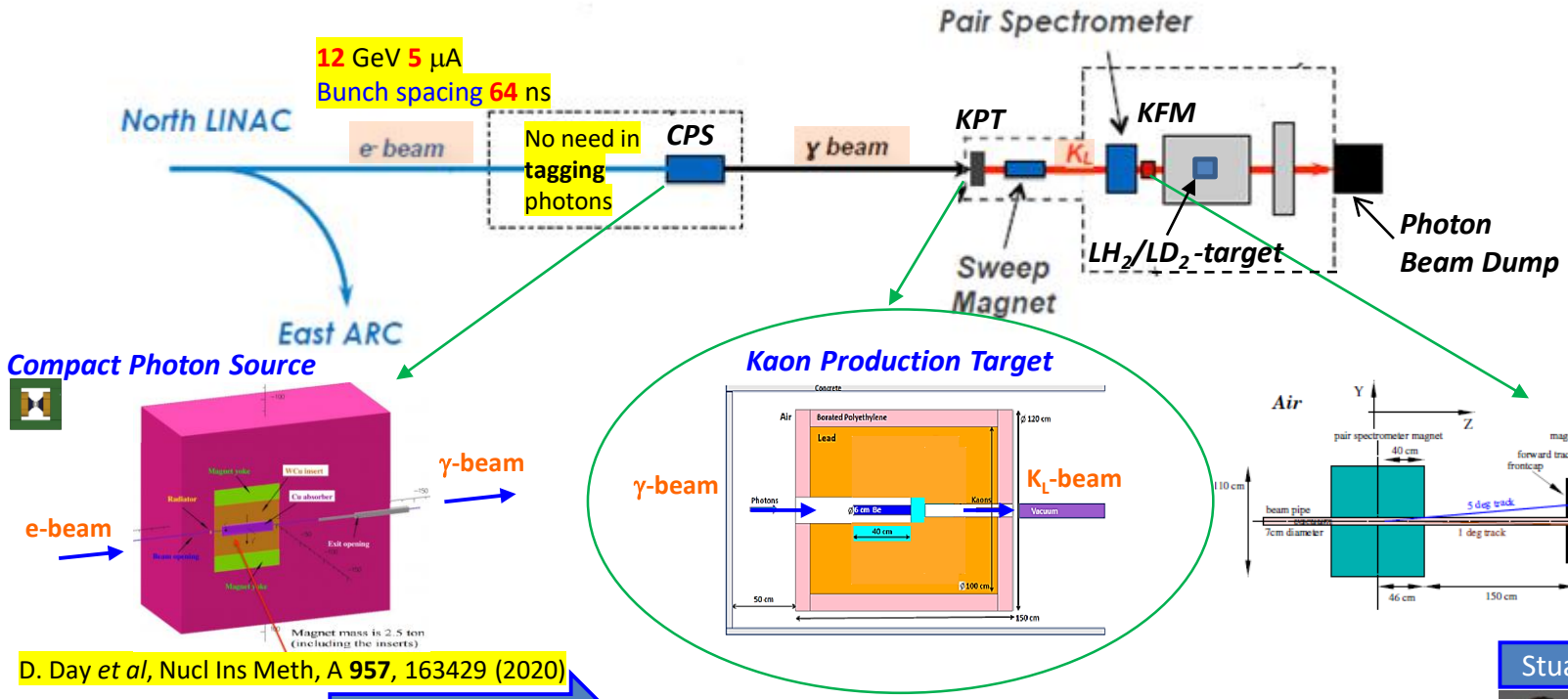


D. Day *et al*, Nucl Ins Meth, A **957**, 163429 (2020)

Sean Dobb's Talk

Hall D Beam Line for K-long

- Electrons (**3.1 x 10^{13}** e/sec) are hitting Cu-radiator @ CPS located in Tagger alcove.
- Photons (**4.7 x 10^{12}** γ/sec @ E > 1.5 GeV) are hitting Be-target located in collimator alcove.
- K_Ls (**1 x 10^{4}** K_L/sec) are hitting LH_2/LD_2 target within GLueX setting.



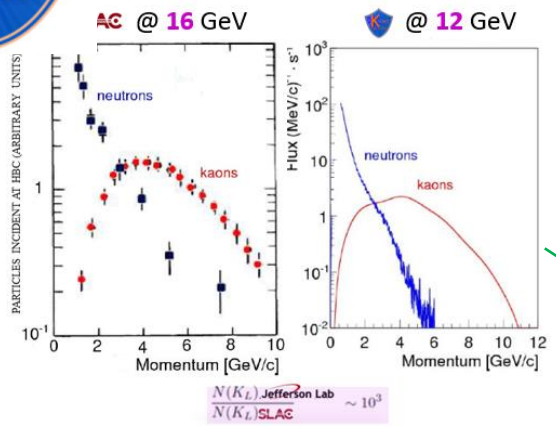
D. Day *et al*, Nucl Ins Meth, A **957**, 163429 (2020)

Sean Dobb's Talk

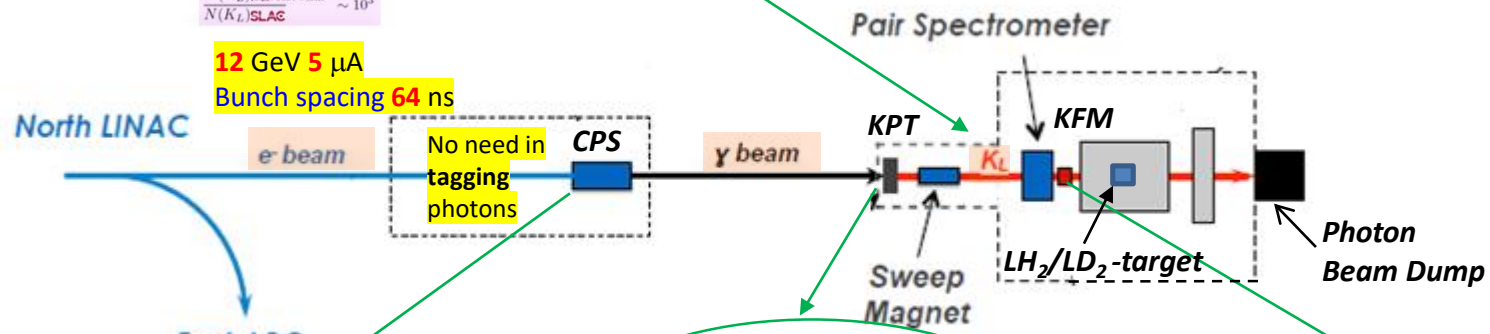
Stuart Fegan's Talk

Hall D Beam Line for K-long

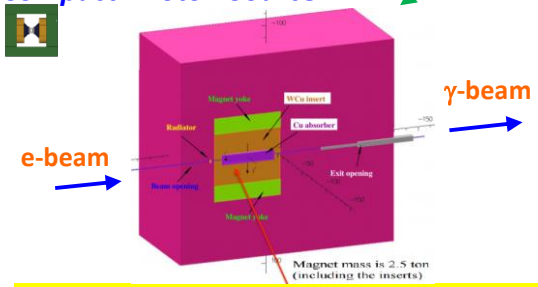
- Electrons (**3.1 x 10^{13}** e/sec) are hitting Cu-radiator @ CPS located in Tagger alcove.
- Photons (**4.7 x 10^{12}** γ/sec @ E > 1.5 GeV) are hitting Be-target located in collimator alcove.
- K_Ls (**1 x 10^4** K_L/sec) are hitting LH_2/LD_2 target within GLueX setting.



12 GeV 5 μA
Bunch spacing 64 ns

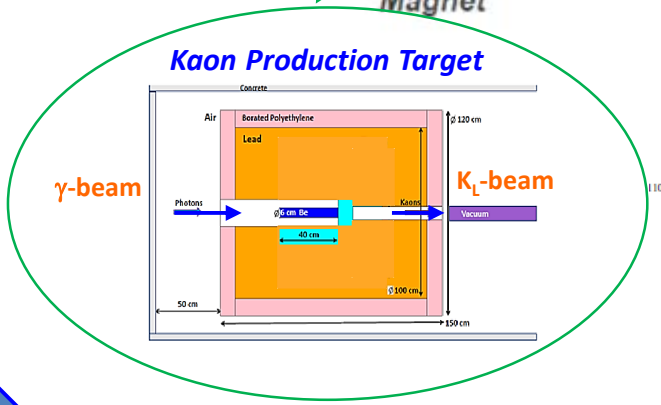


Compact Photon Source

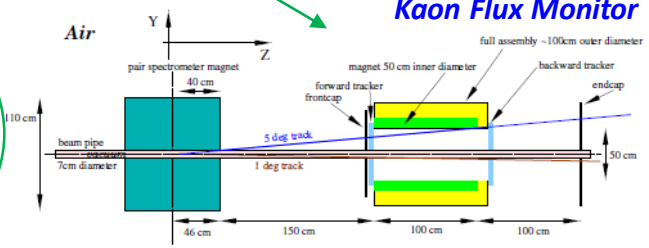


D. Day *et al*, Nucl Ins Meth, A **957**, 163429 (2020)

Kaon Production Target



Kaon Flux Monitor

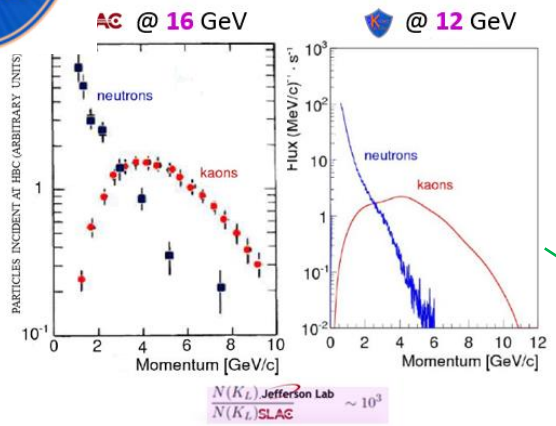


Sean Dobb's Talk

Stuart Fegan's Talk

Hall D Beam Line for K-long

- Electrons (**3.1 x 10^{13}** e/sec) are hitting Cu-radiator @ CPS located in Tagger alcove.
- Photons (**4.7 x 10^{12}** γ/sec @ E > 1.5 GeV) are hitting Be-target located in collimator alcove.
- K_Ls (**1 x 10^4** K_L/sec) are hitting LH_2/LD_2 target within GLueX setting.



12 GeV 5 μA
Bunch spacing 64 ns

North LINAC

e- beam

No need in **tagging** photons

CPS

γ beam

Pair Spectrometer

KPT

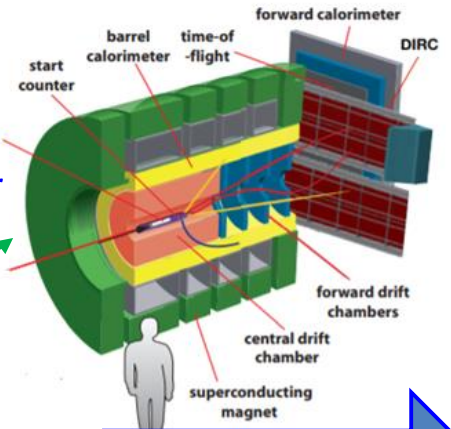
KFM

K_L

LH_2/LD_2-target

Sweep Magnet

Photon Beam Dump

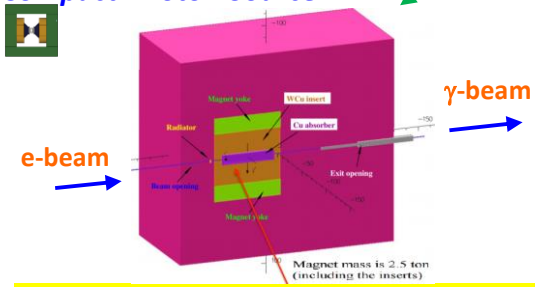


GlueX Spectrometer

Sergey Furletov's Talk
Sasha Somov's Talk

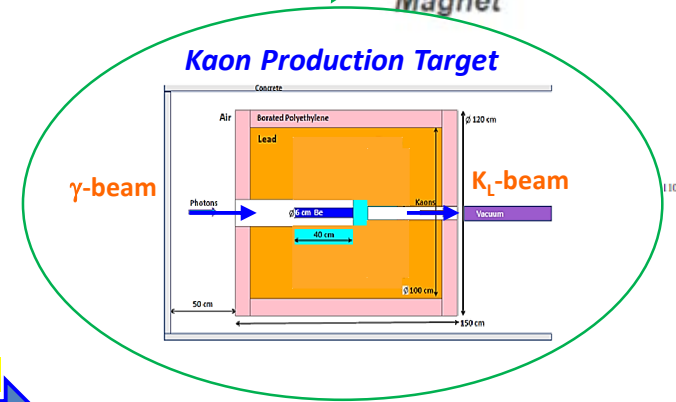
East ARC

Compact Photon Source

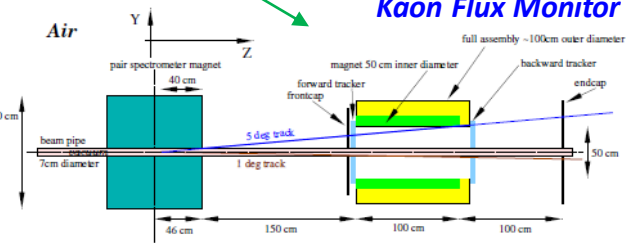


D. Day *et al*, Nucl Ins Meth, A **957**, 163429 (2020)

Kaon Production Target



Kaon Flux Monitor

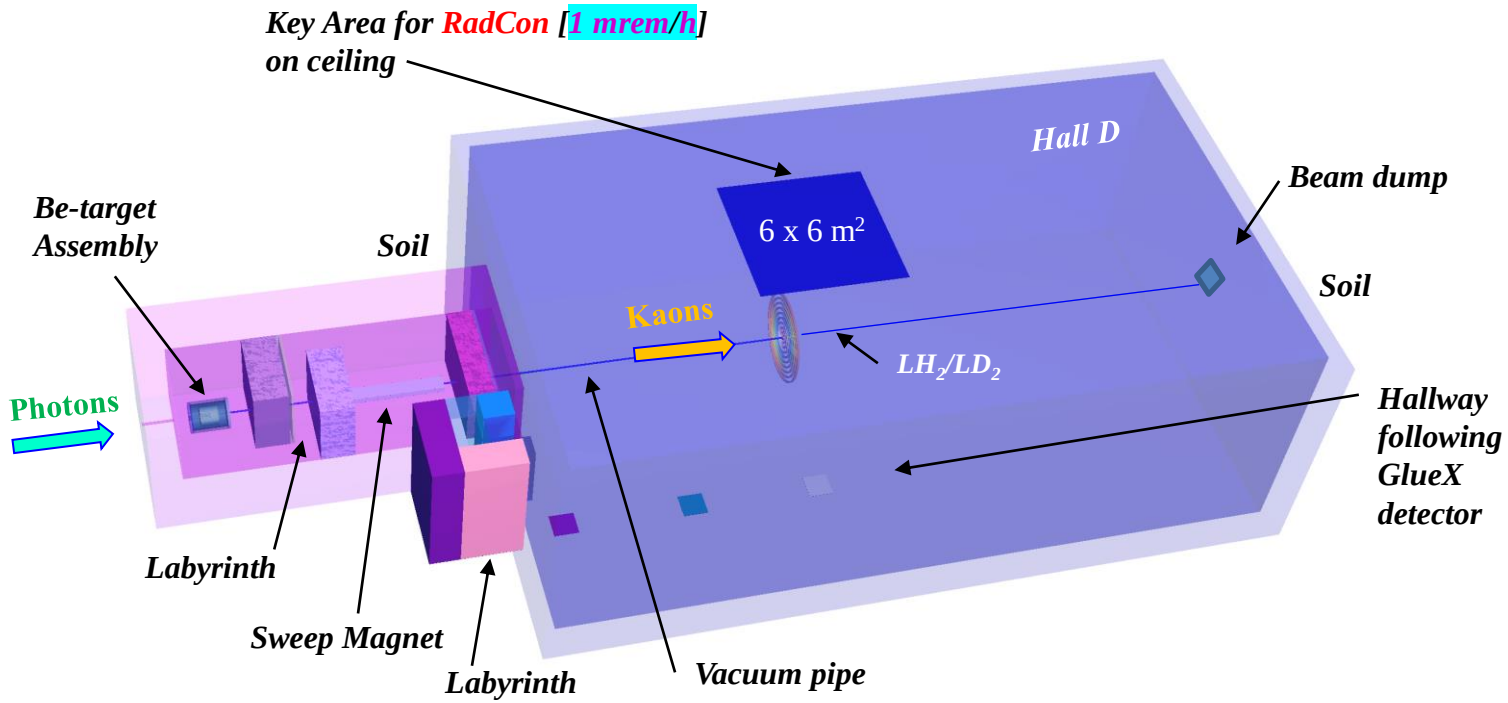


Stuart Fegan's Talk

Sean Dobb's Talk

Hall D Setting

- For neutron & gamma calculations, we use MCNP6 radiation transport code.

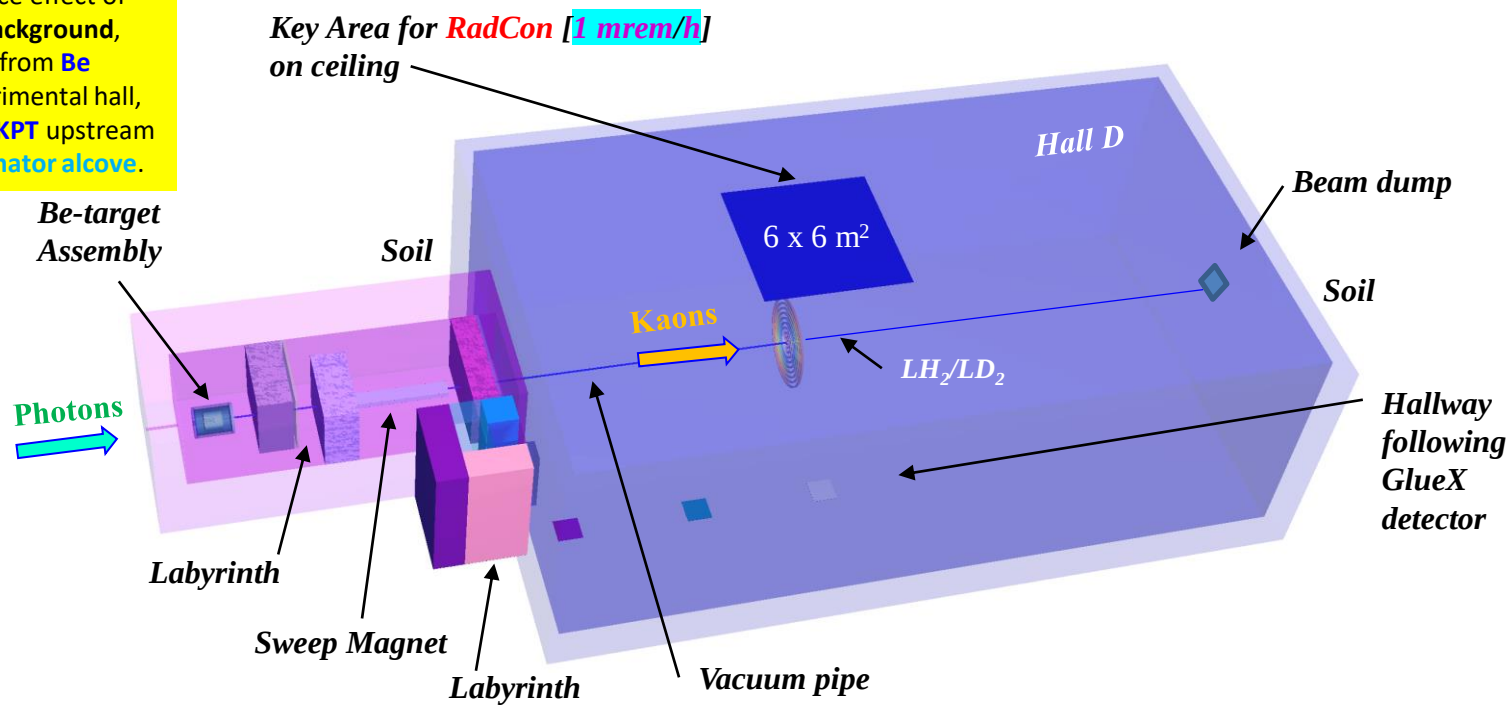


- Most important & unpleasant background for K_L comes from neutrons.

Hall D Setting

- For neutron & gamma calculations, we use MCNP6 radiation transport code.

To reduce effect of **n** & **γ background**, coming from **Be** in experimental hall, we put **KPT** upstream in **collimator alcove**.

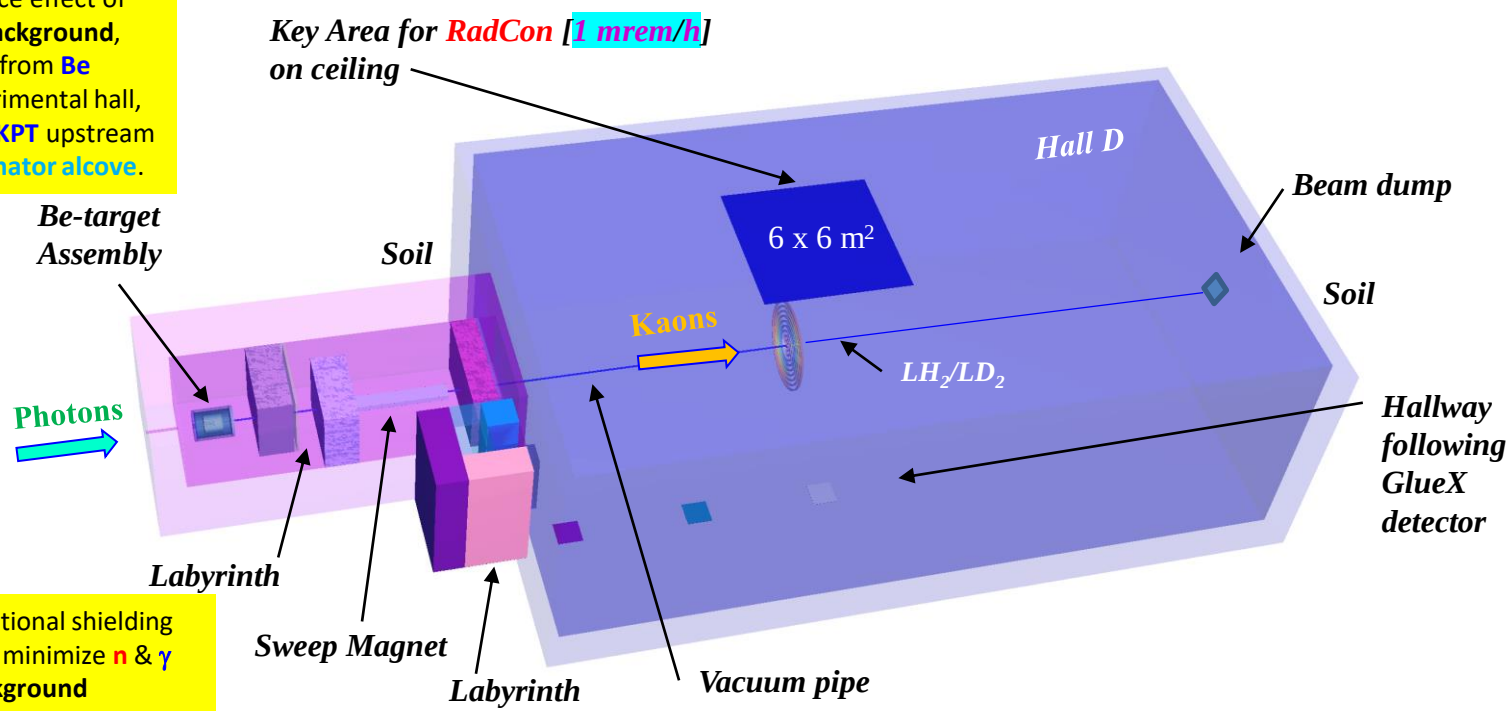


- Most important & unpleasant background for K_L comes from neutrons.

Hall D Setting

- For neutron & gamma calculations, we use MCNP6 radiation transport code.

To reduce effect of **n** & **γ background**, coming from **Be** in experimental hall, we put **KPT** upstream in **collimator alcove**.



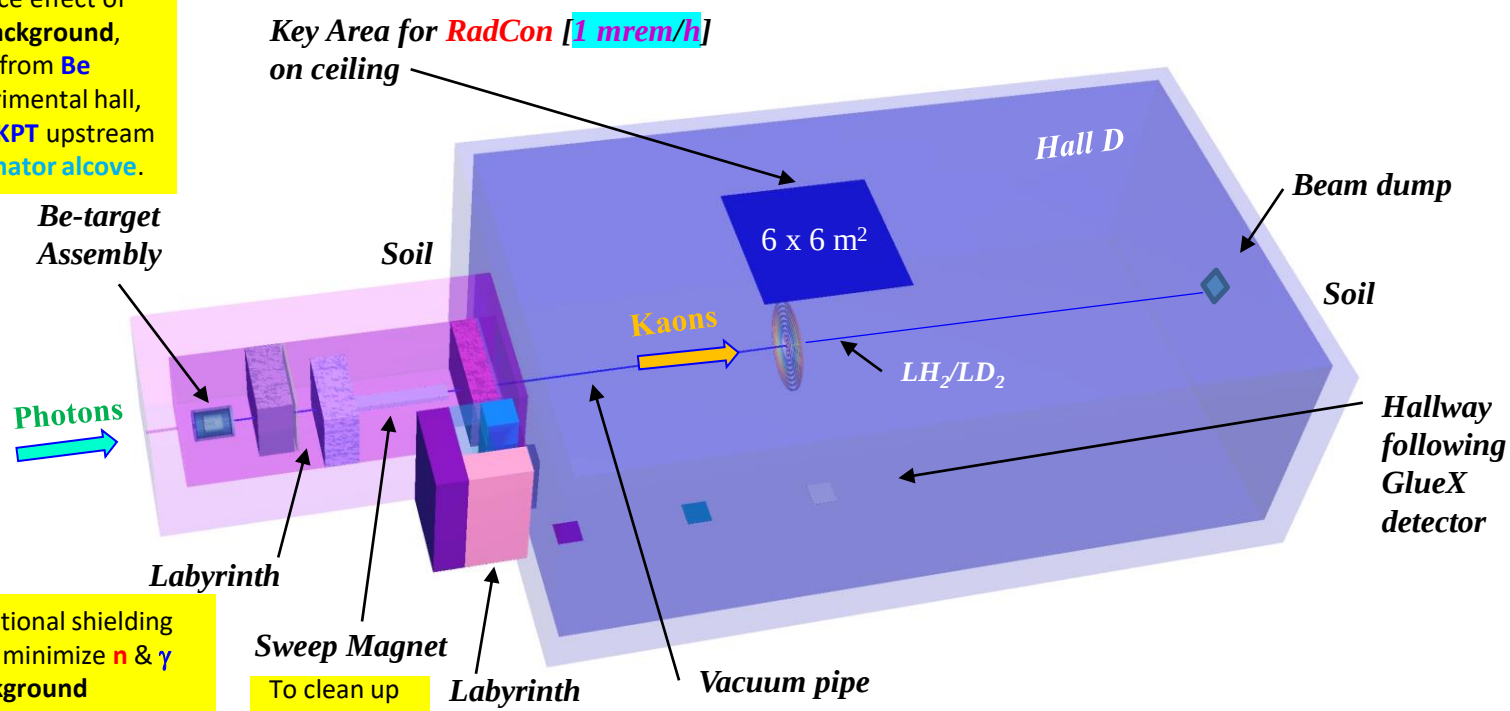
Additional shielding is to minimize **n** & **γ background** in experimental hall.

- Most important & unpleasant background for K_L comes from neutrons.

Hall D Setting

- For neutron & gamma calculations, we use MCNP6 radiation transport code.

To reduce effect of **n** & **γ background**, coming from **Be** in experimental hall, we put **KPT** upstream in **collimator alcove**.



Additional shielding is to minimize **n** & **γ background** in experimental hall.

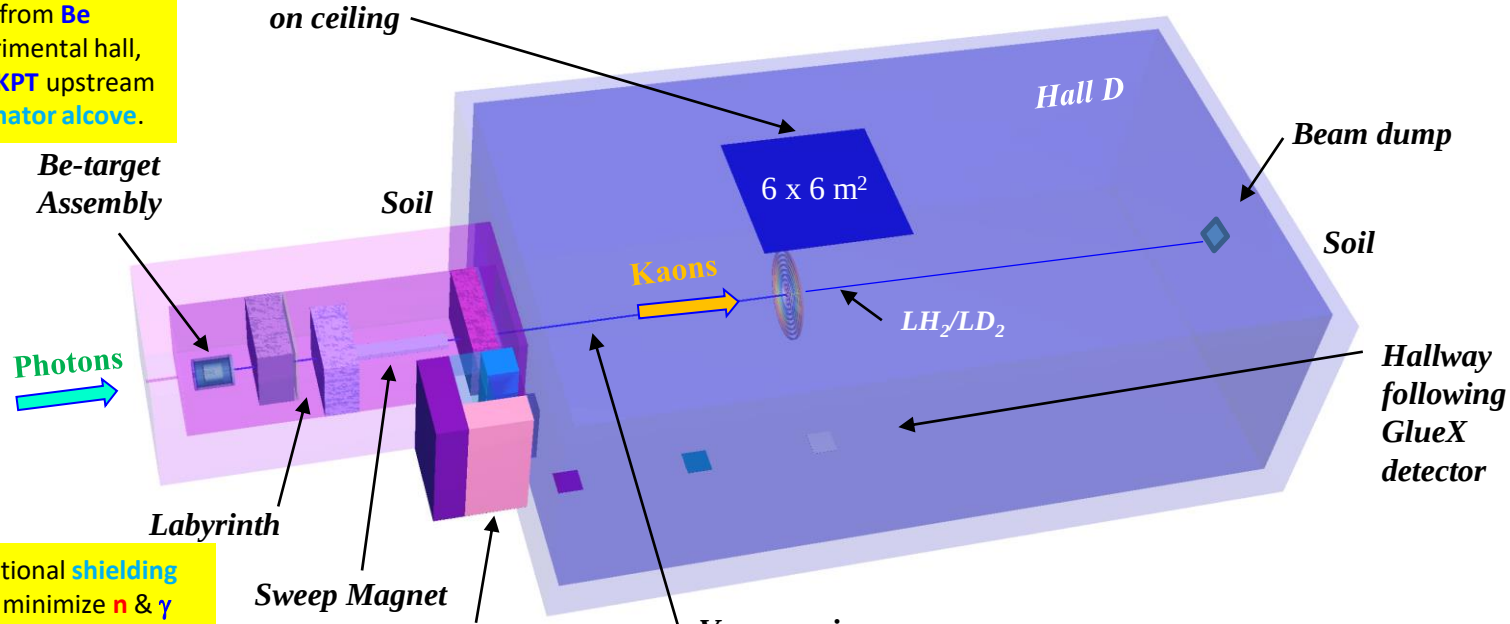
To clean up charged component of beam (including muons).

- Most important & unpleasant background for K_L comes from neutrons.

Hall D Setting

- For neutron & gamma calculations, we use MCNP6 radiation transport code.

To reduce effect of **n** & **γ background**, coming from **Be** in experimental hall, we put **KPT** upstream in **collimator alcove**.



Additional **shielding** is to minimize **n** & **γ background** in experimental hall.

To clean up charged component of beam (including muons).

Vacuum beam pipe prevents neutrons re-scattering in air.

- Most important & unpleasant background for K_L comes from neutrons.

MCNP6 Radiation Transport Code

- Realism of MCNP6 simulations is based on advanced nuclear cross section **libraries** created & maintained in national laboratories of DOE complex.

- Physical models, implemented in MCNP6 code, take into account
  - *bremsstrahlung* photon production,
  - *photonuclear* reactions,
  - neutron & photon *multiple scattering* processes.

- MCNP6 model simulates **12** GeV **5** μA **electron** beam hitting **Cu**-radiator inside CPS.

- Electron transport is traced in **Cu**-radiator,
  vacuum beam pipe for bremsstrahlung photons,
  Be.

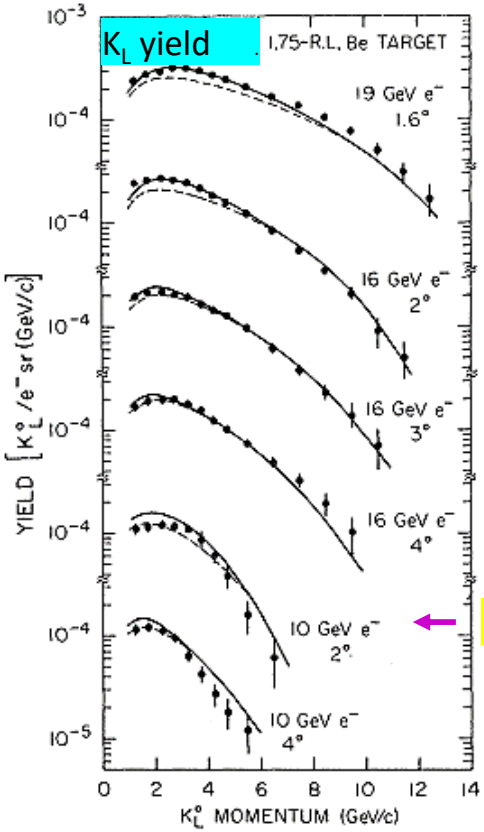
- Neutrons & gammas is traced in all components of MCNP6 model.

- Media outside concrete walls of collimator *alcove* & bremsstrahlung photon beam *pipe* were excluded from consideration to facilitate calculations.
  Additionally, we ignore PS & KFM magnets but
  took into account **5** SEG-blocks around beam pipe in front of GlueX spectrometer.

- For MCNP6 calculations (in terms of **flux** [part/s/cm^2] & **biological dose rate** [mrem/h]).
  several **tallies** were placed along beam, collimator alcove, & experimental hall for neutron & gamma fluence estimation.

Why Be was Selected for KPT

- Previous SLAC studies shown that **Be** is optimal material for kaon photoproduction.



12 GeV

G.W. Brandenburg *et al*, Phys Rev D **7**, 708 (1973)

- Kaon yield ~ X_0 * ρ & Ratio(Be/C) = (65/43) = **1.51**

- MCNP6 calculations show that **Be** reduces yield of **n** & γ.

At key area for RadCon on ceiling

Be: **n**: 0.273±0.083 mrem/h **R(C/Be)=1.45**

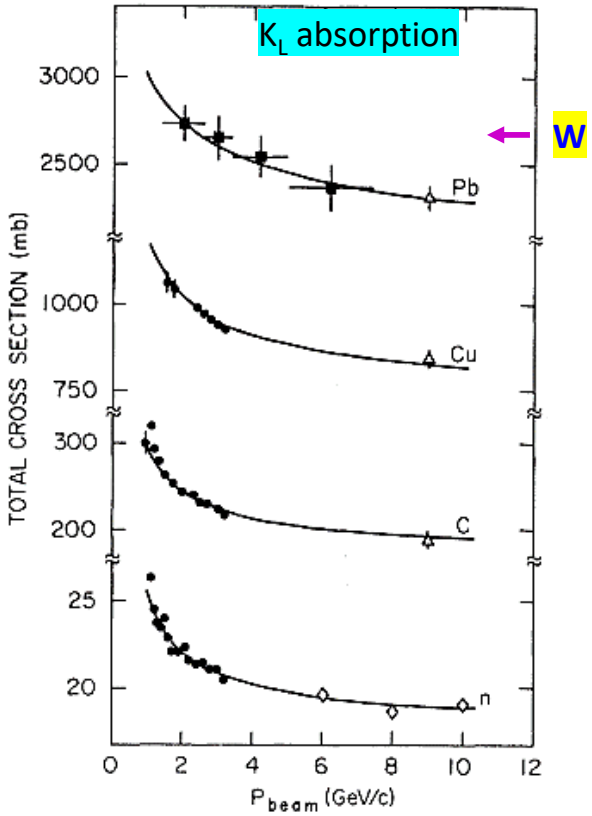
γ: 0.065±0.002 mrem/h

C: **n**: 0.397±0.197 mrem/h

γ: 0.080±0.002 mrem/h

Why W was Selected for Plug

- Previous SLAC studies shown that **W** has low absorption factor for K_L.



G.W. Brandenburg *et al*, Phys Rev D **7**, 708 (1973)

Kaon: W/Cu(20%) = **1.16** @ P_k = **1.0** GeV/c
= **1.36** @ P_k = **0.5** GeV/c

- MCNP6 calculations show that **W**-plug reduces yield for **n** & γ.

At key area for RadCon on ceiling

W: **n**: 0.273±0.083 mrem/h **R(Pb/W)=2.25** **R(Cu/W)=9.29**
γ: 0.065±0.002 mrem/h

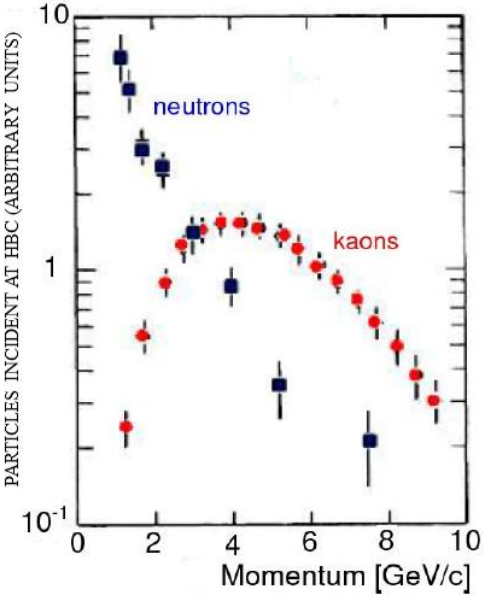
Pb: **n**: 0.614±0.246 mrem/h
γ: 0.527±0.006 mrem/h

Cu: **n**: 2.537±0.385 mrem/h
γ: 4.343±0.020 mrem/h

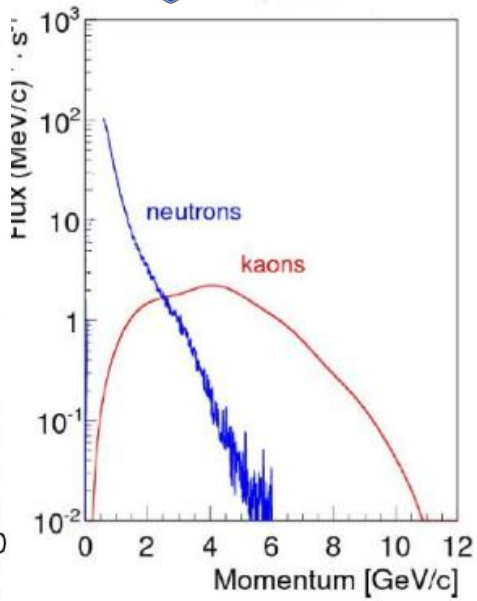
Flux of Kaon Beam

Jefferson Lab
Thomas Jefferson National Accelerator Facility

SLAC @ 16 GeV



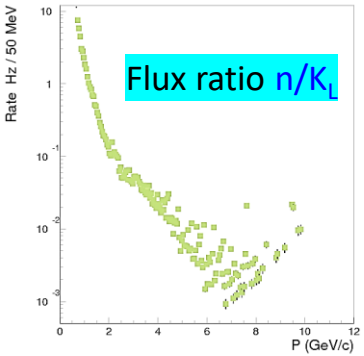
@ 12 GeV



$\frac{N(K_L)_{\text{Jefferson Lab}}}{N(K_L)_{\text{SLAC}}} \sim 10^3$

G.W. Brandenburg *et al*, Phys Rev D **7**, 708 (1973)

- Flux of Kaons will be **1** x **10^4** K_L/sec on **LH_2/LD_2** within GlueX detector, which has large *acceptance* with coverage of both ***charged*** & ***neutral*** particles.
- This flux will allow statistics in case of **LH_2 /LD_2** to exceed that of earlier SLAC experiments by almost **three orders** of magnitude.
- We simulated ***Kaon*** & ***neutron*** production from **12** GeV electrons for KLF by PYTHIA & MCNP6 & results are in reasonable agreement with results measured by SLAC @ **16** GeV.
- Delivered with **64** nsec bunch spacing avoids overlap between ***neutrons*** & ***Kaons*** in range of **p** = **0.35** – **10.0** GeV/c.



- With **proton** beam, ratio **n/K_L** = **10^3–10^4**.

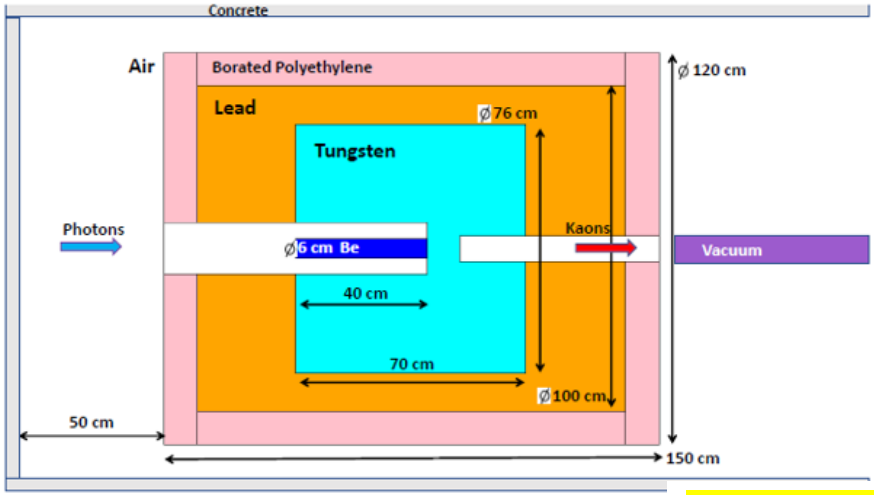
See recent talk by Todd Satogata

GW INS Data Analysis Center — Institute for Nuclear Studies, The George Washington University

Be-Target Assembly

- Be-target assembly will weight **14.5** t
- Be-target has estimated cost of $**1.12**M

xy-cross section, x-dimension

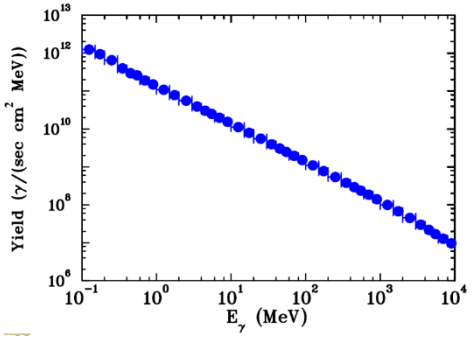


ρ(W) = **16.3** g/cm^3 – Rolf's value

Concrete **walls** are out of scale

- Changeover from photon to Kaon beamline & vice versa is expected to take about **half year** or less, & thus should fit well into beam breaks of current CEBAF **schedule**.
- Collimator alcove has enough space (with **4.52** m width) for Be-target assembly to remain far enough from beamline.
- Water Cooling is available in experimental hall, & is sufficient to dissipate **6** kW of power delivered by photon beam to Be-target & W-plug.

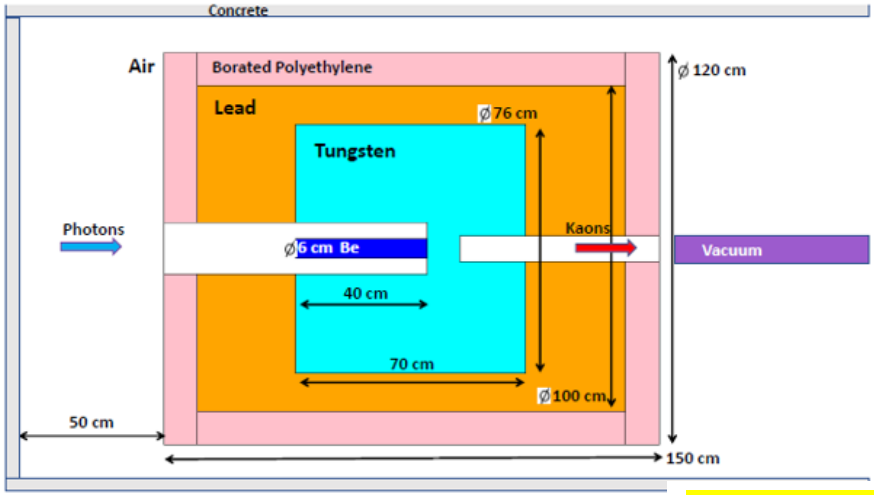
Gammas on face of Be-target



Be-Target Assembly

- Be-target assembly will weight **14.5** t
- Be-target has estimated cost of $**1.12**M

xy-cross section, x-dimension



ρ(W) = **16.3** g/cm^3 – Rolf's value

Concrete **walls** are out of scale

- **Changeover** from **photon** to **Kaon** beamline & vice versa is expected to take about **half year** or less, & thus should fit well into beam breaks of current CEBAF **schedule**.
- Collimator alcove has enough space (with **4.52** m width) for **Be**-target assembly to remain far enough from beamline.
- Water Cooling is available in experimental hall, & is sufficient to dissipate **6** kW of power delivered by photon beam to **Be**-target & **W**-plug.

At key area for RadCon on ceiling

Pb & W

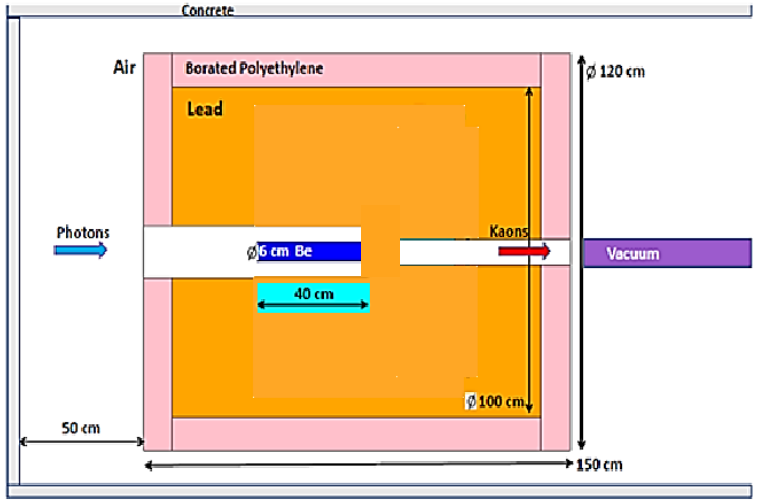
n: 0.349±0.172 mrem/h

γ: 0.078±0.005 mrem/h

Be-Target Assembly

- Be-target assembly will weight **14.5** t
- Be-target has estimated cost of $**1.12**M

xy-cross section, x-dimension



ρ(W) = **16.3** g/cm^3 – Rolf's value

Concrete **walls** are out of scale

- Changeover from **photon** to **Kaon** beamline & vice versa is expected to take about **half year** or less, & thus should fit well into beam breaks of current CEBAF **schedule**.
- Collimator alcove has enough space (with **4.52** m width) for **Be**-target assembly to remain far enough from beamline.
- Water Cooling is available in experimental hall, & is sufficient to dissipate **6** kW of power delivered by photon beam to **Be**-target & **W**-plug.

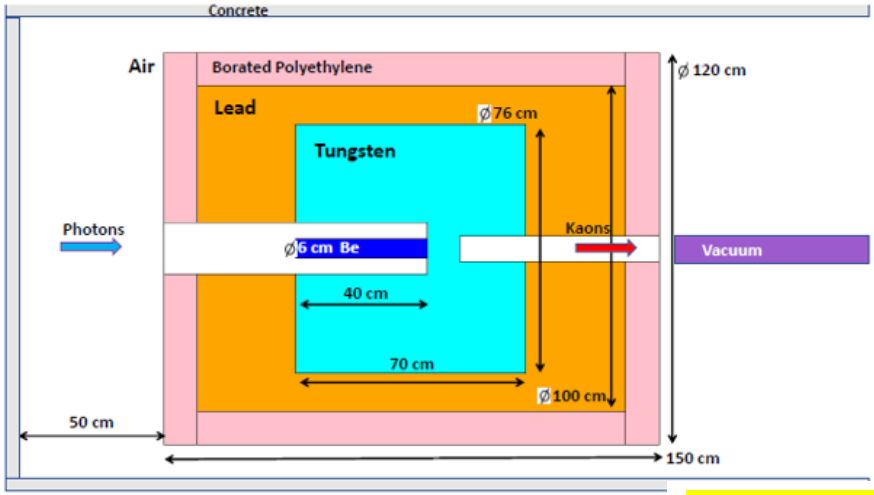
At key area for RadCon on ceiling

Pb & W	n: 0.349±0.172 mrem/h γ: 0.078±0.005 mrem/h
Pb & no W	n: 0.614±0.246 mrem/h γ: 0.527±0.006 mrem/h

Be-Target Assembly

- Be-target assembly will weight **14.5** t
- Be-target has estimated cost of $**1.12**M

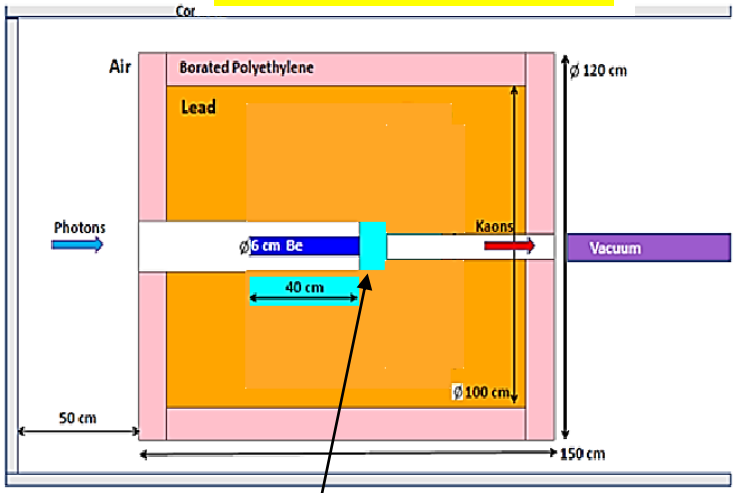
xy-cross section, x-dimension



- Changeover from **photon** to **Kaon** beamline & vice versa is expected to take about **half year** or less, & thus should fit well into beam breaks of current CEBAF **schedule**.
- Collimator alcove has enough space (with **4.52** m width) for **Be**-target assembly to remain far enough from beamline.
- Water Cooling is available in experimental hall, & is sufficient to dissipate **6** kW of power delivered by photon beam to **Be**-target & **W**-plug.

ρ(W) = **16.3** g/cm^3 – Rolf's value

Concrete **walls** are out of scale



W-plug
16 cm in diam
10 cm in length

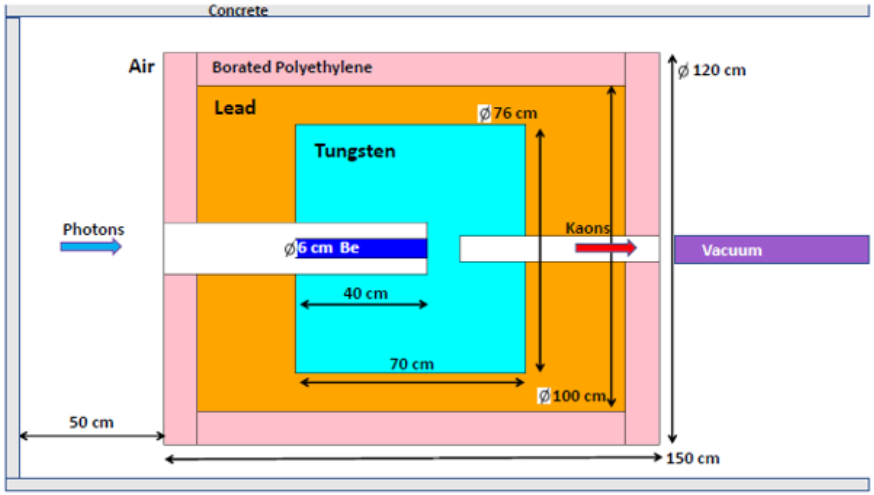
At key area for RadCon on ceiling

Pb & W	n: 0.349±0.172 mrem/h γ: 0.078±0.005 mrem/h
Pb & no W	n: 0.614±0.246 mrem/h γ: 0.527±0.006 mrem/h
Pb & W-plug	n: 0.273±0.083 mrem/h γ: 0.065±0.002 mrem/h

Be-Target Assembly

- Be-target assembly will weight 14.5 t → 12 t
- Be-target has estimated cost of $1.12M → $0.134M

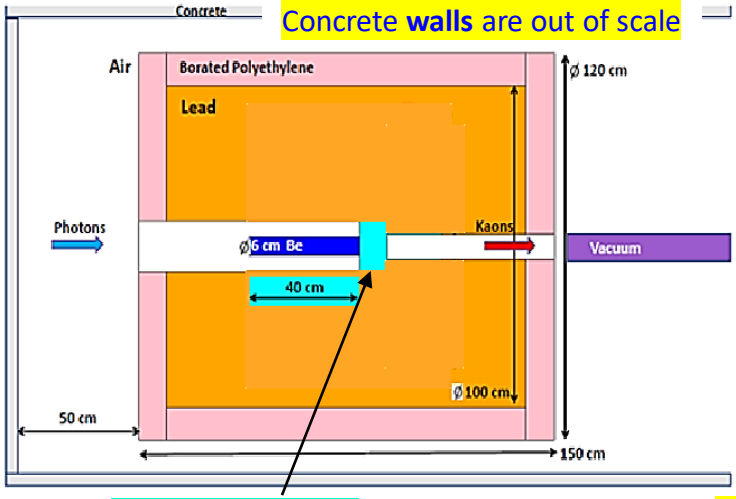
xy-cross section, x-dimension



- Changeover from photon to Kaon beamline & vice versa is expected to take about **half year** or less, & thus should fit well into beam breaks of current **CEBAF schedule**.
- Collimator alcove has enough space (with 4.52 m width) for Be-target assembly to remain far enough from beamline.
- Water Cooling is available in experimental hall, & is sufficient to dissipate 6 kW of power delivered by photon beam to Be-target & W-plug.

$\rho(W) = 16.3$ g/cm^3 – Rolf's value

Concrete **walls** are out of scale



At key area for RadCon on ceiling

Pb & W	n: 0.349±0.172 mrem/h γ: 0.078±0.005 mrem/h
Pb & no W	n: 0.614±0.246 mrem/h γ: 0.527±0.006 mrem/h
Pb & W-plug	n: 0.273±0.083 mrem/h γ: 0.065±0.002 mrem/h

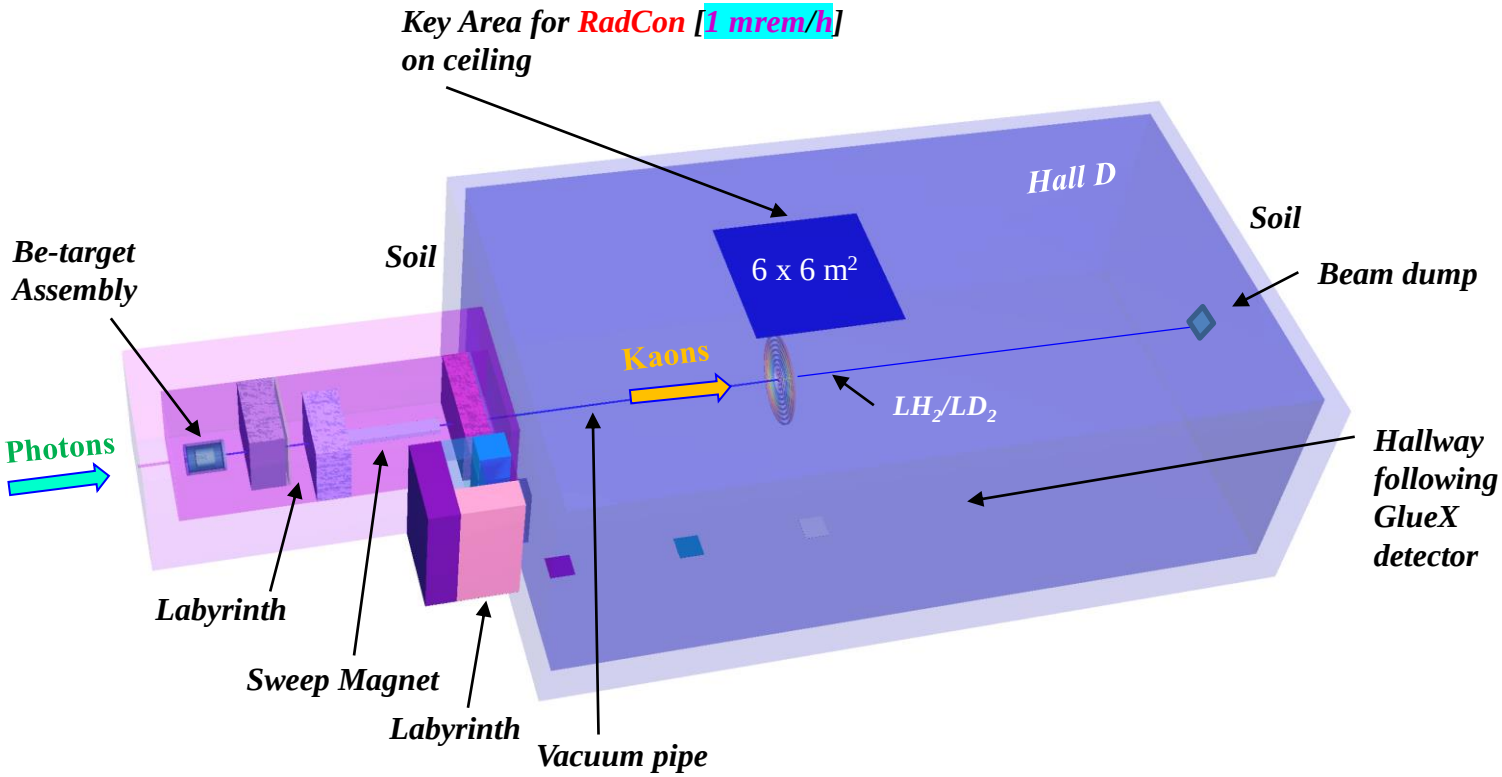
W-plug
16 cm in diam
10 cm in length

- Increasing **plug diam** will increase **n** background.
- Increasing **plug length** will reduce **kaon** flux.

24 cm in diam:	n: 0.773±0.330 mrem/h γ: 0.074±0.002 mrem/h
15 cm in length:	n: 0.163±0.061 mrem/h γ: 0.003±0.001 mrem/h

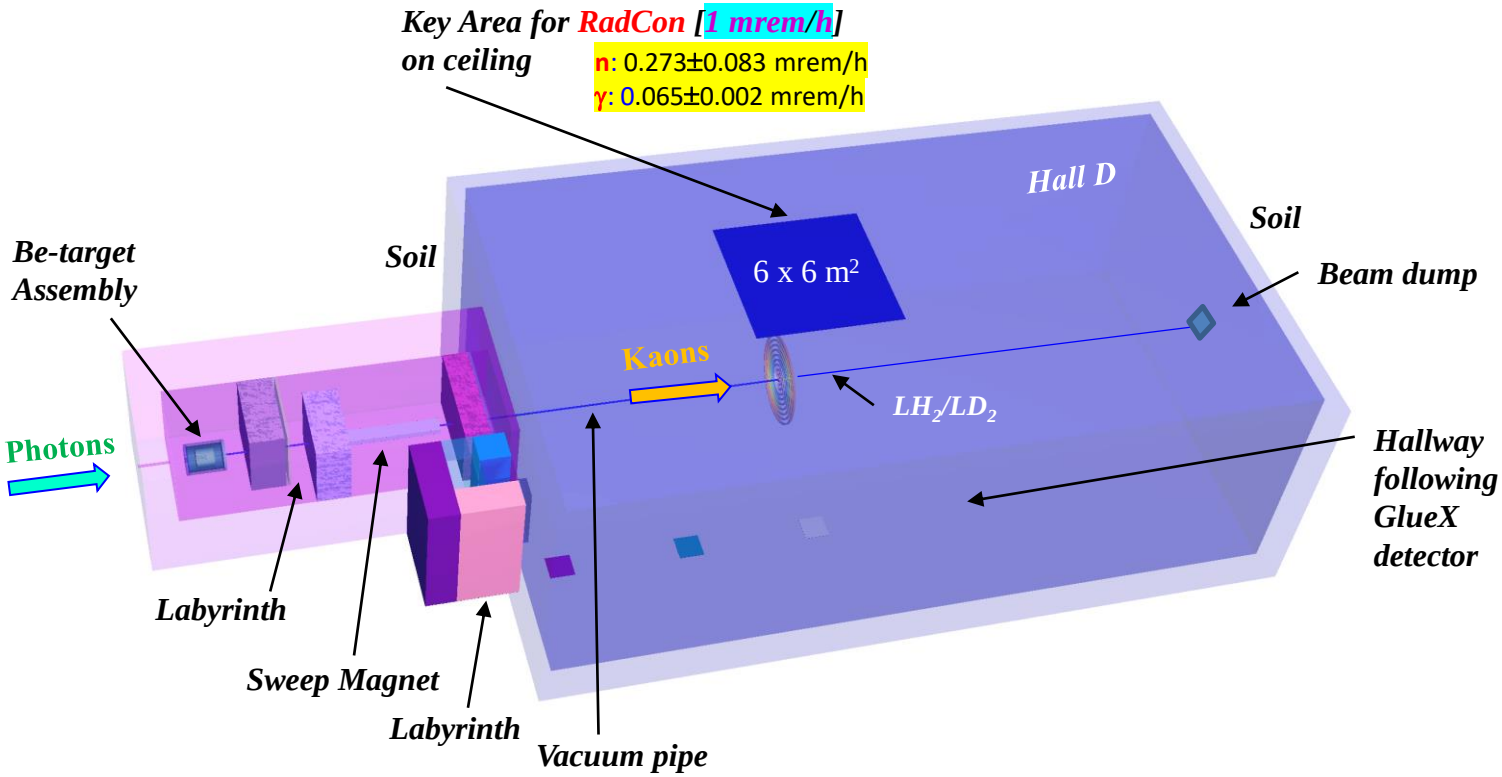
Hall D Setting & Dose Rate

- For neutron & gamma calculations, we use MCNP6 radiation transport code.



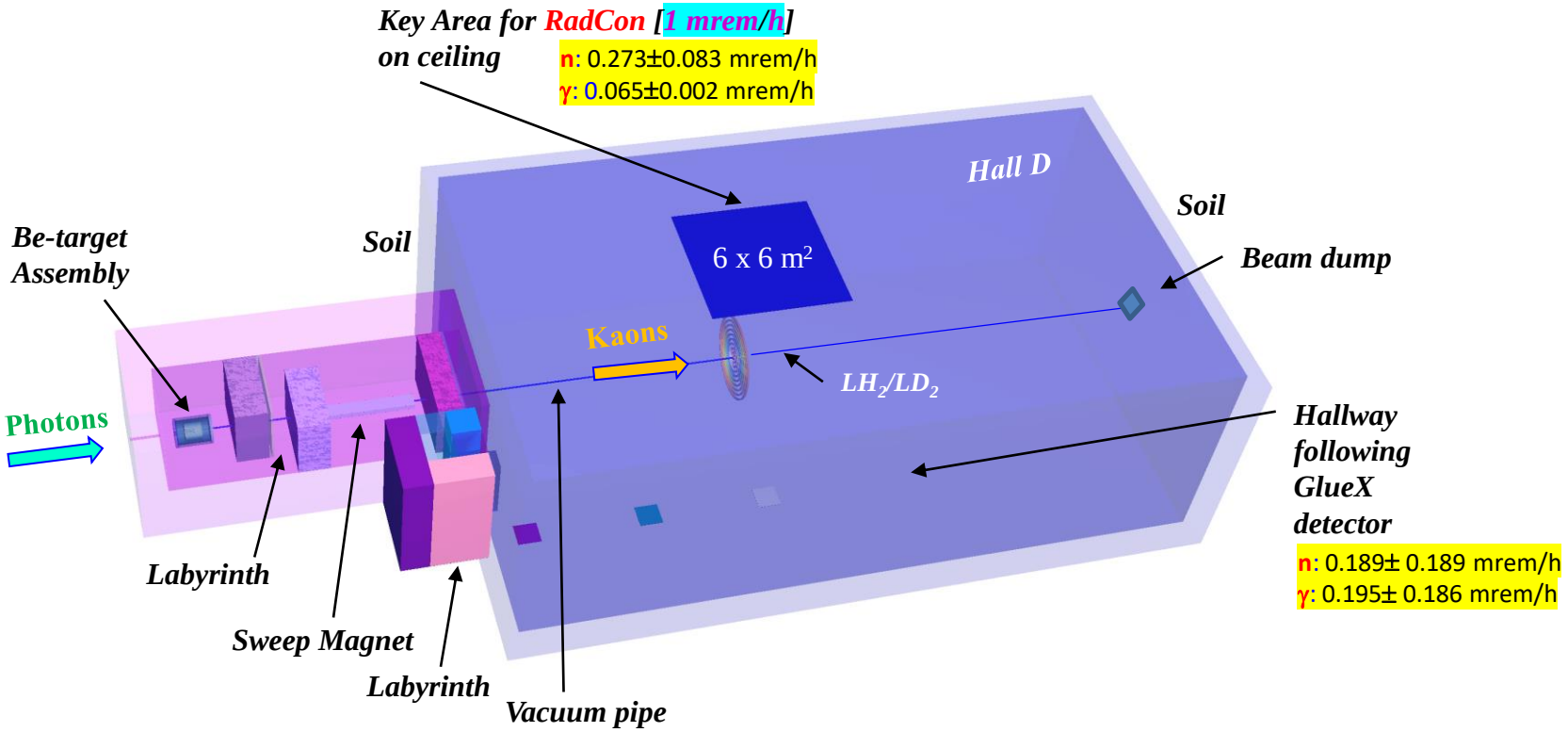
Hall D Setting & Dose Rate

- For neutron & gamma calculations, we use MCNP6 radiation transport code.



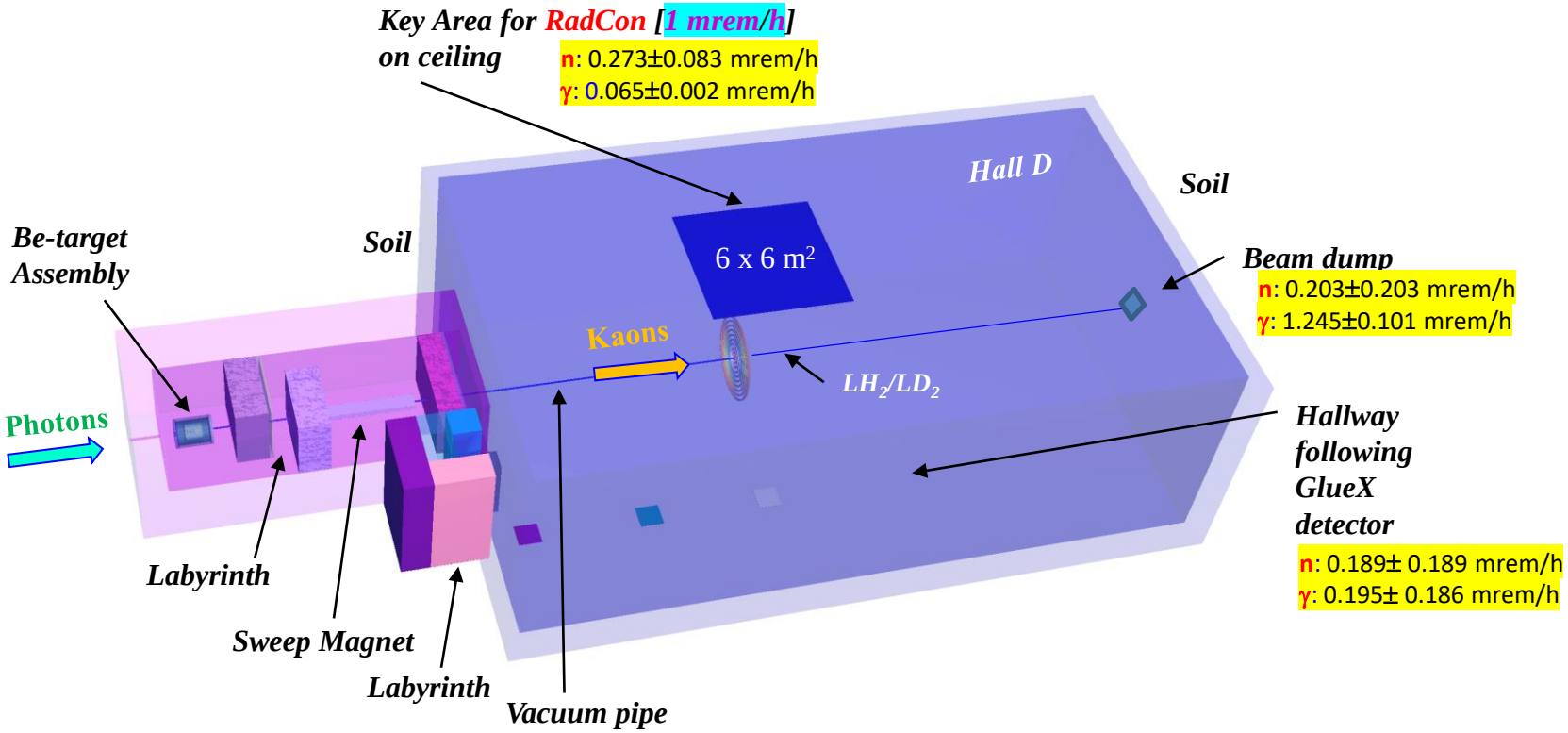
Hall D Setting & Dose Rate

- For neutron & gamma calculations, we use MCNP6 radiation transport code.



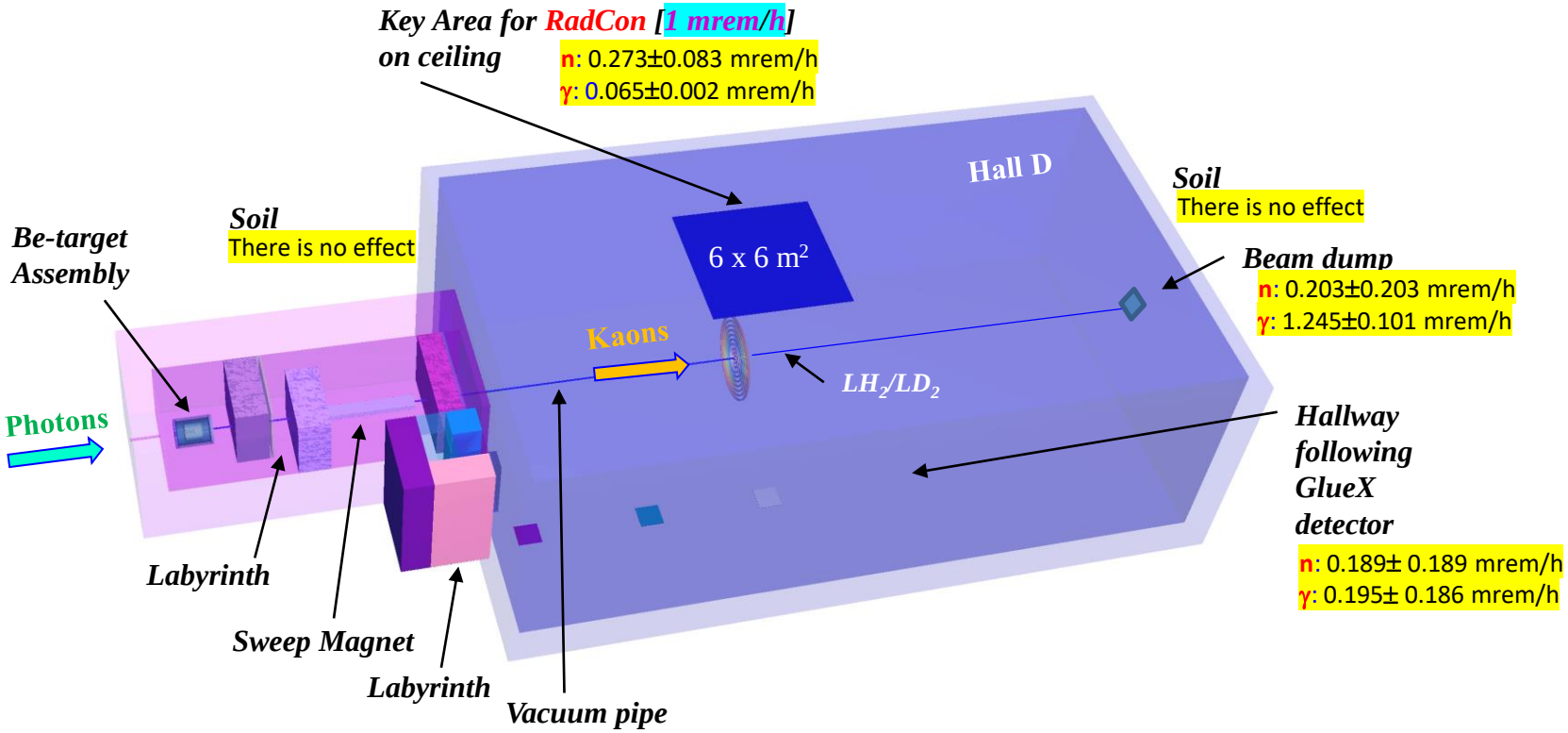
Hall D Setting & Dose Rate

- For neutron & gamma calculations, we use MCNP6 radiation transport code.



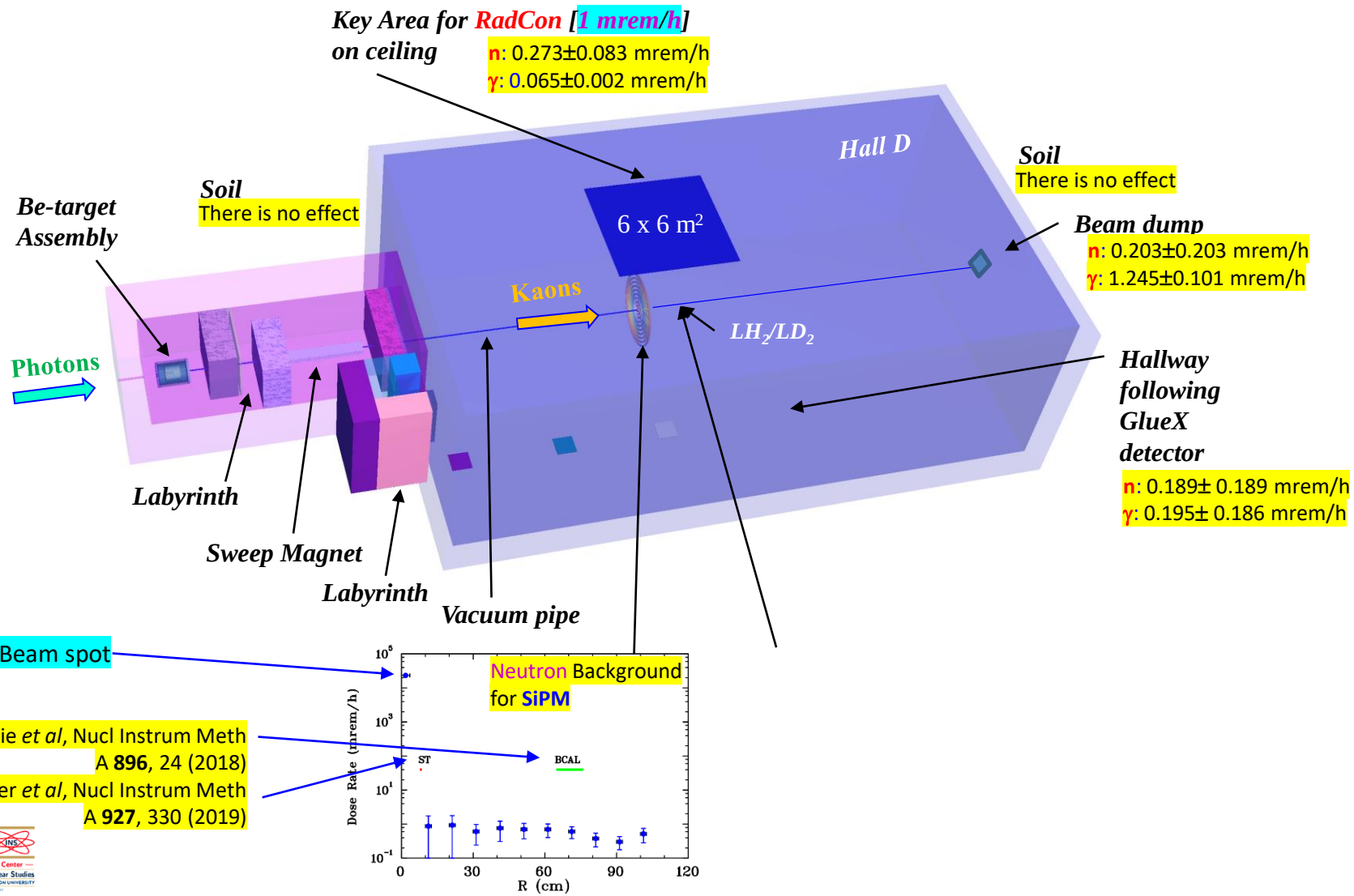
Hall D Setting & Dose Rate

- For neutron & gamma calculations, we use MCNP6 radiation transport code.



Hall D Setting & Dose Rate

- For neutron & gamma calculations, we use MCNP6 radiation transport code.

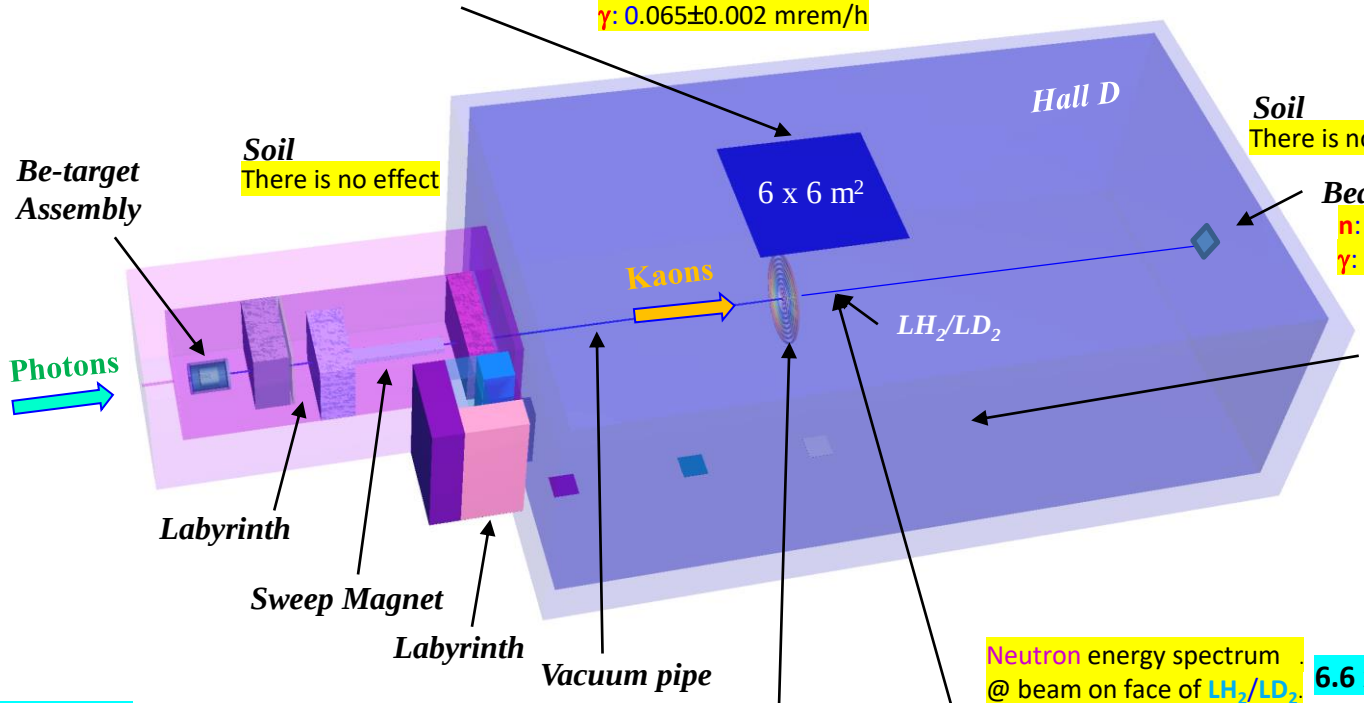


BCAL: T.D. Beattie *et al*, Nucl Instrum Meth A **896**, 24 (2018)

SC: E. Pooser *et al*, Nucl Instrum Meth A **927**, 330 (2019)

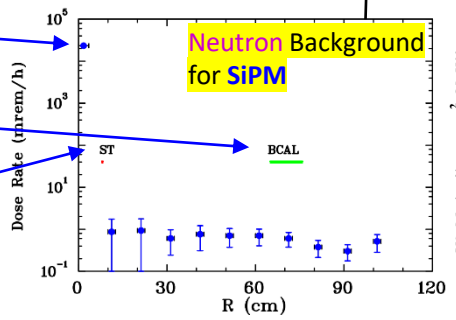
Hall D Setting & Dose Rate

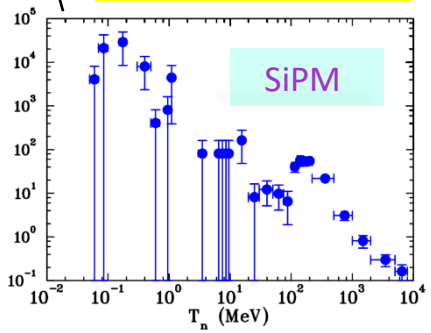
- For neutron & gamma calculations, we use MCNP6 radiation transport code.



Neutron energy spectrum @ beam on face of LH_2/LD_2. **6.6×10^5** n/s

Beam spot





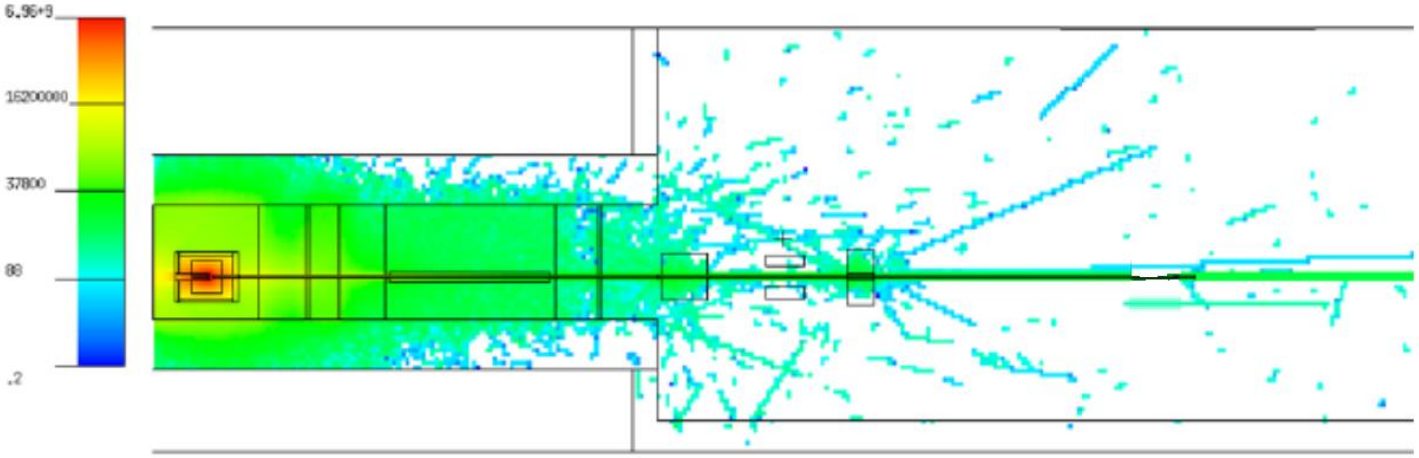
BCAL: T.D. Beattie *et al*, Nucl Instrum Meth A **896**, 24 (2018)

SC: E. Pooser *et al*, Nucl Instrum Meth A **927**, 330 (2019)

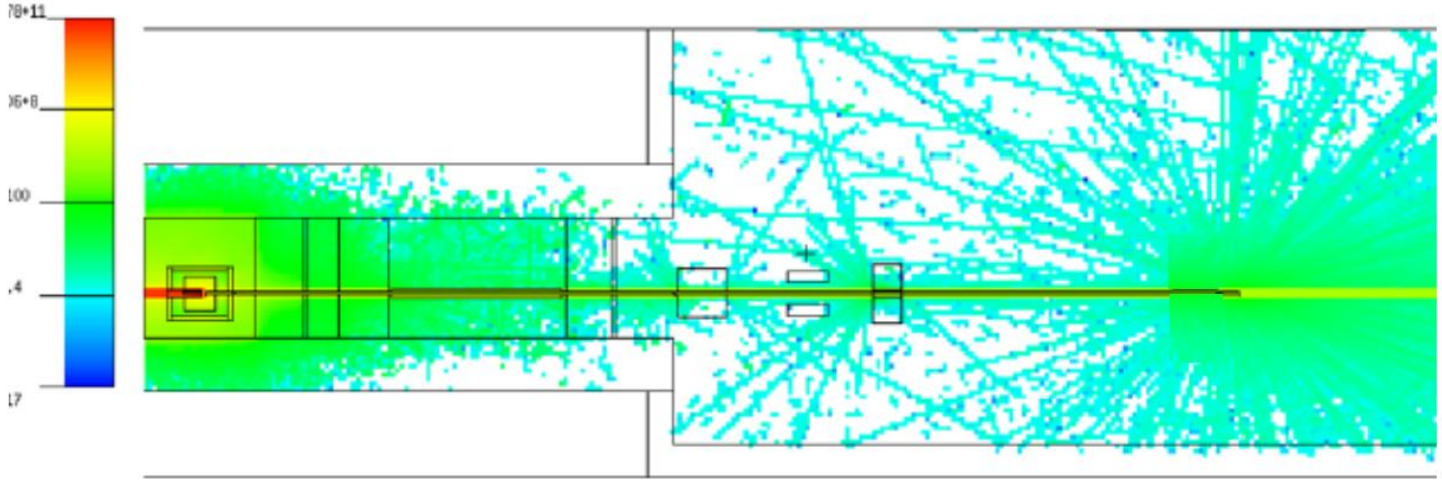
Previous studies stand that dose rate of 30 mreh/h increases a dark current at SiPM by a factor of 5 after 75 days of running period.

Prompt Plots

- **Vertical** cross section of **neutron** flux calculated using MCNP6.

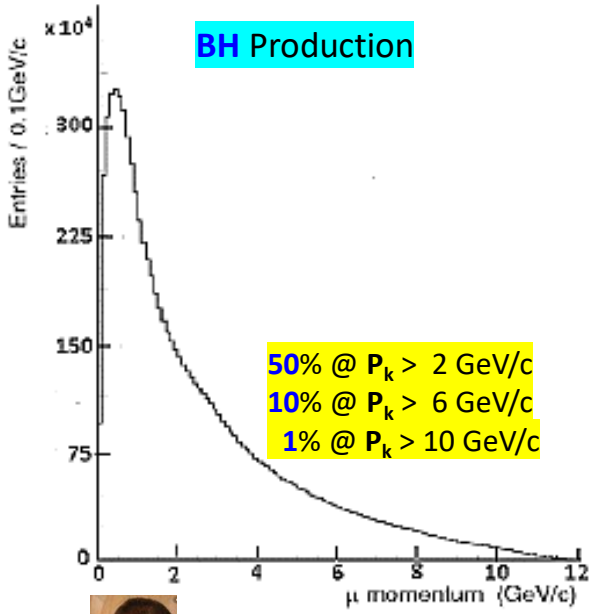


- **Vertical** cross section of **gamma** flux calculated using MCNP6.



Soft gammas from elements of LH_2/LD_2

Muon Background



- Our simulations included **BH** muon background from **KPT** & photon dump @ **CPS**, both backgrounds into **GlueX** detector & muon dose rate outside **Hall D**.
- Most of muons are coming from **W**-plug.
- Number of produced muon in **KPT** & **W**-plug is about the same, but muons originating in **W** have much softer momenta.
- **Muon Flux** is **~10^7** μ/sec.
- Our calculations show that **muons** will be **swept** out of kaon beamline.

Overall, Muon Flux for experiment is tolerable.

Where We are Now & Where to Go

- Kaon flux @ KLF will allow statistics in case of LH_2 target to exceed that of earlier SLAC experiments by almost **three orders** of magnitude.

- Calculations for KPT were performed for different **shielding** configurations to minimize **neutron** & **gamma** prompt radiation dose rate & reduce price of KPT.

- Neutron & gamma *flux* & *dose rate* for  is below JLab RadCon requirement establishing radiation dose rate limit in experimental hall.
  Materials & equipment: $0.134M.

- Neutron flux & energy distribution on face of LH_2/LD_2 cryogenic target is important physical background in case of np or nd interactions in cryogenic target.

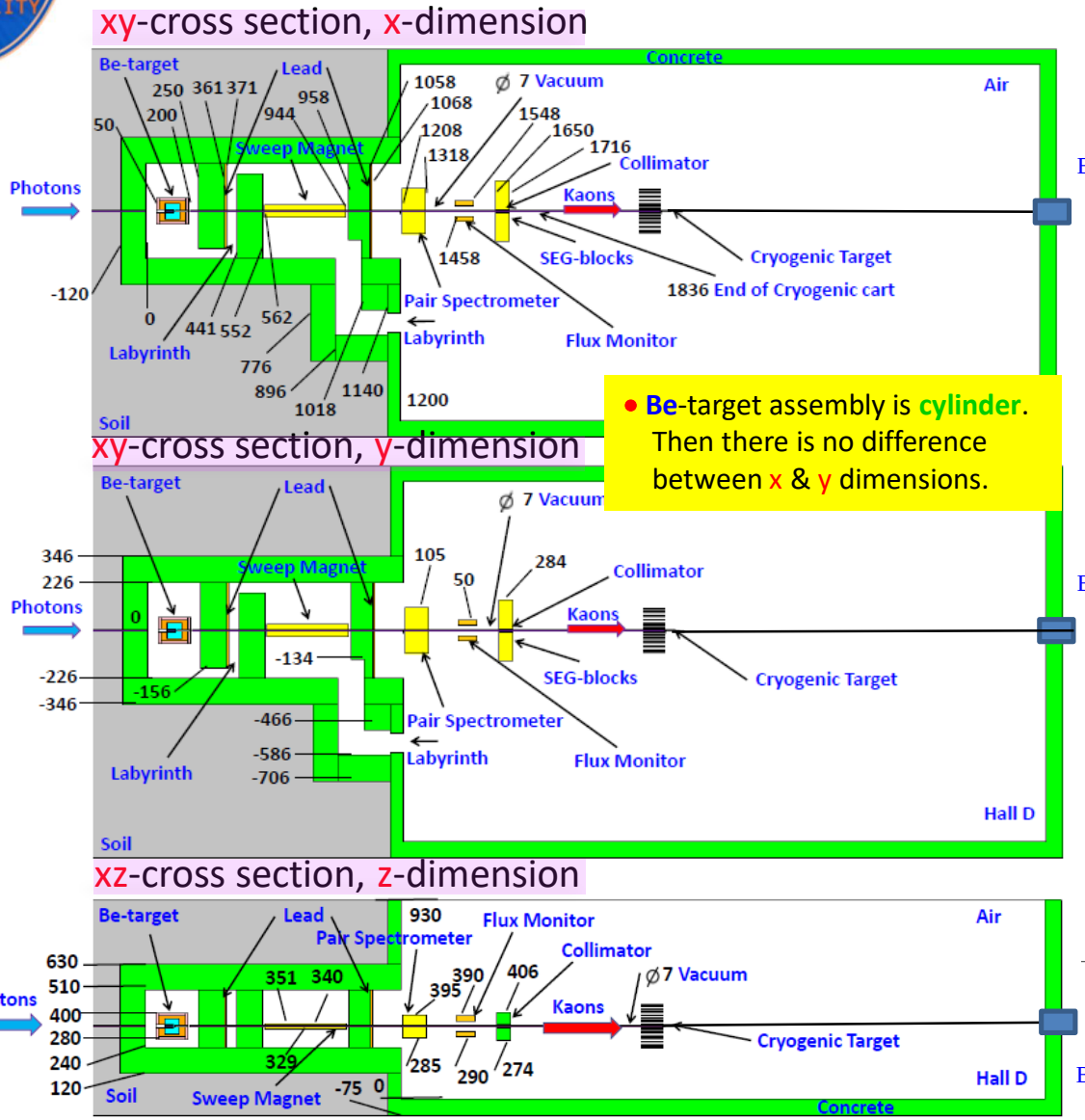
- SiPMs of SC & BCAL are expected to tolerate expected **neutron** background.

- Engineering design is in order ?

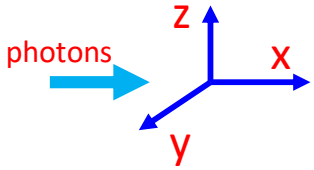
Any Questions ?

Collimator Alcove & Experimental Hall

[29.5 m long x 17.2 m wide]



- **Be**-target assembly is **cylinder**. Then there is no difference between x & y dimensions.



Beam dump