

Be-Target Assembly Conceptual Design: Progress & Plans

Igor Strakovsky

The George Washington University
(for KLF Collaboration)



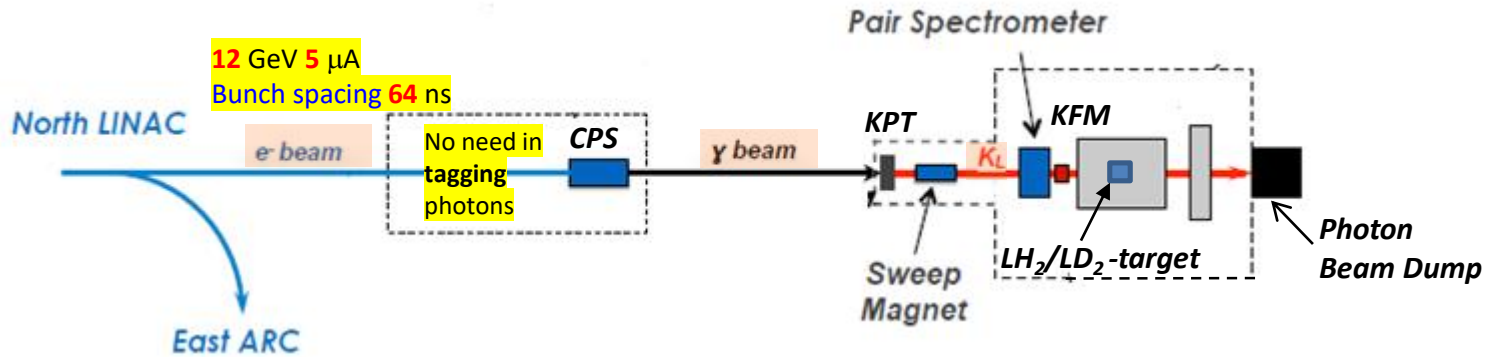
- Hall D beam line for .
- Hall D setting.
-  radiation transport code.
- KPT & Plug materials.
- Be-target assembly.
- Biological dose rate for n & γ .
- Muon background.
- Where we are now & where to go.





Hall D Beam Line for K-long

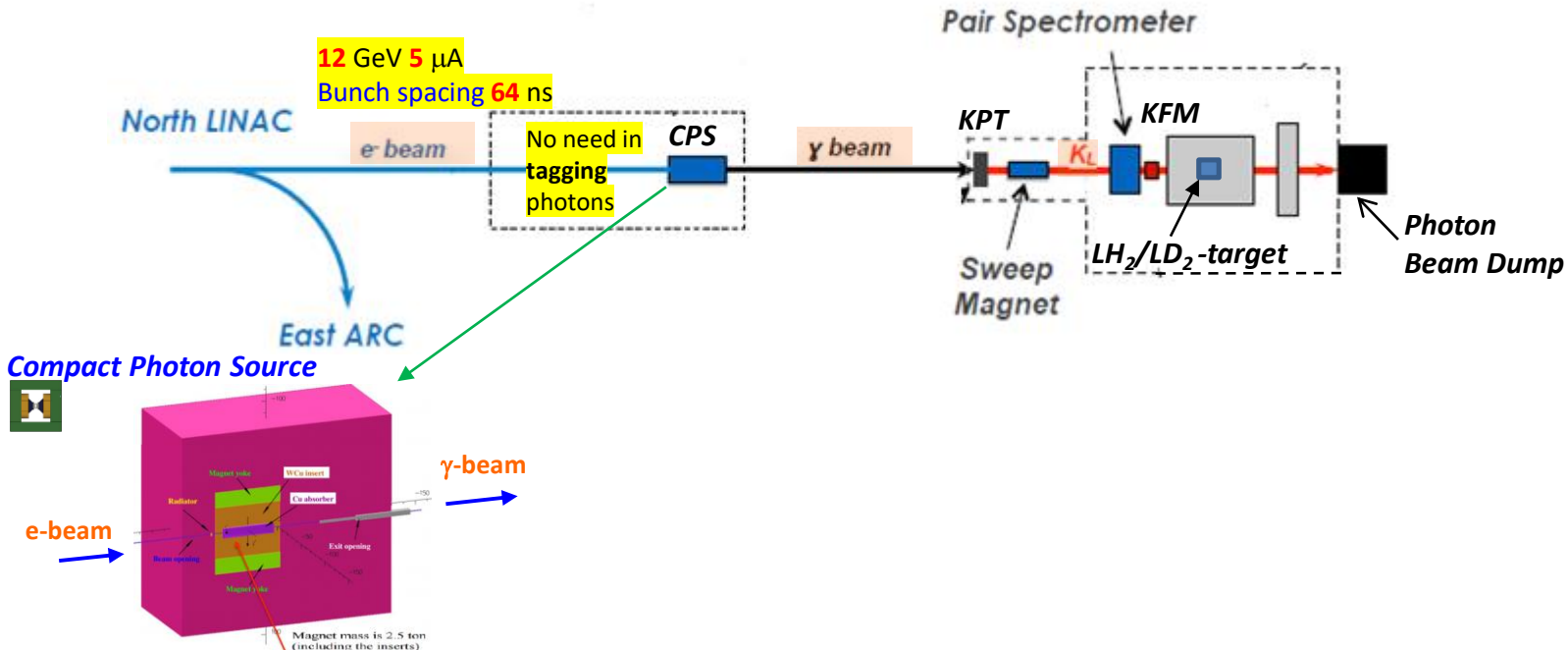
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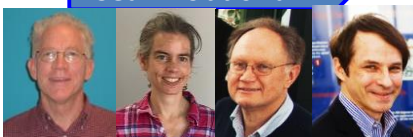


D. Day et al, Nucl Ins Meth, A 957, 163429 (2020)

Sean Dobb's Talk



2/6/2020



KLF-2020, Newport News, Virginia, February 2020

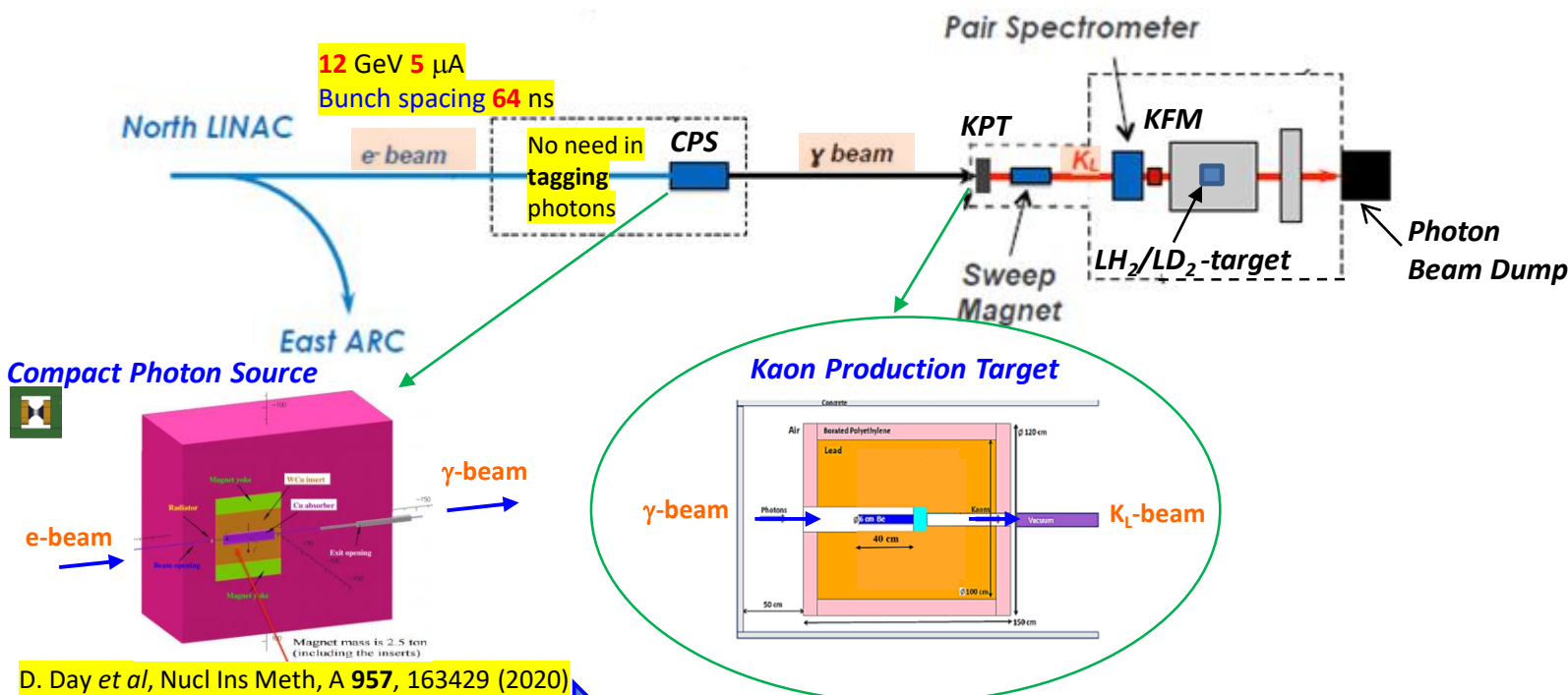
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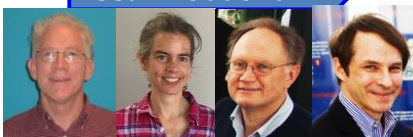
Hall D Beam Line for K_L -long

- **Electrons** (3.1×10^{13} e/sec) are hitting **Cu-radiator** @ **CPS** located in **Tagger** alcove.
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- **K_L s** (1×10^4 K_L /sec) are hitting **LH₂/LD₂** target within **GLueX** setting.



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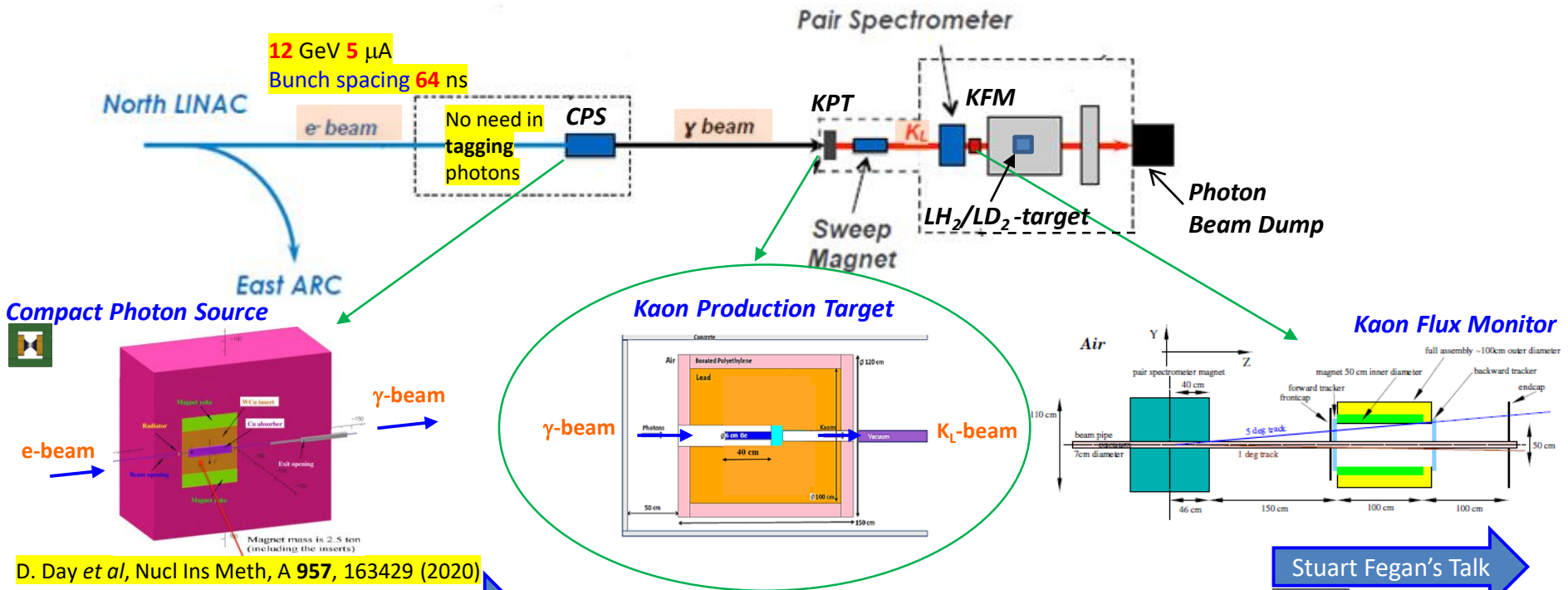
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Stuart Fegan's Talk



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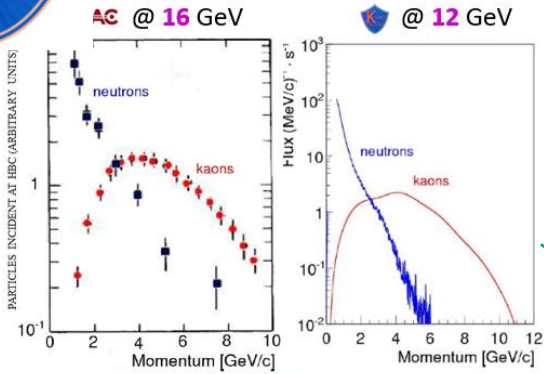
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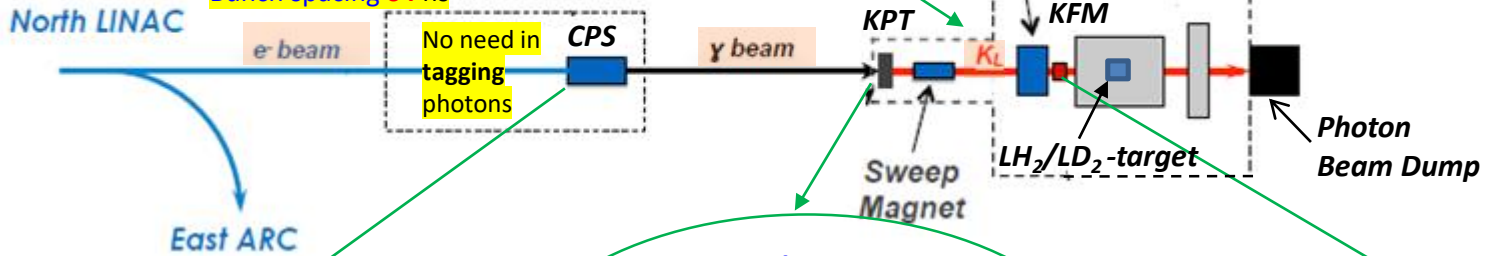
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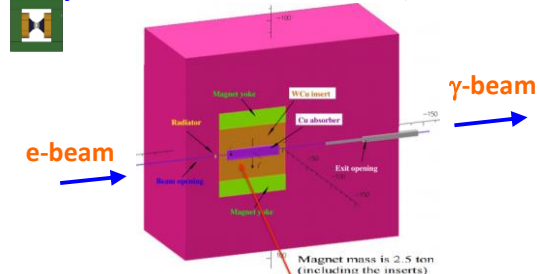


$$\frac{N(K_L)_{Jefferson\ Lab}}{N(K_L)_{SLAC}} \sim 10^3$$

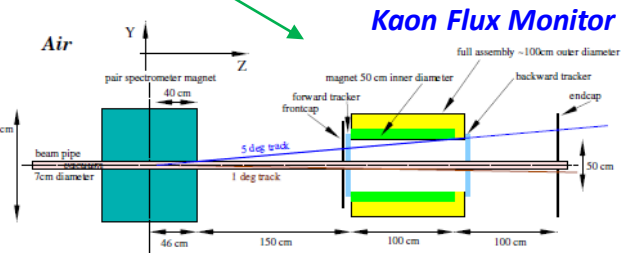
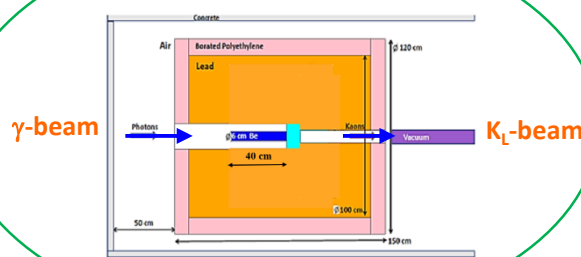
12 GeV 5 μ A
Bunch spacing 64 ns



Compact Photon Source



Kaon Production Target



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

Sean Dobb's Talk

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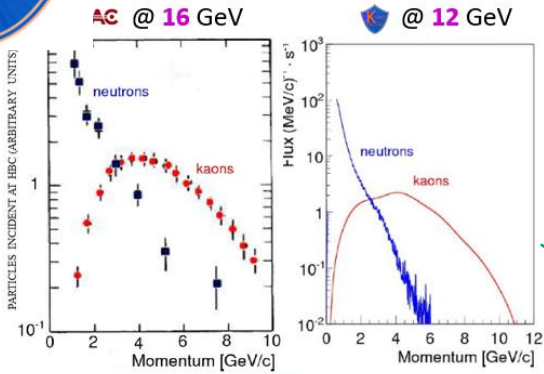
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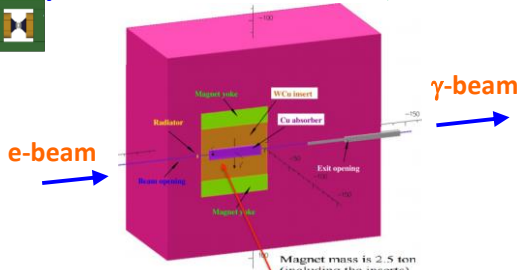
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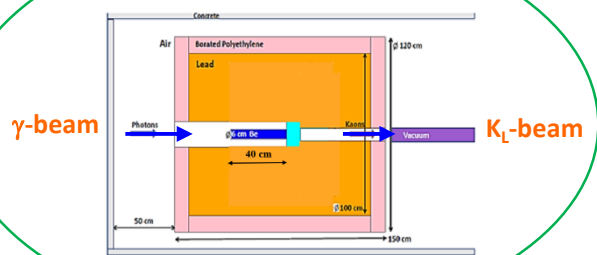
North LINAC

East ARC

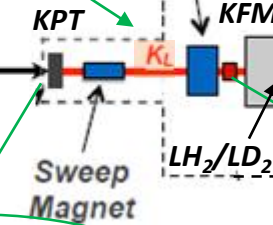
Compact Photon Source



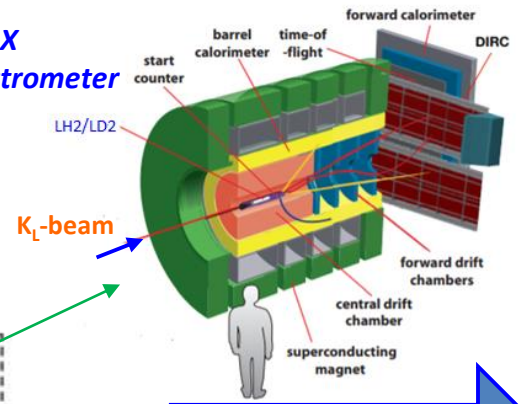
Kaon Production Target



Pair Spectrometer



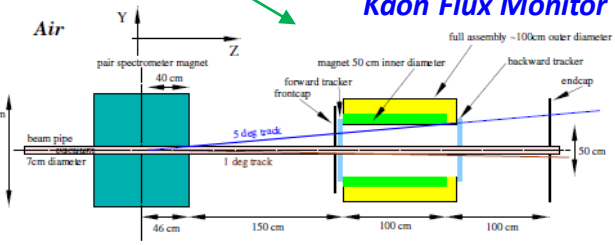
GlueX Spectrometer



Sergey Furletov's Talk
Sasha Somov's Talk

Photon Beam Dump

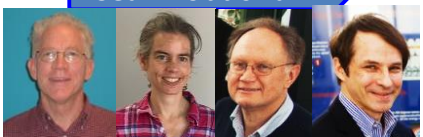
Kaon Flux Monitor



Stuart Fegan's Talk



Sean Dobb's Talk



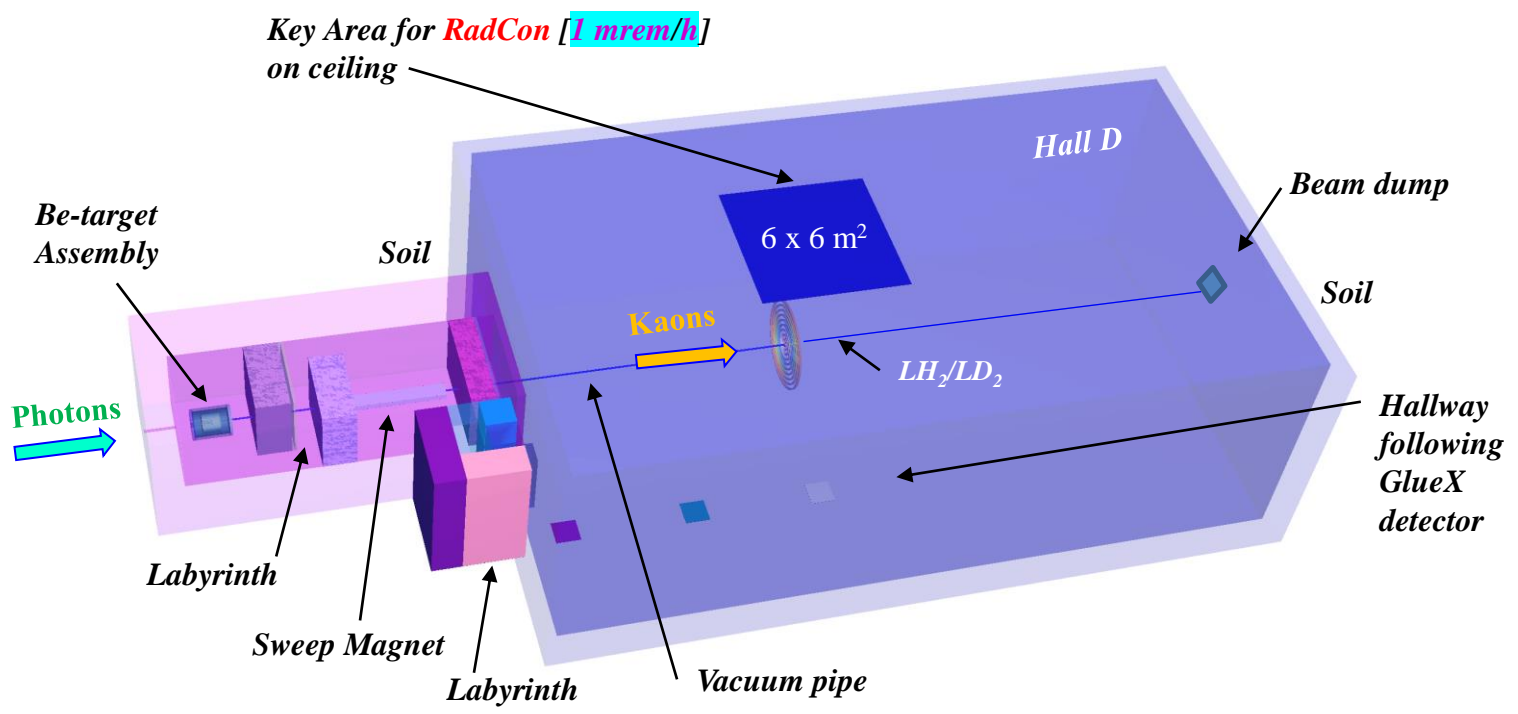
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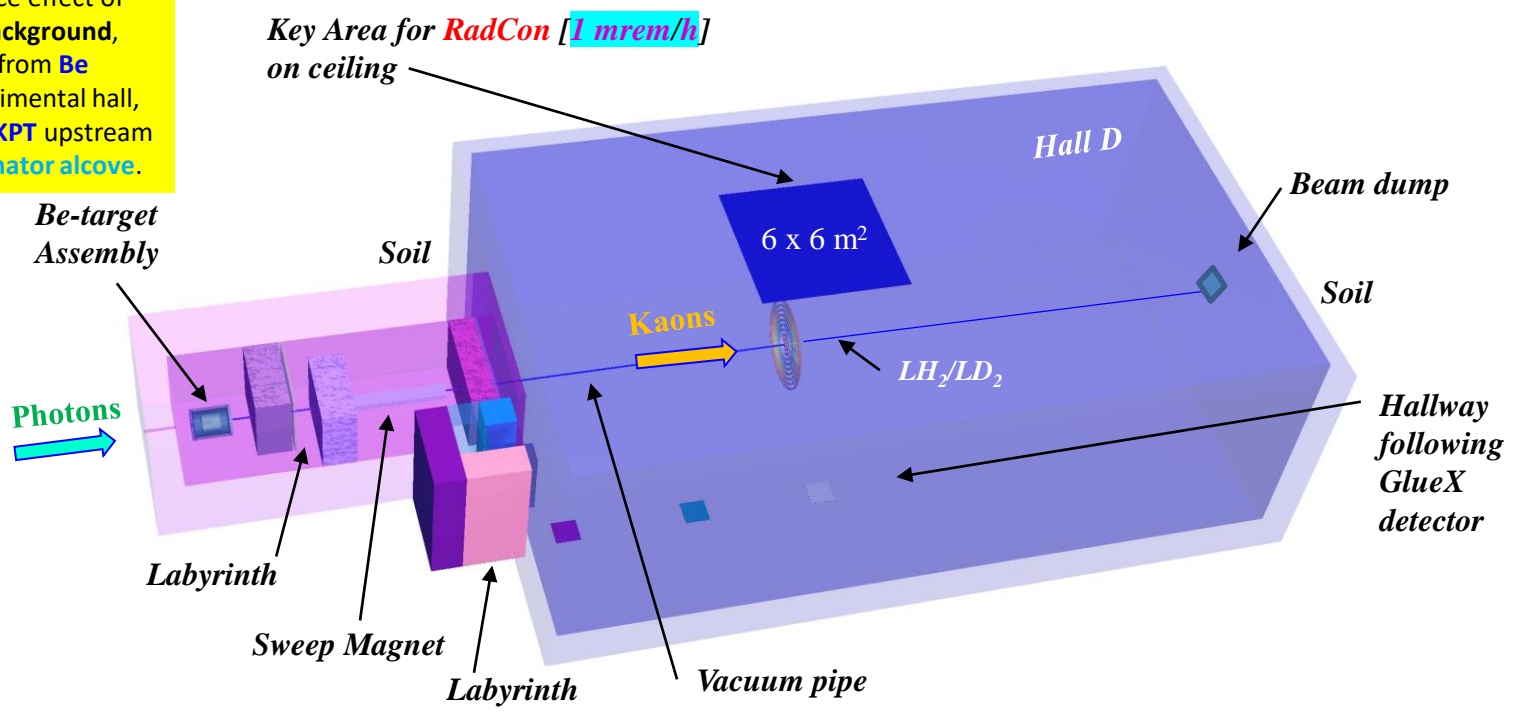
- For **neutron** & **gamma** calculations, we use **MCNP6** radiation transport code.



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

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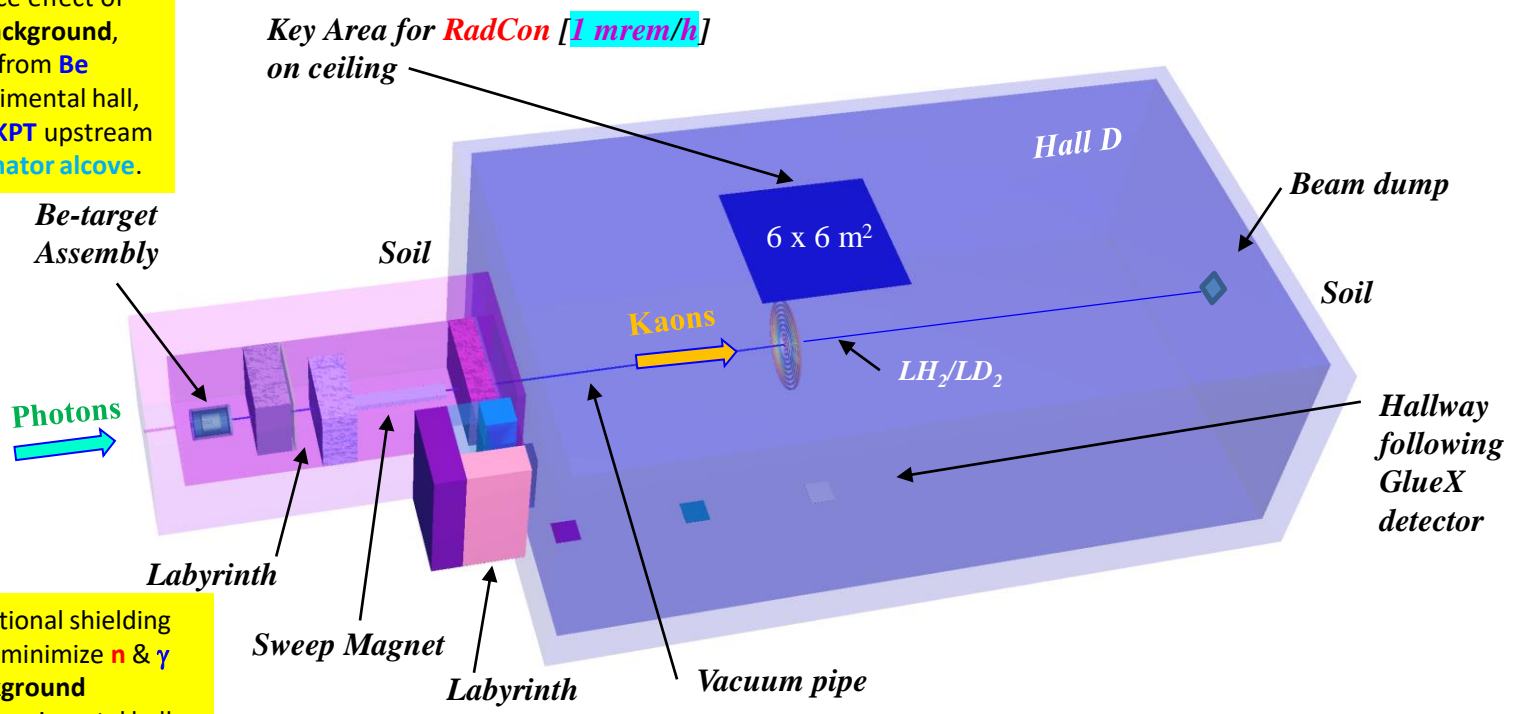
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Additional shielding is to minimize **n** & **γ** background in experimental hall.

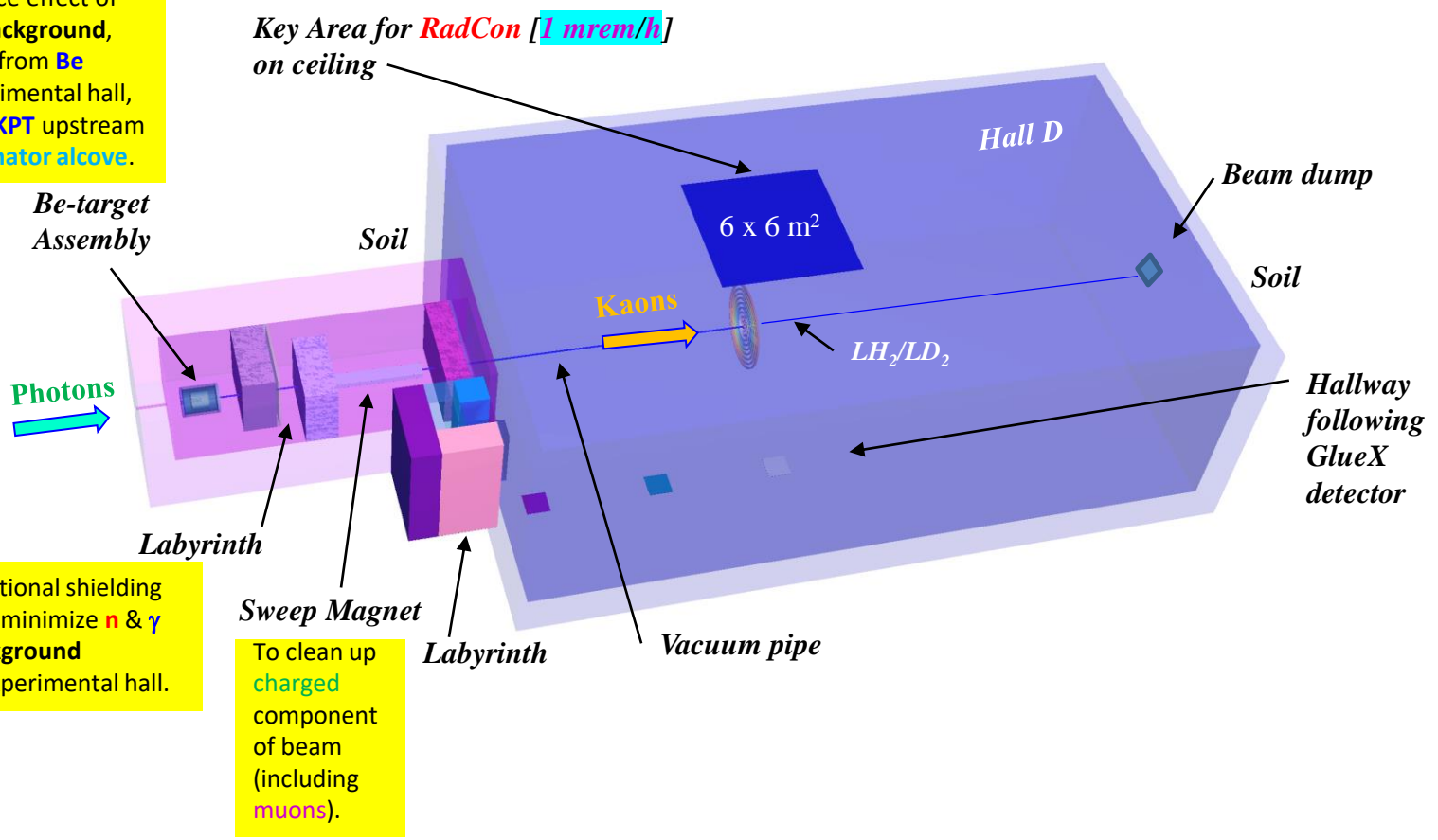
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Hall D Setting

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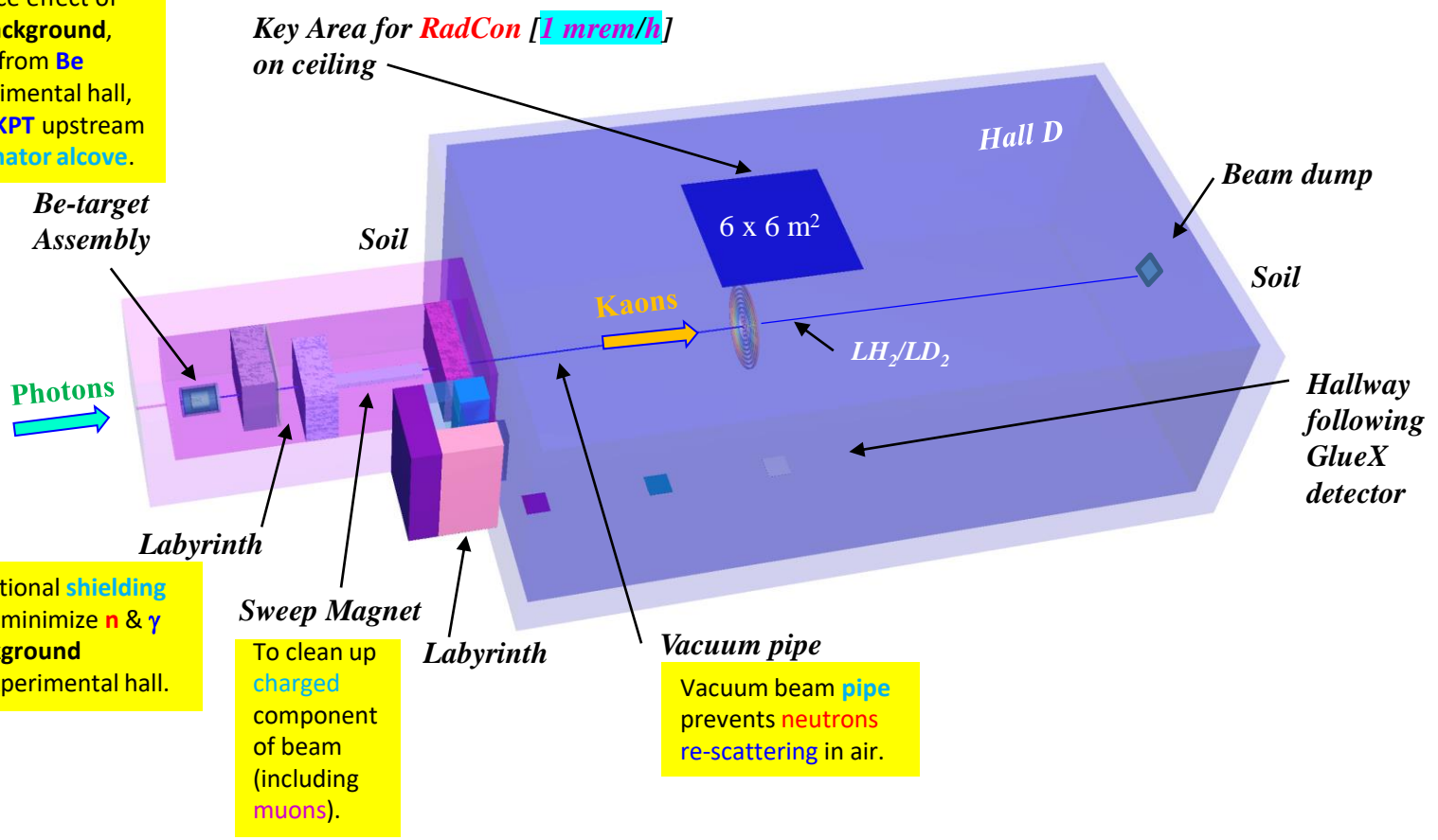
To clean up **charged** component of beam (including **muons**).

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Vacuum beam pipe prevents **neutrons** re-scattering in air.

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Radiation Transport Code

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

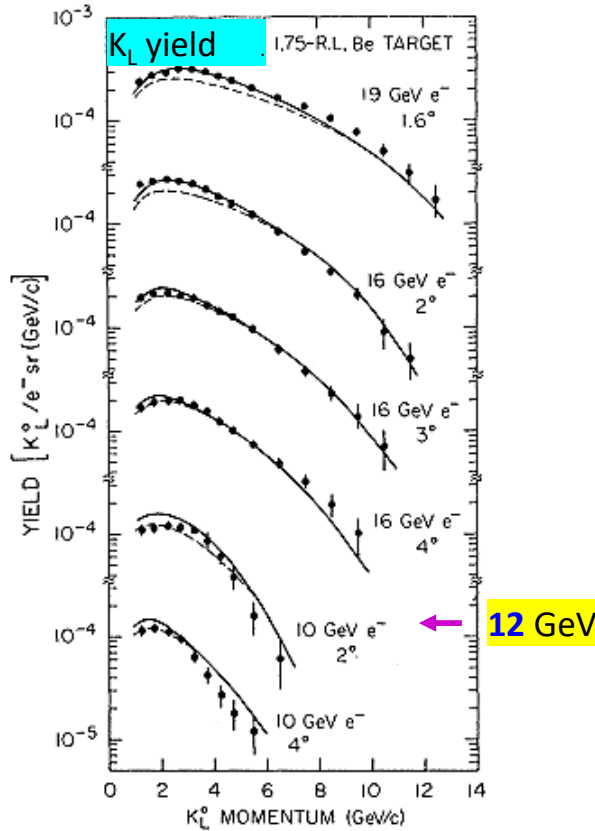
- Physical models, implemented in  code, take into account
 - *bremsstrahlung* photon production,
 - *photonuclear* reactions,
 - neutron & photon *multiple scattering* processes.
-  model simulates **12 GeV 5 μA electron** beam hitting **Cu**-radiator inside **CPS**.
- **Electron** transport is traced in **Cu**-radiator, vacuum beam **pipe** for bremsstrahlung photons, **Be**.
- **Neutrons & gammas** is traced in all components of  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  calculations (in terms of **flux** [**part/s/cm²**] & **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.



- Kaon yield $\sim X_0 * \rho$ & $\text{Ratio}(\text{Be}/\text{C}) = (65/43) = 1.51$



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

At key area for RadCon on ceiling

Be: $n: 0.27 \pm 0.08$ mrem/h **R(C/Be)=1.45**

$\gamma: 0.065 \pm 0.002$ mrem/h

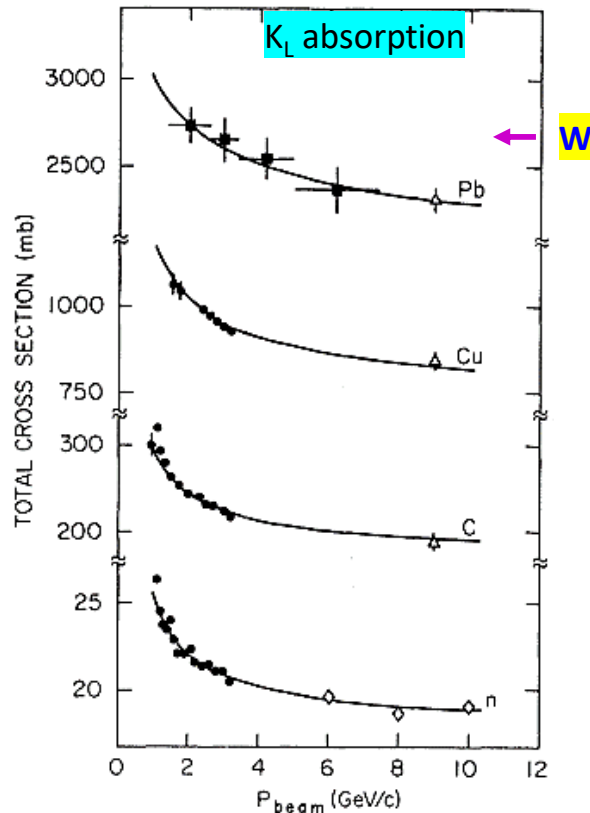
C: $n: 0.40 \pm 0.20$ mrem/h

$\gamma: 0.080 \pm 0.002$ mrem/h

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



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



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: 0.27 ± 0.08 mrem/h **R(Pb/W)=2.25** **R(Cu/W)=9.29**
 γ: 0.065±0.002 mrem/h

Pb: n: 0.61 ± 0.25 mrem/h
 γ: 0.527±0.006 mrem/h

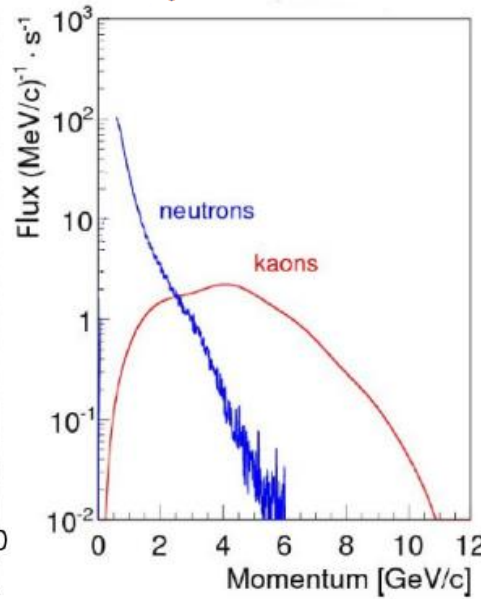
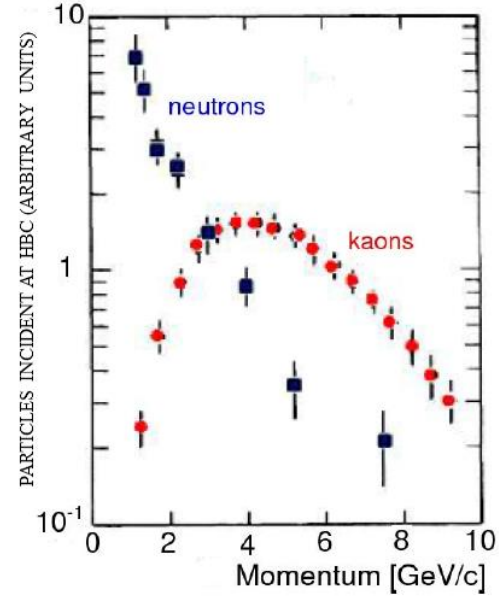
Cu: n: 2.54 ± 0.39 mrem/h
 γ: 4.34 ± 0.02 mrem/h

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



SLAC @ 16 GeV

@ 12 GeV

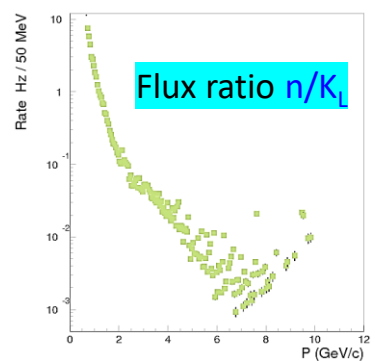


- Flux of Kaons will be 1×10^4 K_L /sec on LH_2/LD_2 within *GlueX* detector, which has large *acceptance* with coverage of both *charged* & *neutral* particles.
- This flux will allow statistics in case of LH_2/LD_2 to exceed that of earlier **SLAC** experiments by almost **three orders** of magnitude.
- We simulated *Kaon* & *neutron* production from **12 GeV** electrons for by **PYTHIA** & **MCNP6** & results are in reasonable agreement with results measured by **SLAC @ 16 GeV**.

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



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- Delivered with **64** nsec bunch spacing avoids overlap between *neutrons* & *Kaons* in range of **p = 0.35 – 10.0** GeV/c. *See recent talk by Todd Satogata*



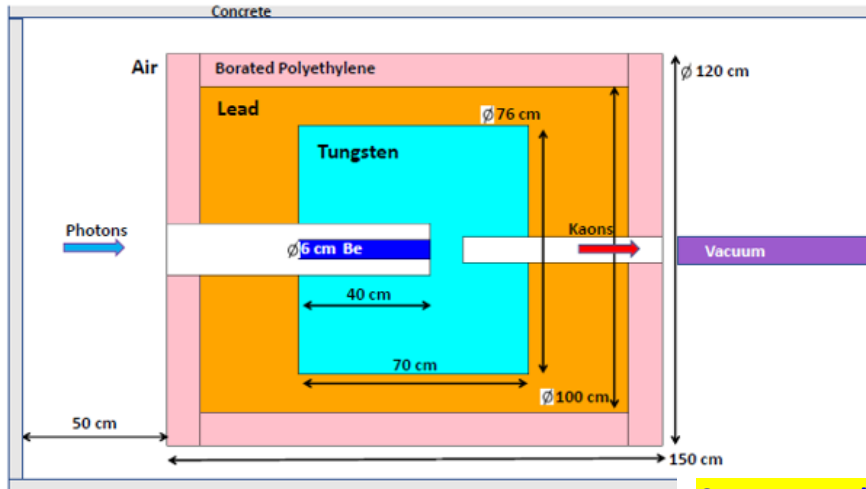
• With **proton** beam, ratio $n/K_L = 10^3 - 10^4$.





Be-Target Assembly

xy-cross section, x-dimension



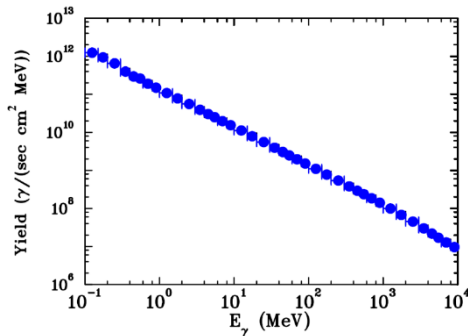
- Be-target assembly will weight **14.5 t**
- Be-target has estimated cost of **\$1.12M**

- **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.

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

Concrete walls are out of scale

Gammas on face of Be-target



At key area for RadCon on ceiling

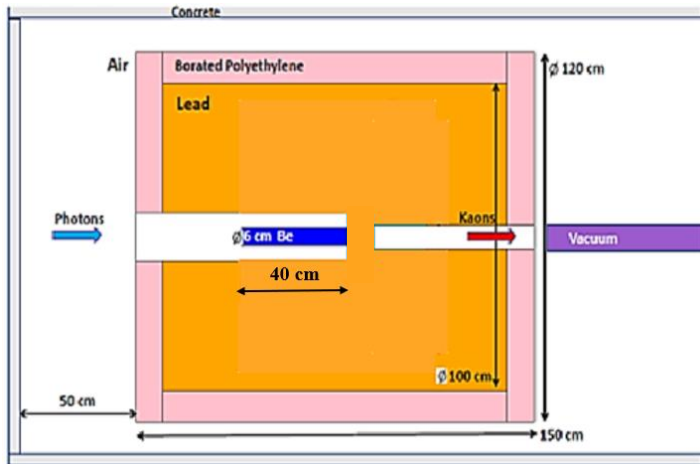
Pb & W **n: 0.35 ± 0.17 mrem/h**
γ: 0.078±0.005 mrem/h





Be-Target Assembly

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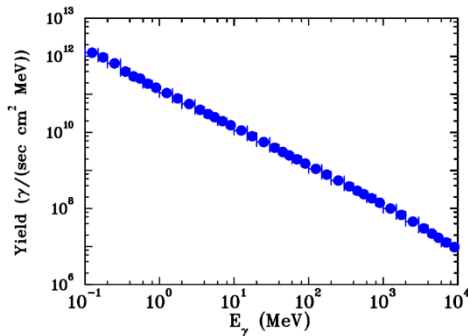
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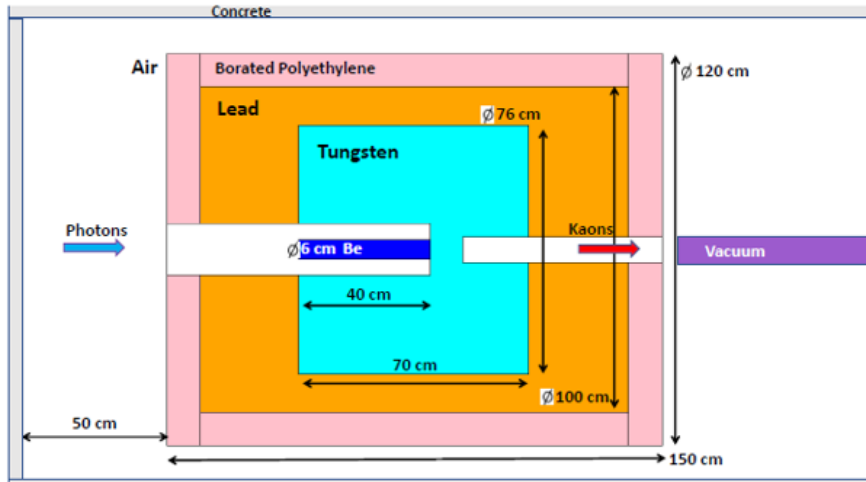
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Be-Target Assembly

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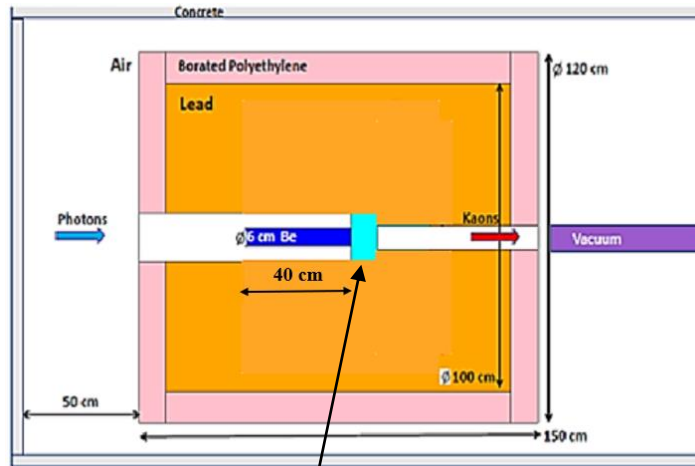


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Concrete walls are out of scale



W-plug
16 cm in diam
10 cm in length

At **key** area for **RadCon** on ceiling

Pb & W **n:** 0.35 ± 0.17 mrem/h
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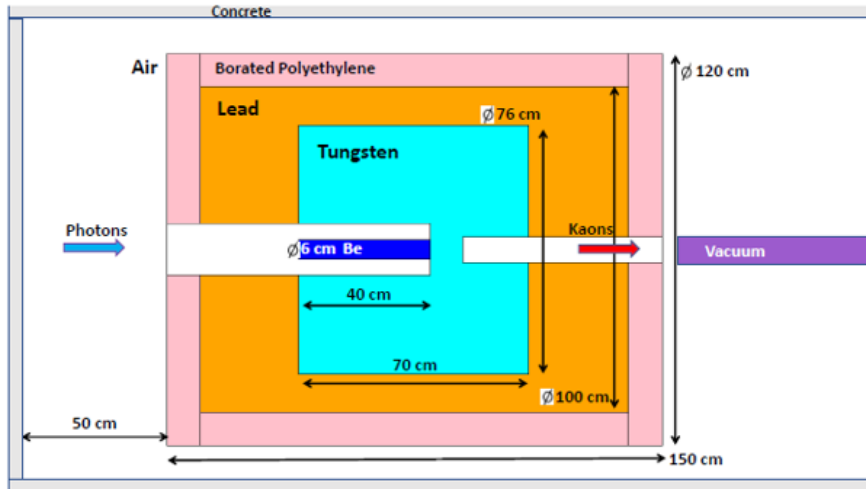
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Be-Target Assembly

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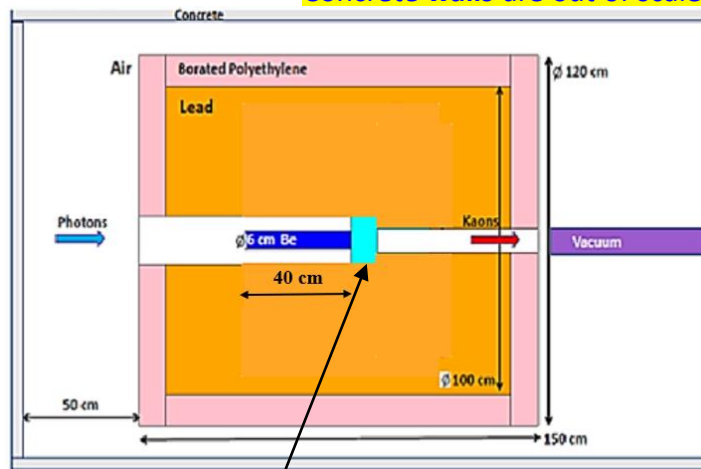
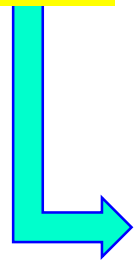


- Be-target assembly will weight **14.5 t** → **12 t**
- Be-target has estimated cost of **\$1.12M** → **\$0.134M**

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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: 0.77 ± 0.33 mrem/h
 γ: 0.074±0.002 mrem/h

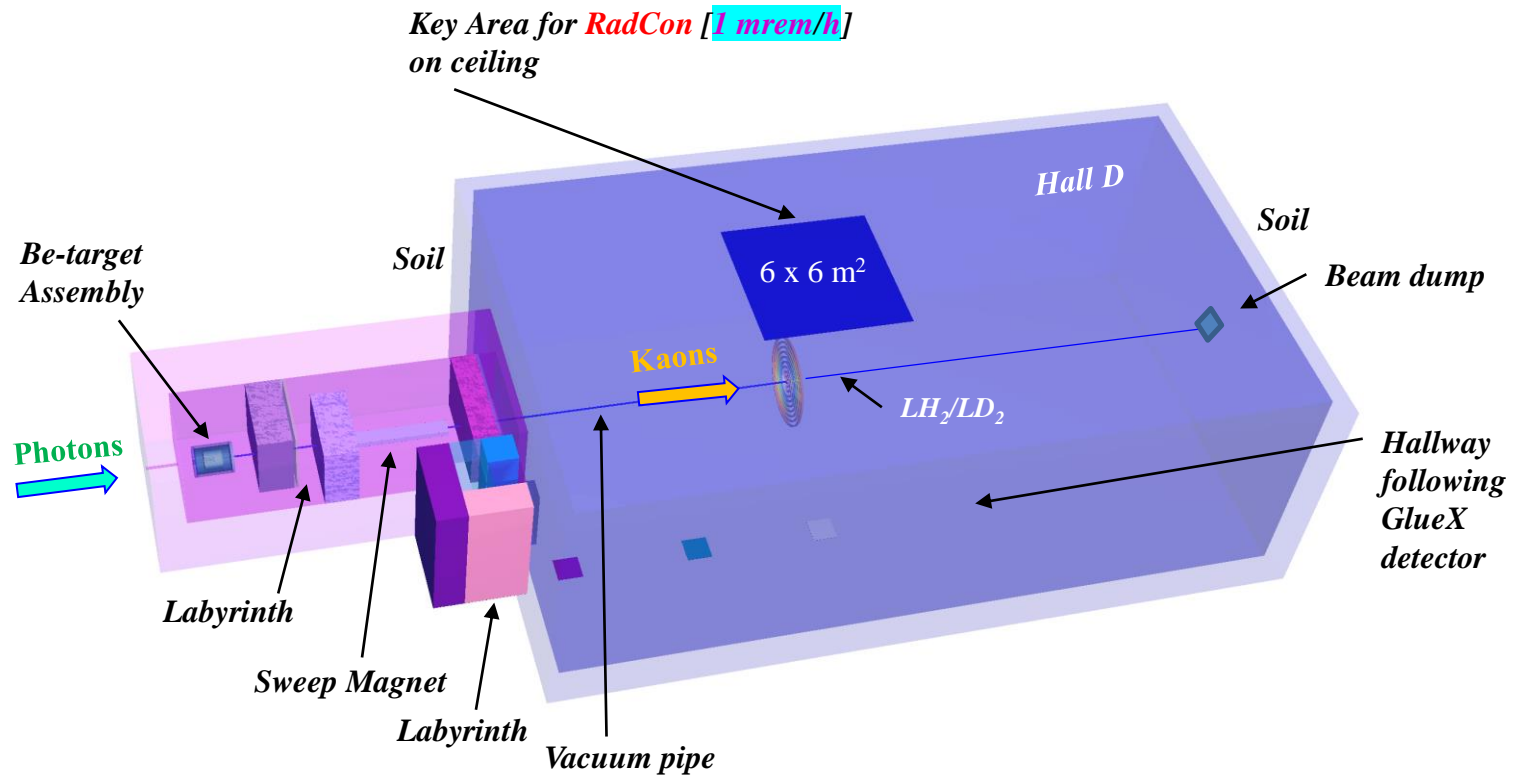
15 cm in length: n: 0.16 ± 0.06 mrem/h
 γ: 0.003±0.001 mrem/h





Hall D Setting & Dose Rate

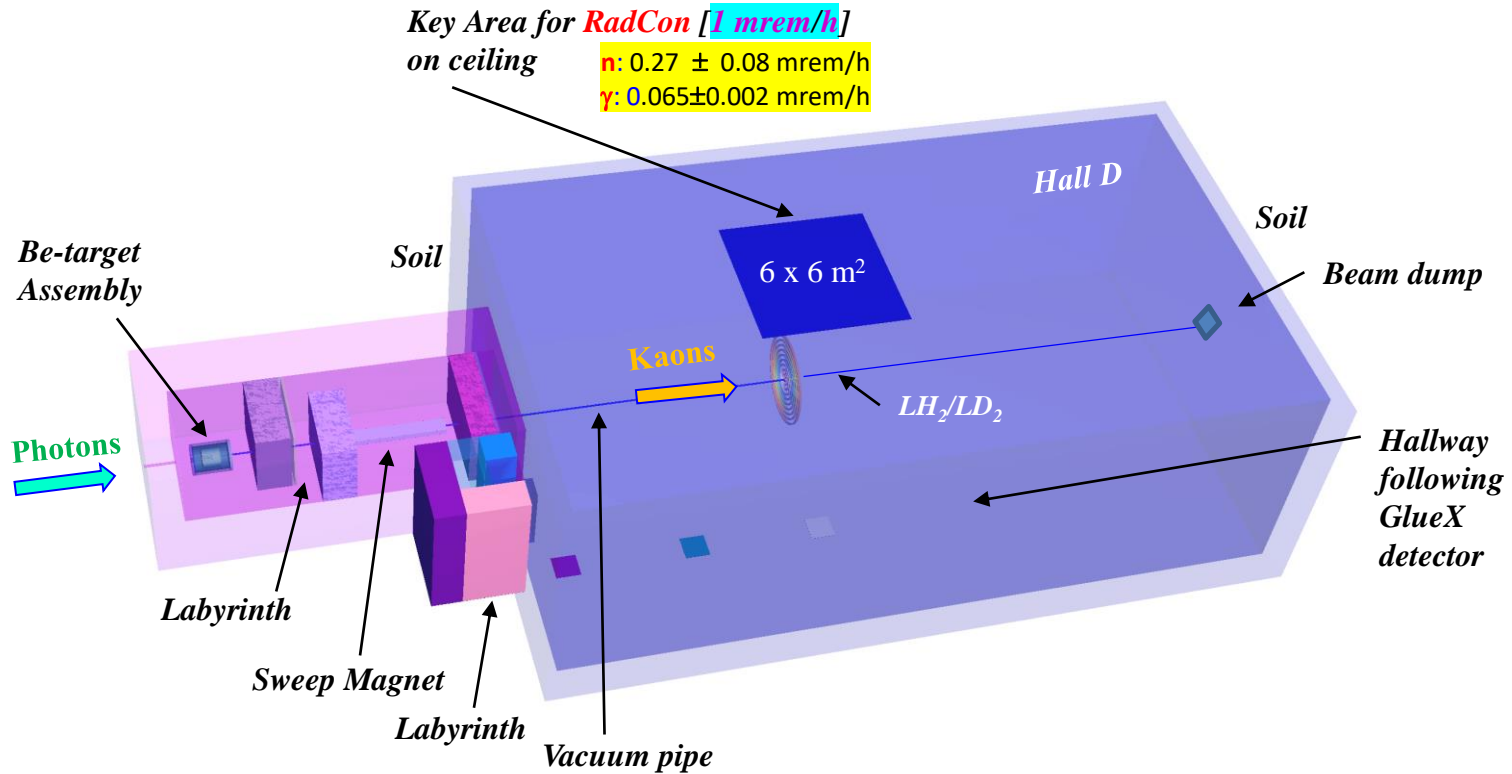
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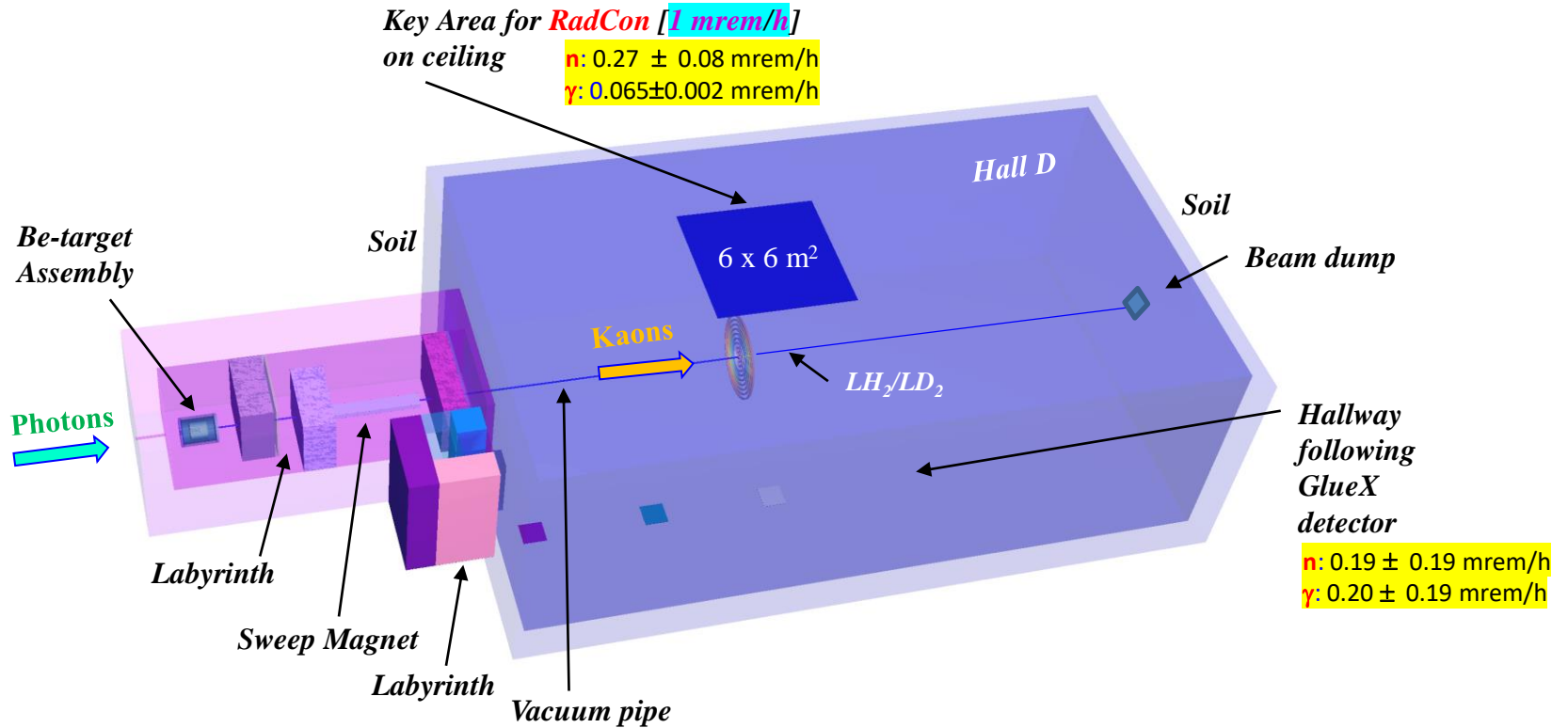
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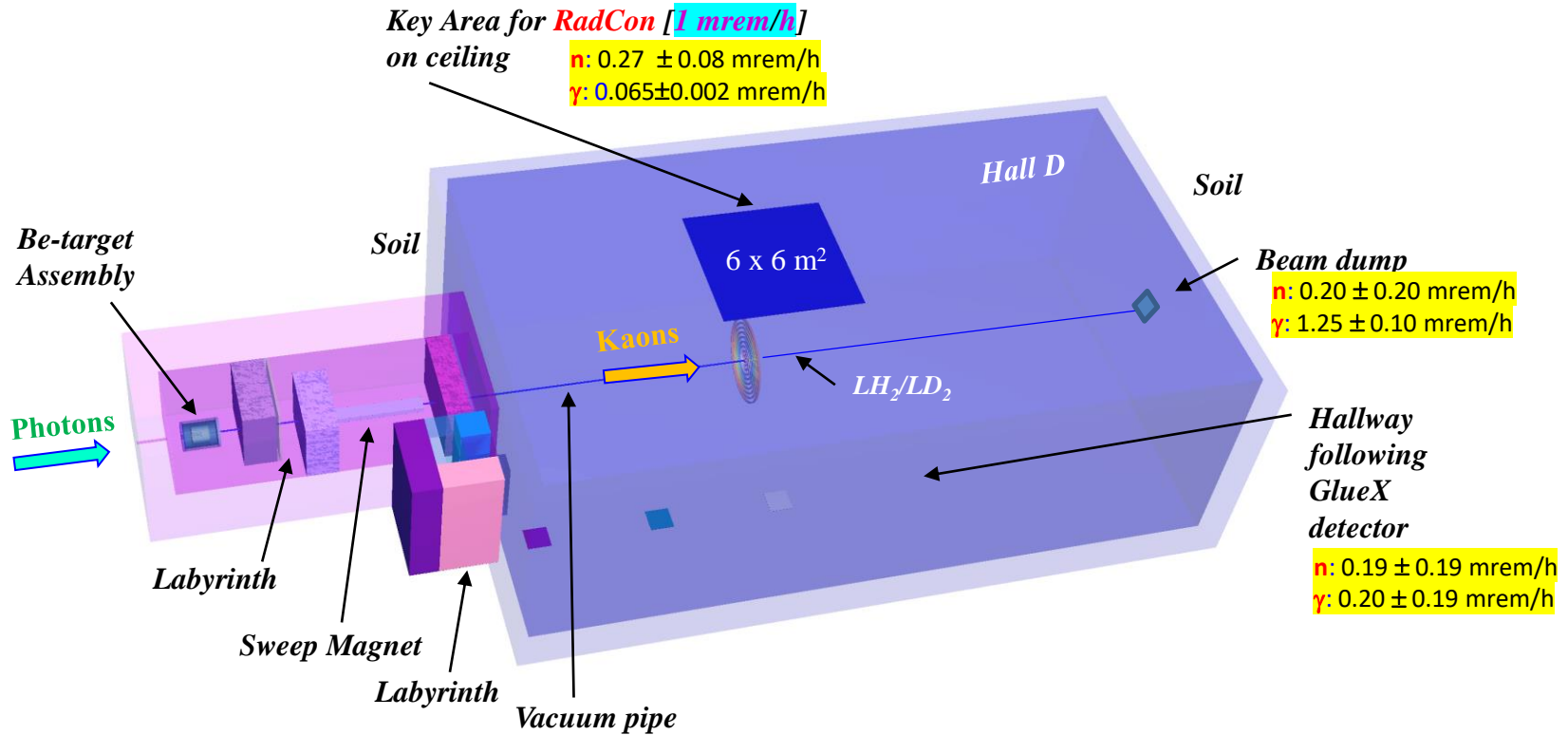
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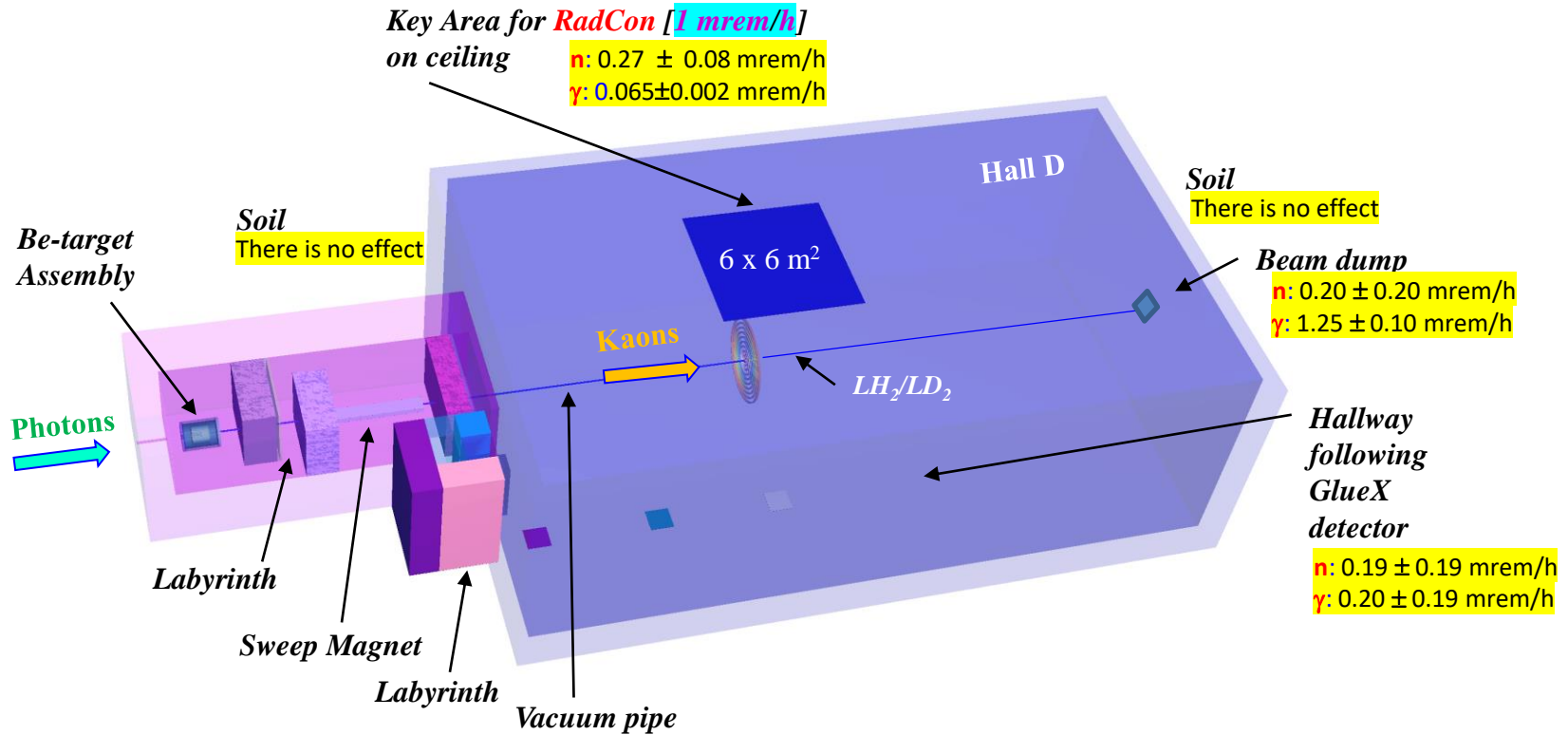
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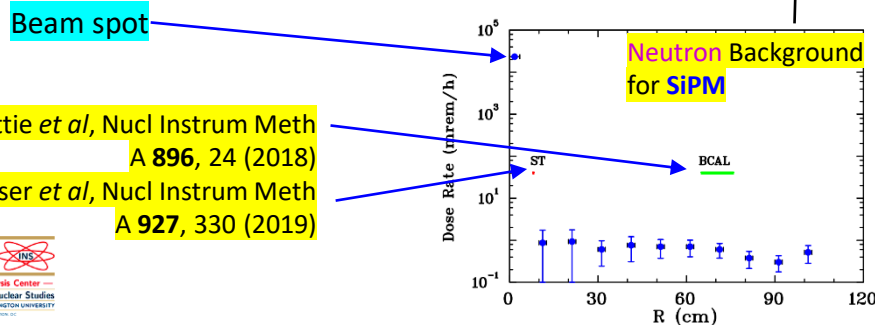
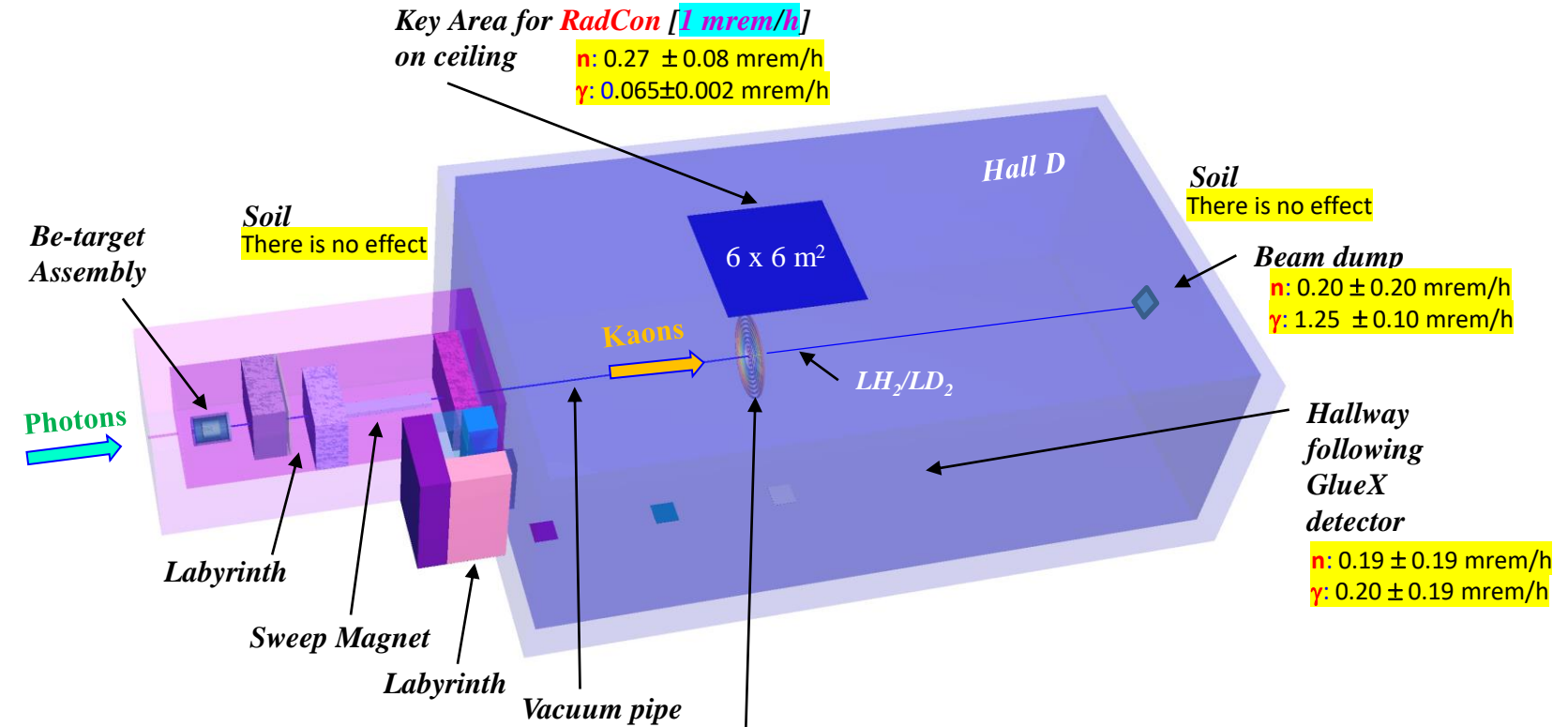
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- For **neutron** & **gamma** calculations, we use **MCNP6** radiation transport code.



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

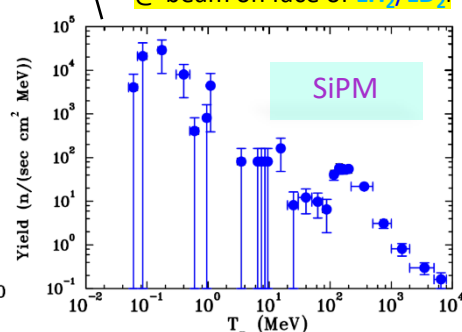
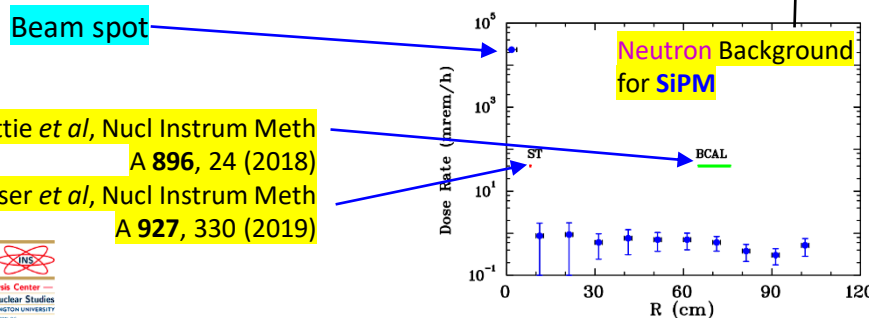
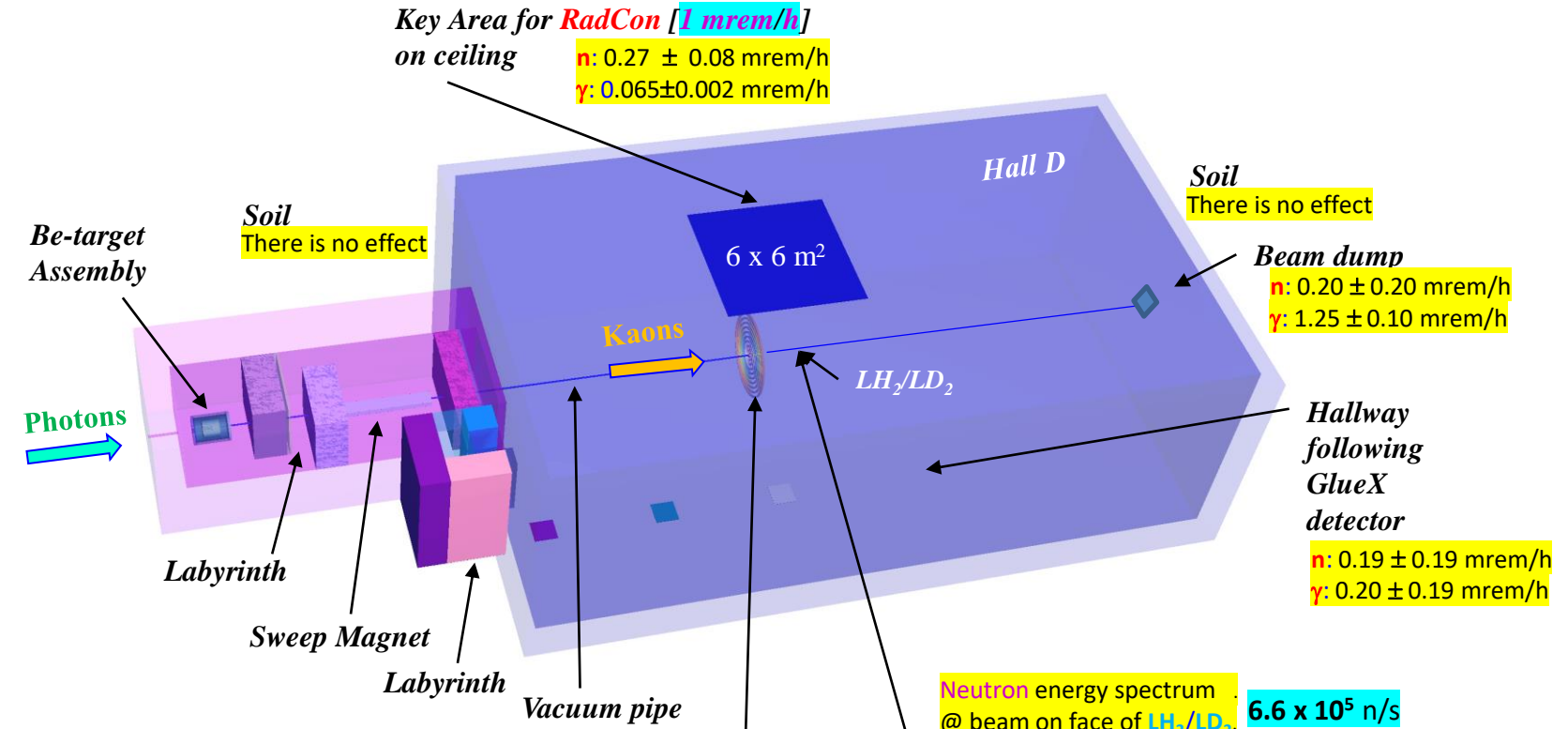
SC: E. Pooser *et al*, Nucl Instrum Meth A 927, 330 (2019)





Hall D Setting & Dose Rate

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



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

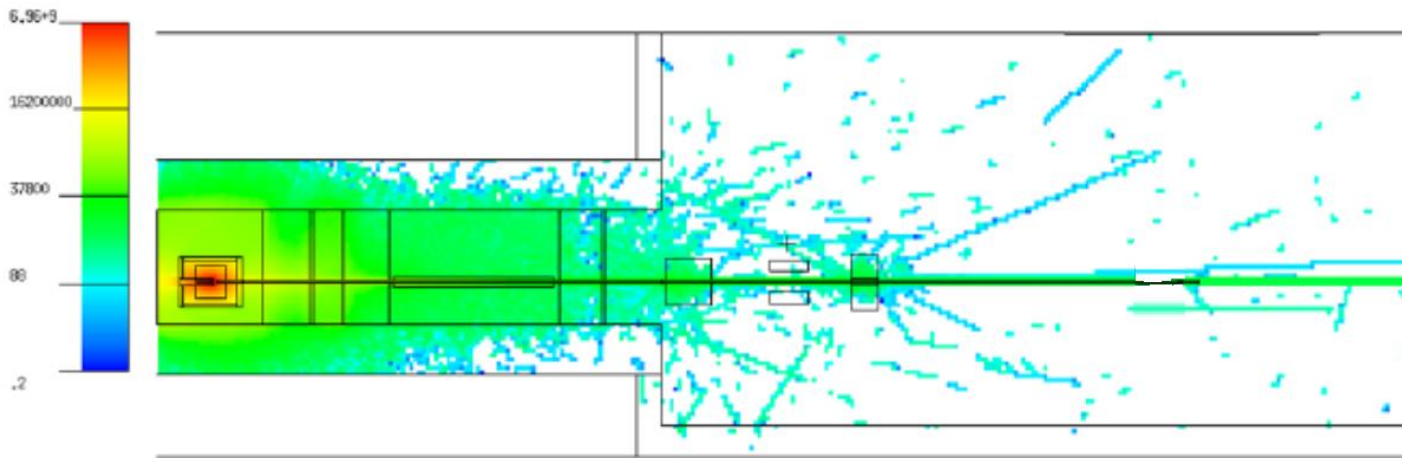
SC: E. Pooser *et al*, Nucl Instrum Meth A 927, 330 (2019)

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.

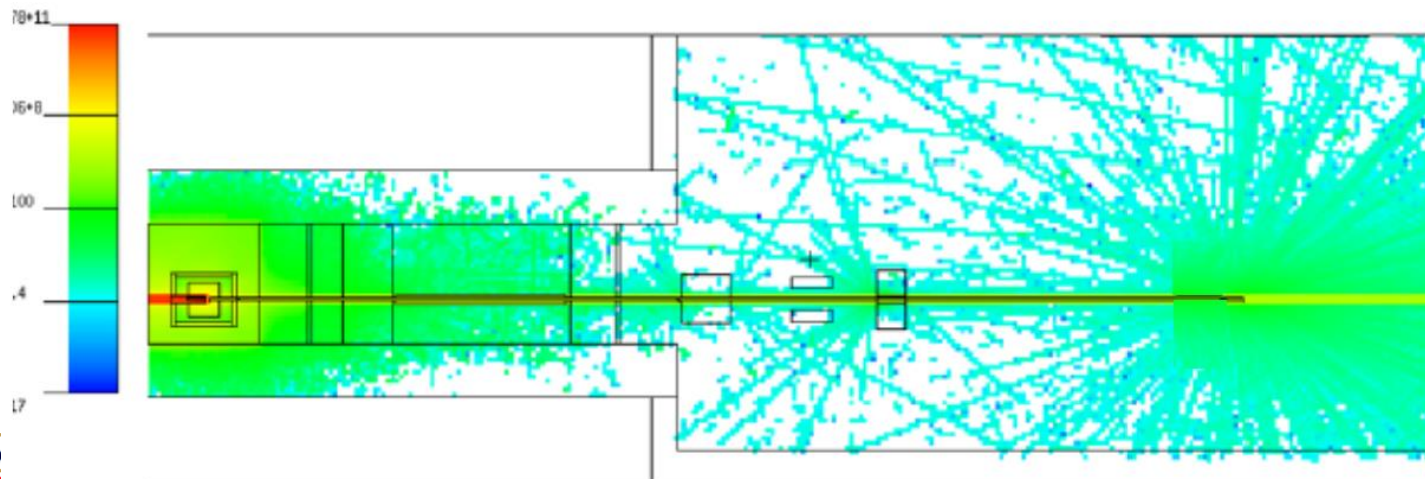




- Vertical cross section of **neutron** flux calculated using .



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

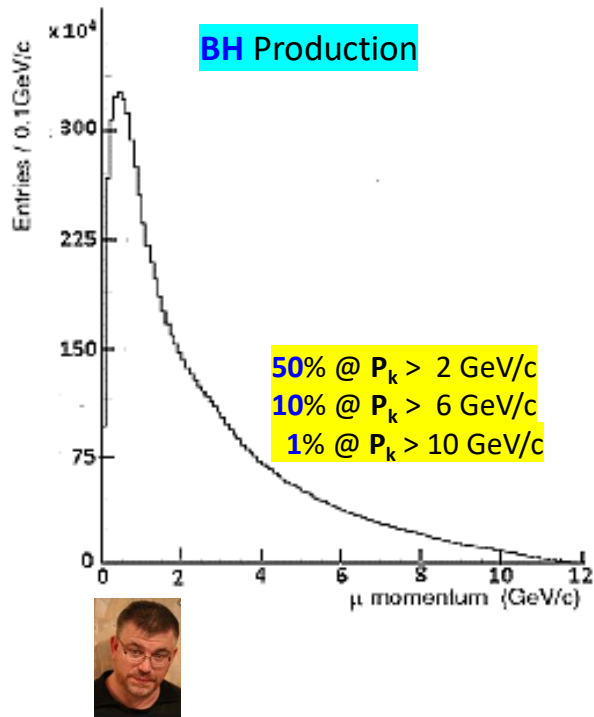



Soft gammas from elements of LH_2/LD_2





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 $\sim 10^7$ 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 LH₂ 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 LH₂/LD₂ 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 ?

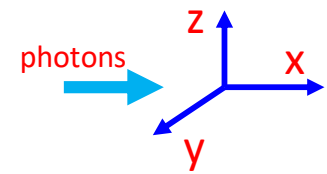
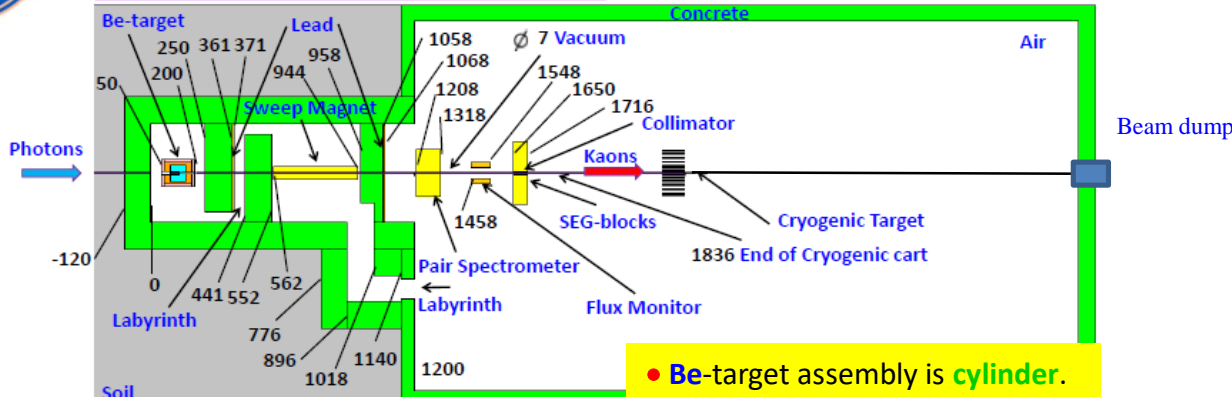




Collimator Alcove & Experimental Hall

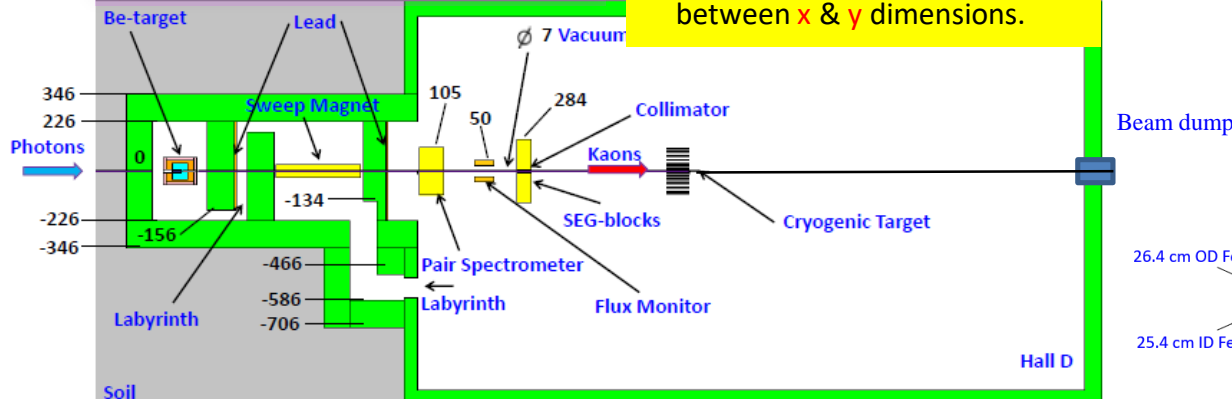
[29.5 m long x 17.2 m wide]

xy-cross section, x-dimension

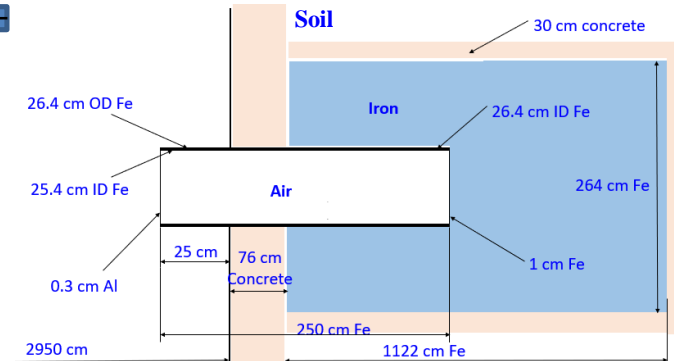


• Be-target assembly is cylinder.
Then there is no difference between x & y dimensions.

xy-cross section, y-dimension



Beam dump



xz-cross section, z-dimension

