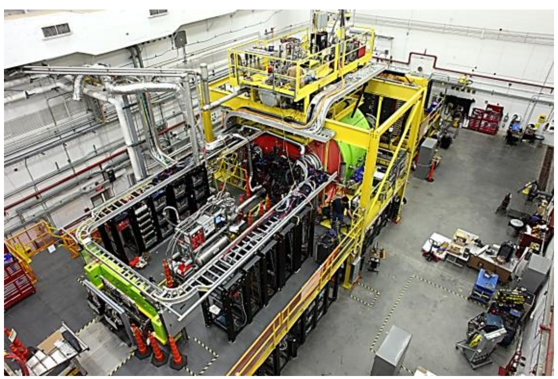
Be-Target Assembly Conceptual Design: Progress & Plans

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.

arXiv:2002.04442 [physics.ins-det]

Supported by DE-SC0016583

Hall D Beam Line for K-long

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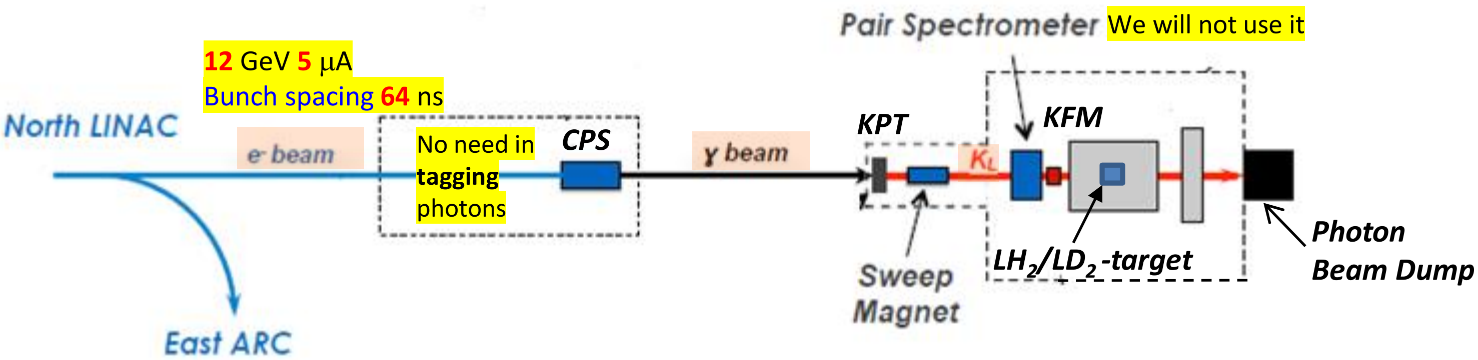

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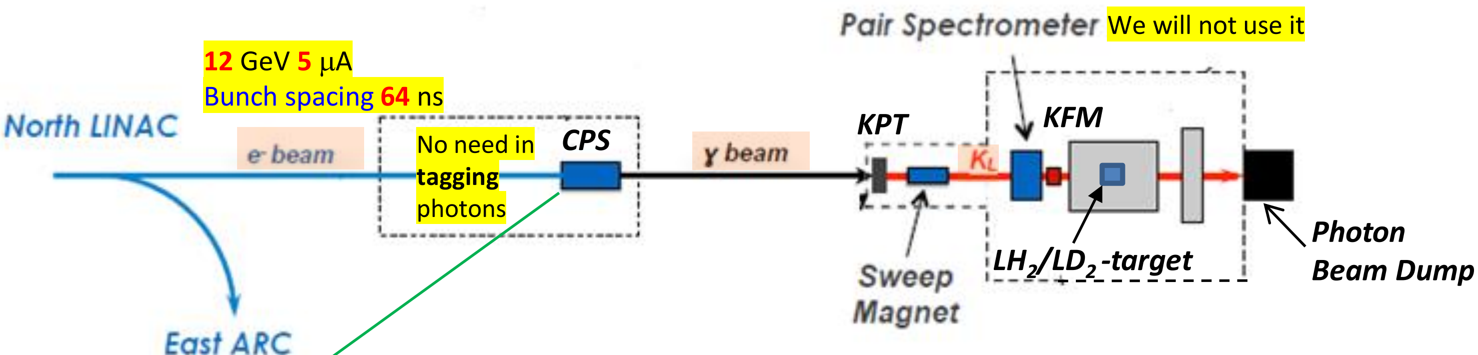
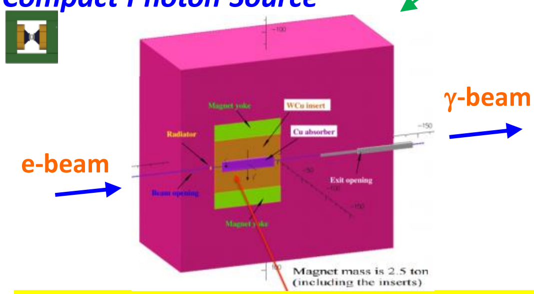
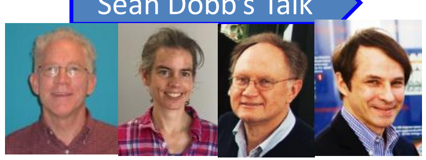


Compact Photon Source



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

Sean Dobb's Talk



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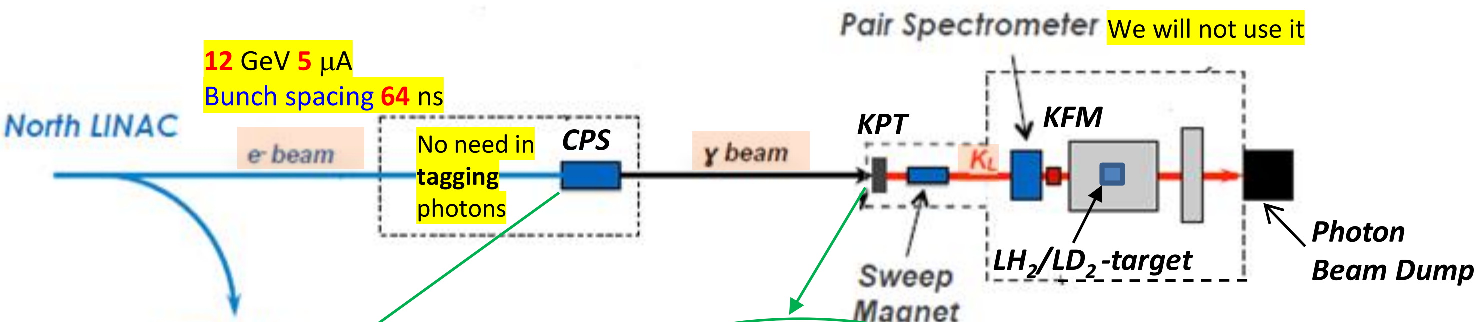

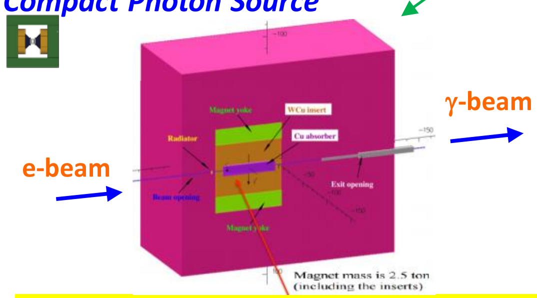

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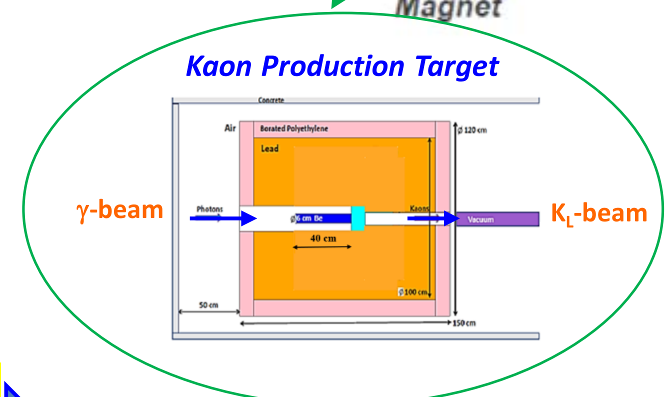

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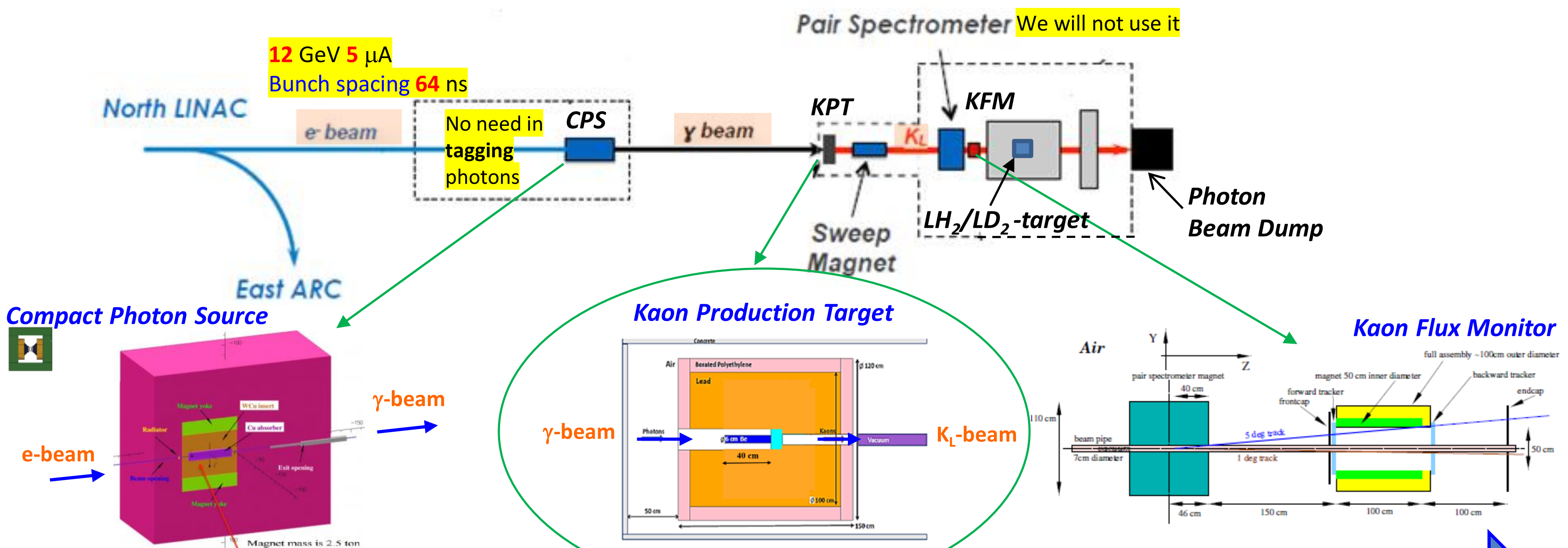

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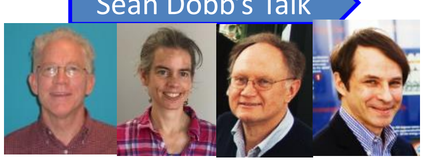
Stuart Fegan's Talk



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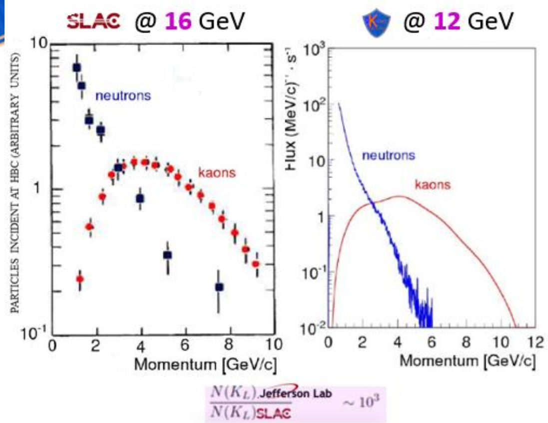

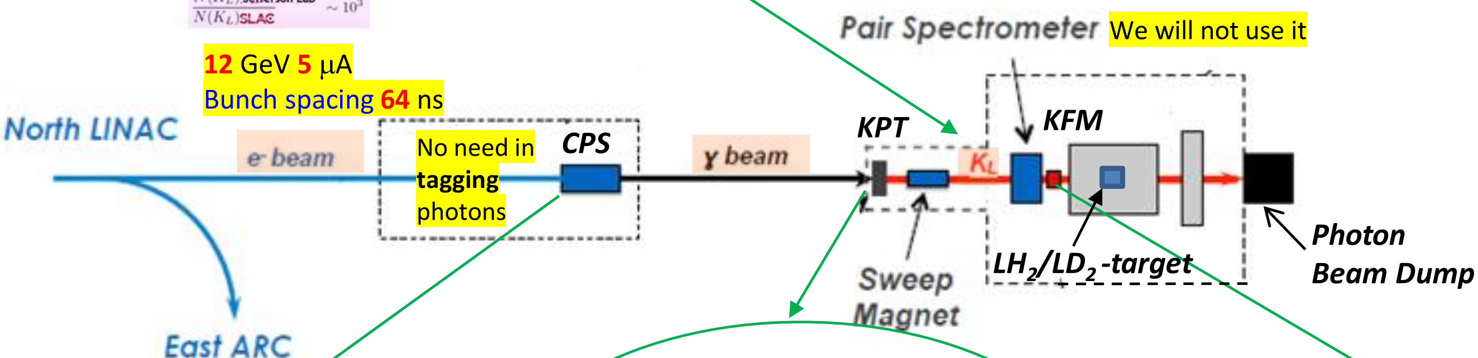

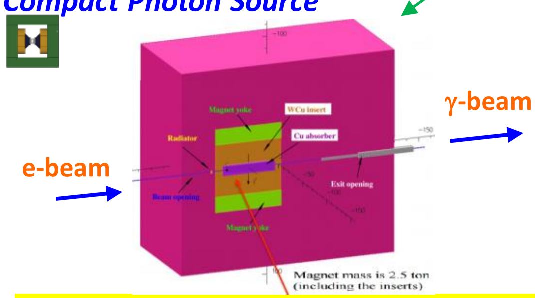

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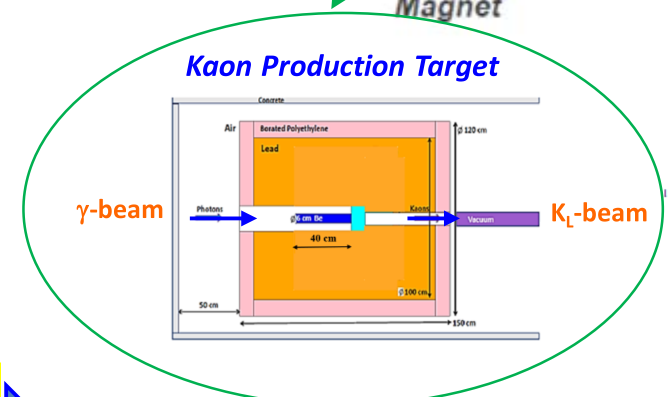

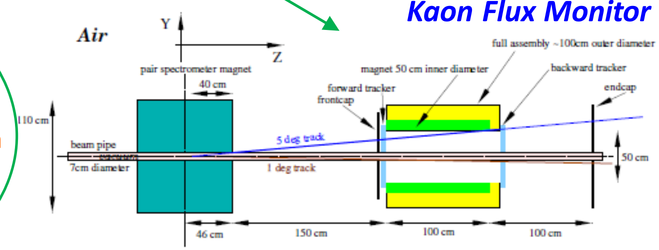

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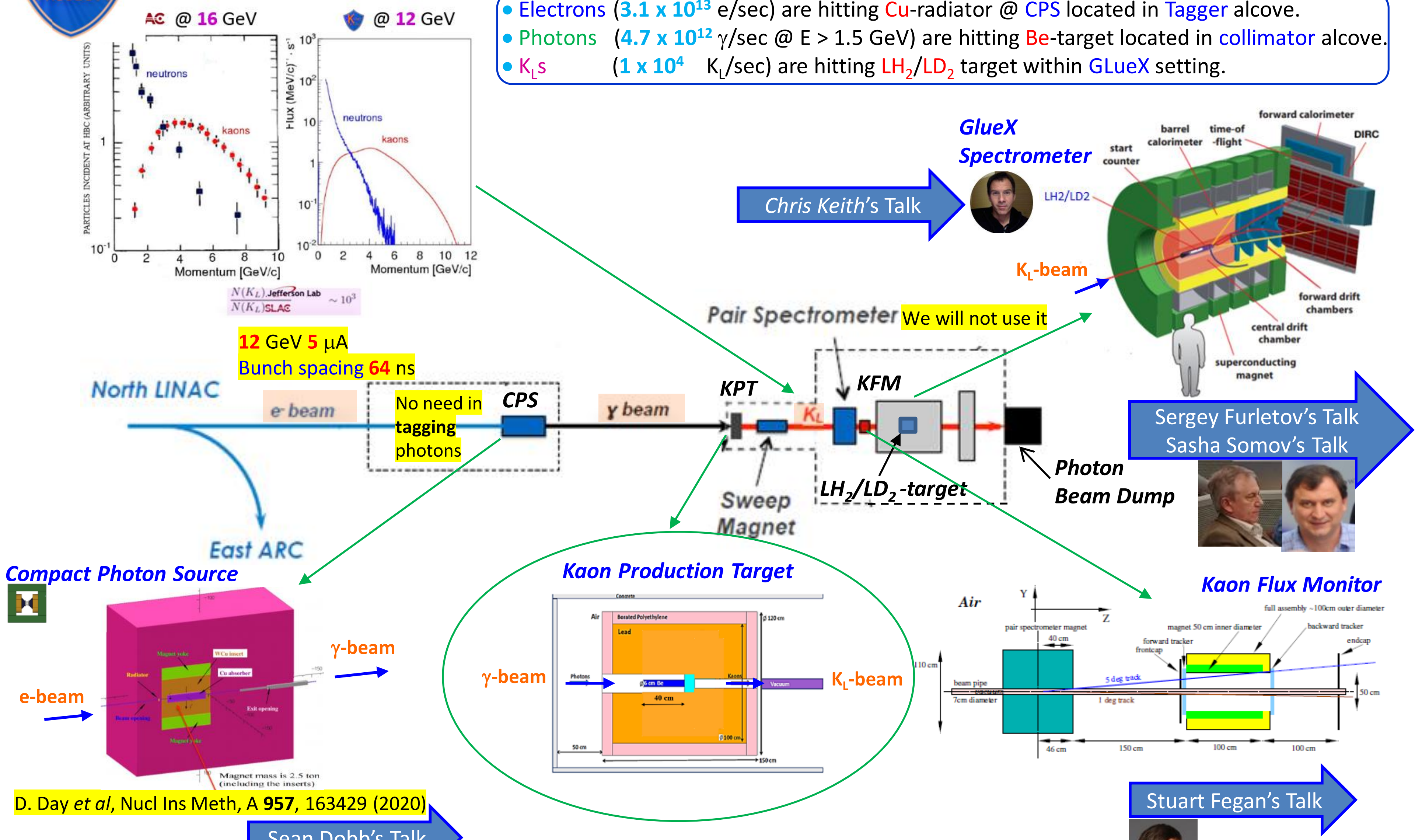
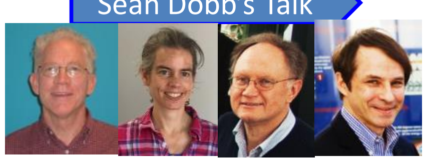
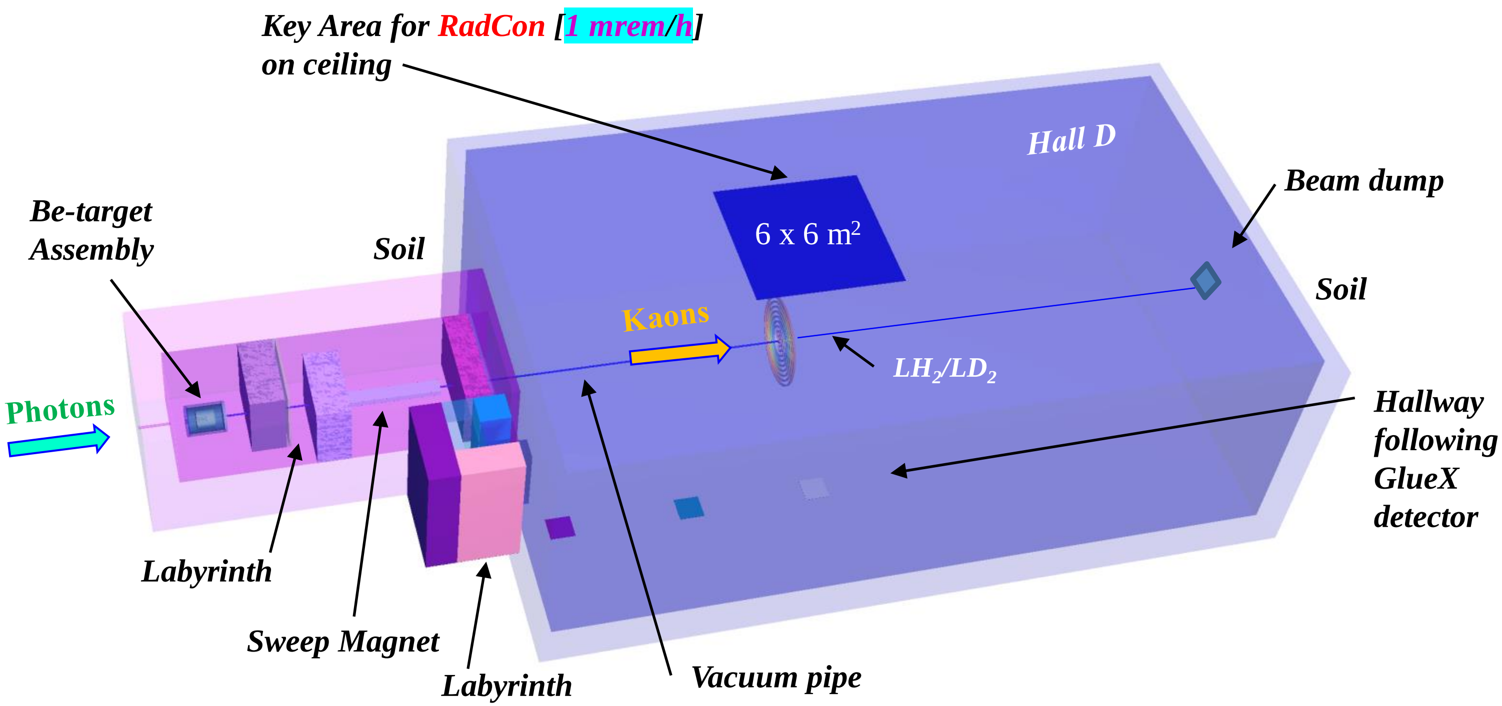




Hall D Setting

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



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

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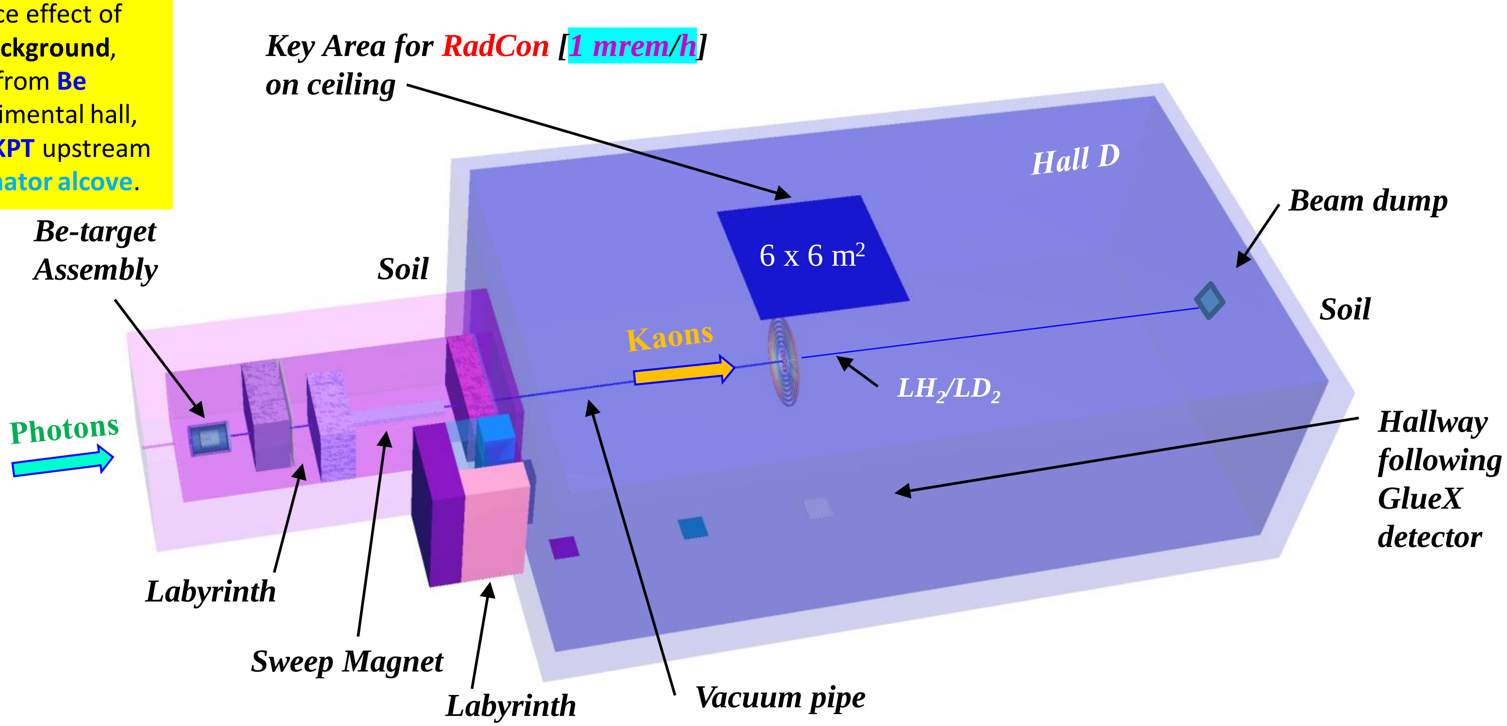

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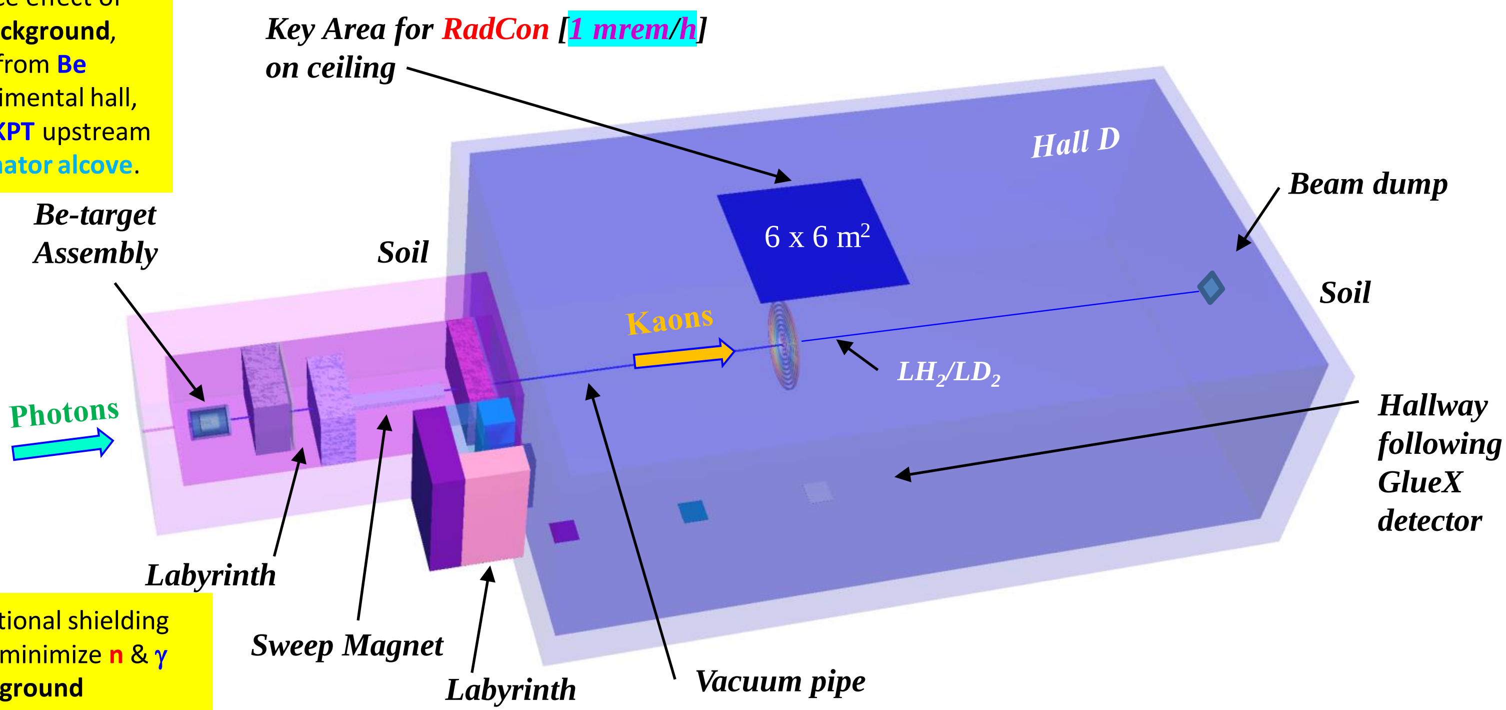

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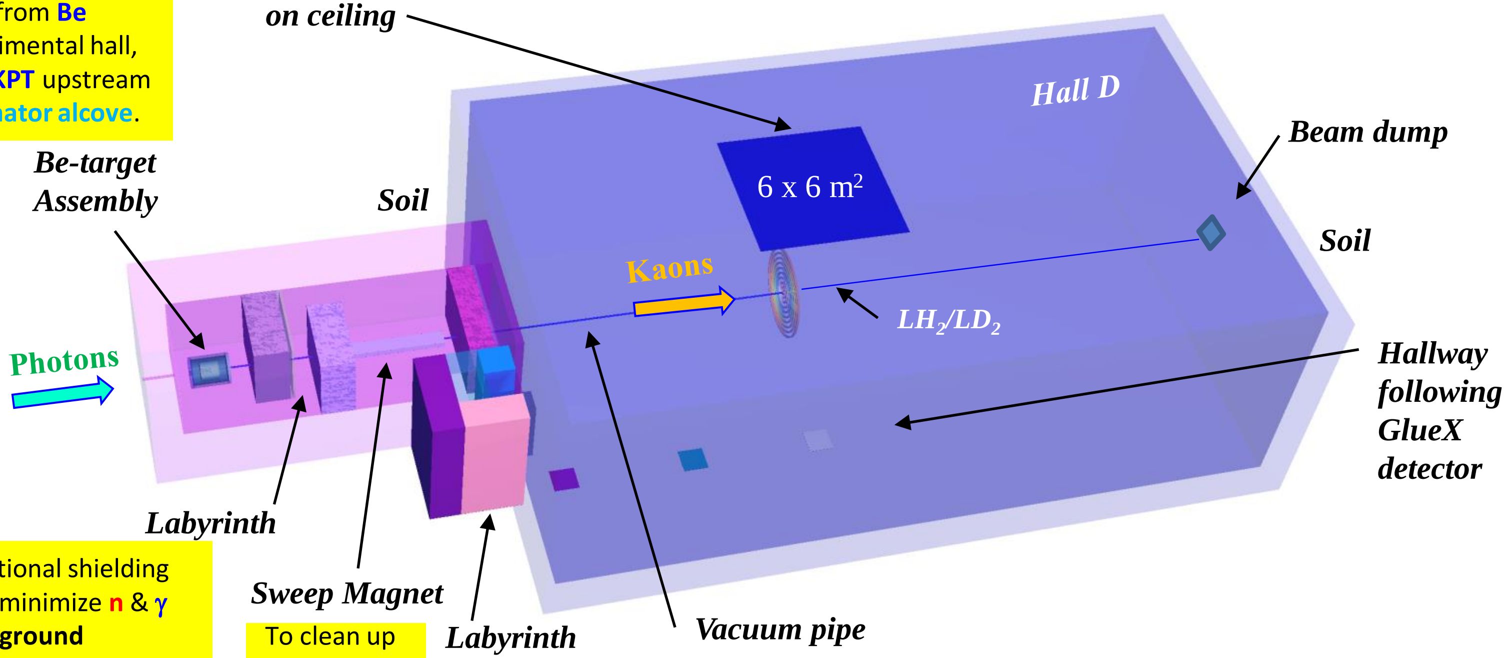

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To clean up charged component of beam (including muons).

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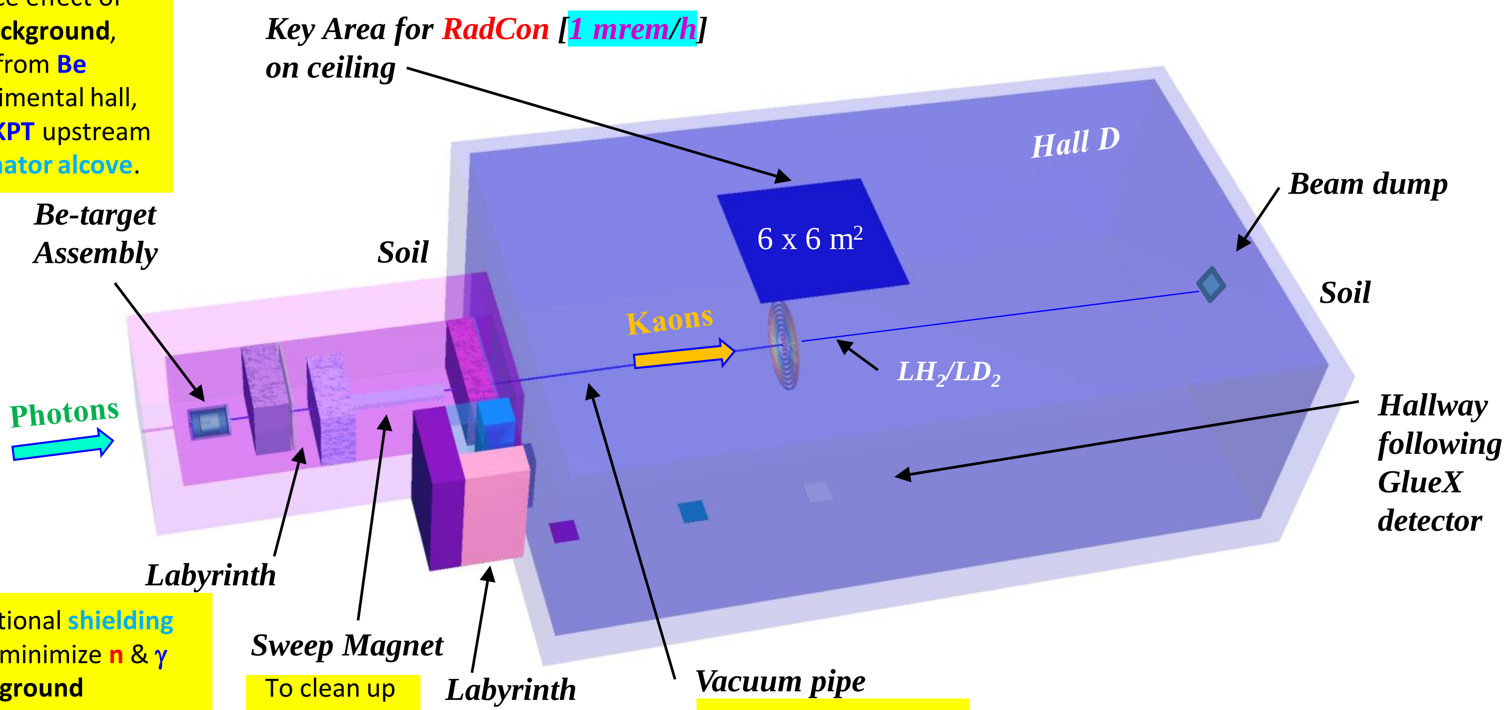

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To clean up charged component of beam (including muons).

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

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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.

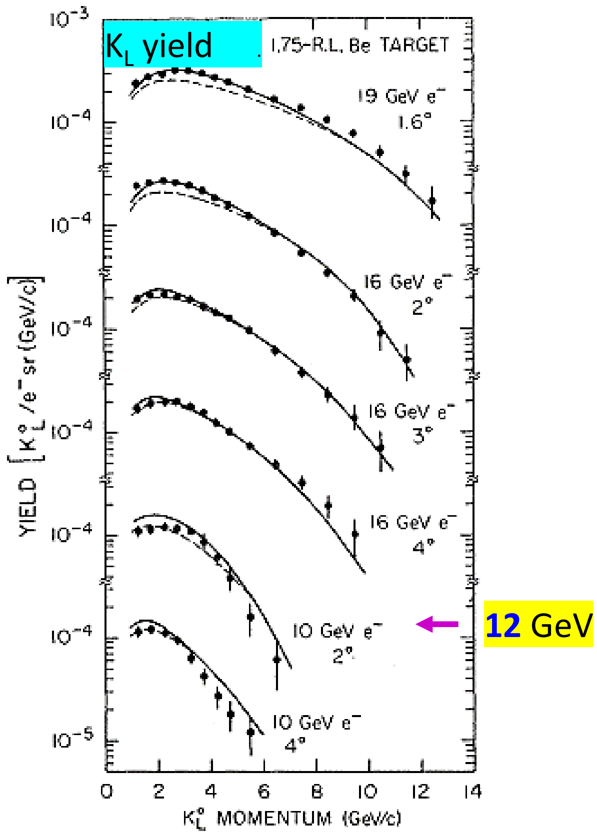
- Neutrons & gammas is traced in all components of MCNP6 model.

- 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** iron-blocks around beam pipe in front of GlueX spectrometer.

- For MCNP6 calculations (in terms of **flux** [part/s/cm^2/ MeV] & **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.



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

- PYTHIA calculations show efficiency of **B** vs **C**.
  Kaon yield ~ X_0 * ρ & Ratio(Be/C) = (65/43) = **1.51**

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

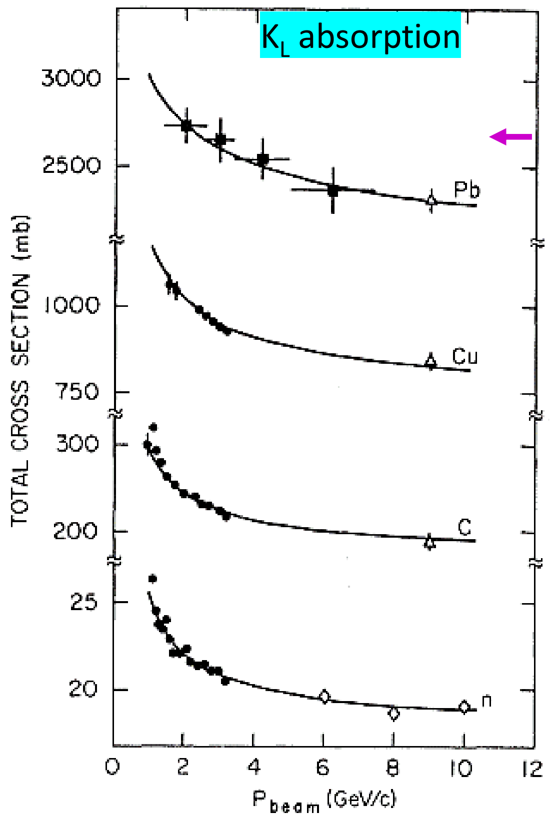
  At key area for RadCon on ceiling

  Be: **n**: 0.27 ± 0.08 mrem/h   **R(C/Be)=1.45**
  γ: 0.065±0.002 mrem/h

  C: **n**: 0.40 ± 0.20 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 $\mathbf{K_L}$.



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- PYTHIA calculations show efficiency of **W** vs **Cu**.

  Kaon: W/Cu(20%) = **1.16** @ $\mathbf{P_k}$ = **1.0** GeV/c
  = **1.36** @ $\mathbf{P_k}$ = **0.5** GeV/c

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

  At key area for RadCon on ceiling

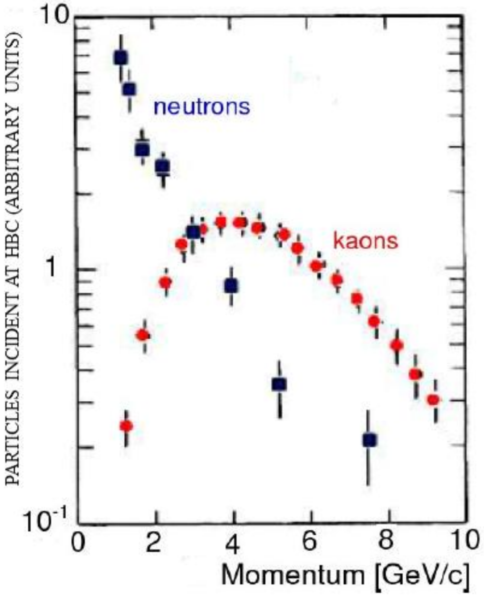
  W: **n**: 0.27 ± 0.08 mrem/h **R(Pb/W)=2.25** **R(Cu/W)=9.29**
  γ: 0.065±0.002 mrem/h

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

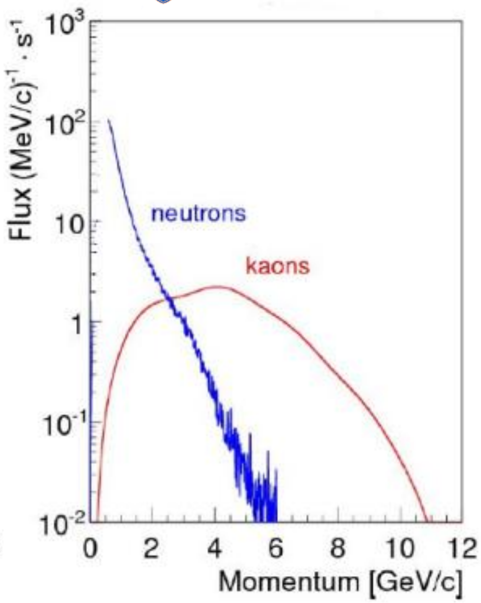
  Cu: **n**: 2.54 ± 0.39 mrem/h
  γ: 4.34 ± 0.02 mrem/h

Flux of Kaon Beam

SLAC @ **16** GeV



@ **12** GeV



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

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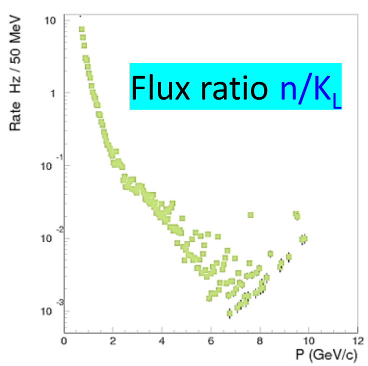
- Flux of Kaons will be **1** x **10^4** K_L/sec on **LH_2/LD_2** within GlueX detector, which has large *acceptance* with coverage of both ***charged*** & ***neutral*** particles.
- This flux will allow statistics in case of **LH_2** /**LD_2** to exceed that of earlier SLAC experiments by almost **three 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.

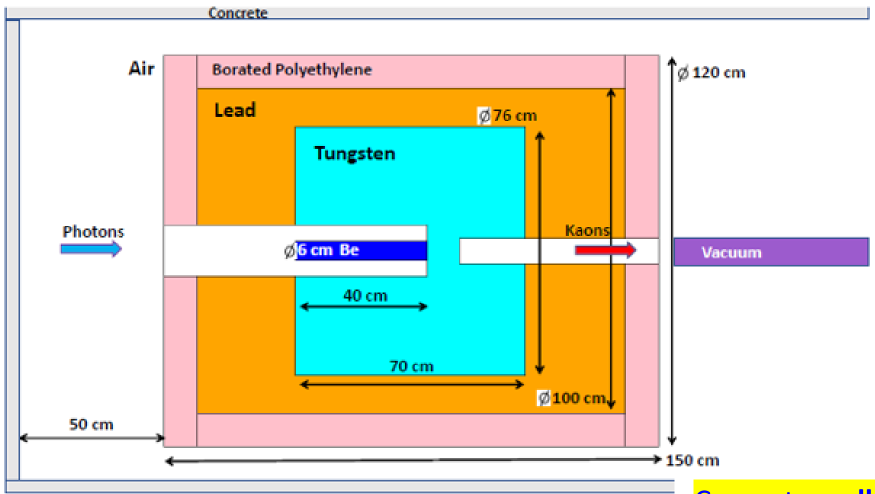
See recent talk by Todd Satogata

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

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

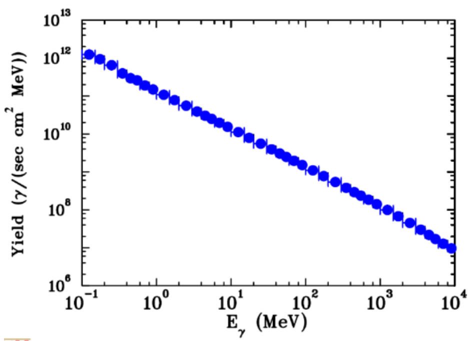


Concrete **walls** are out of scale

ρ(W) = **16.3** g/cm^3 – Rolf's value

- **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.

MCNP6: 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

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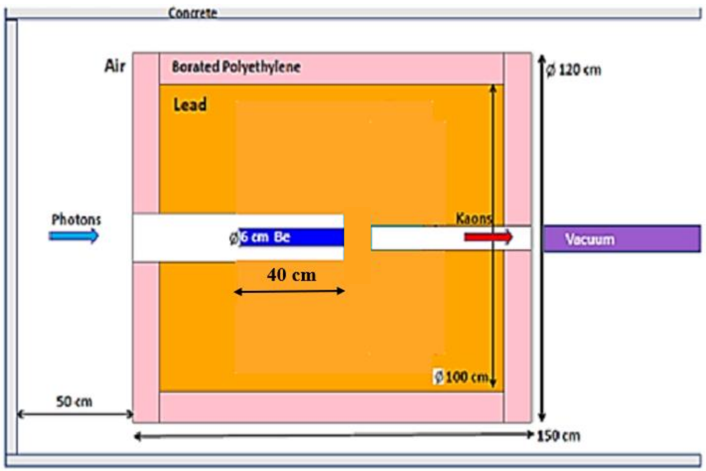

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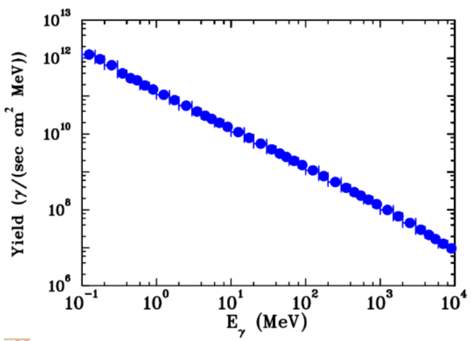

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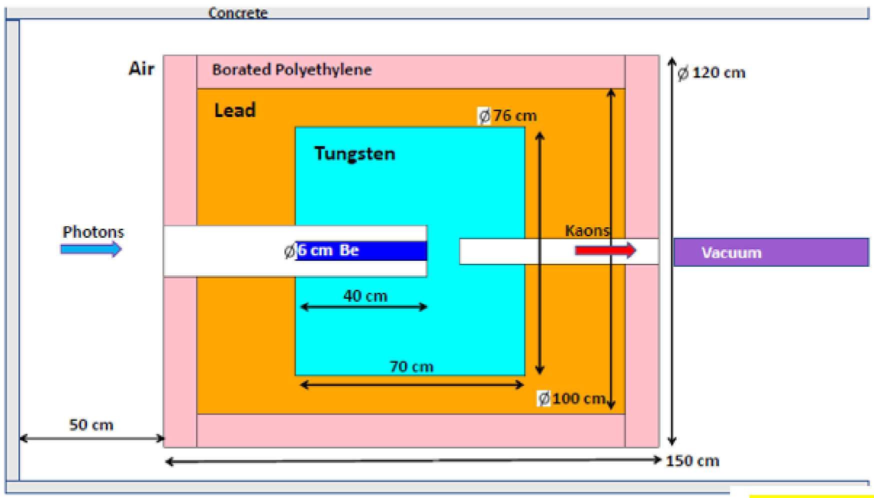

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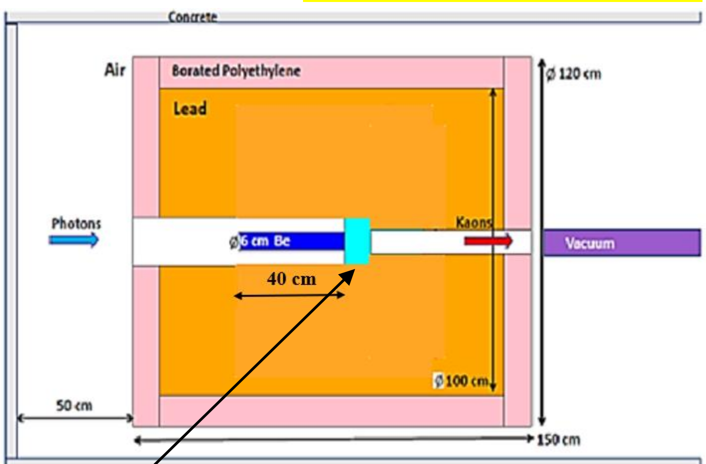

W-plug
16 cm in **diam**
10 cm in **length**

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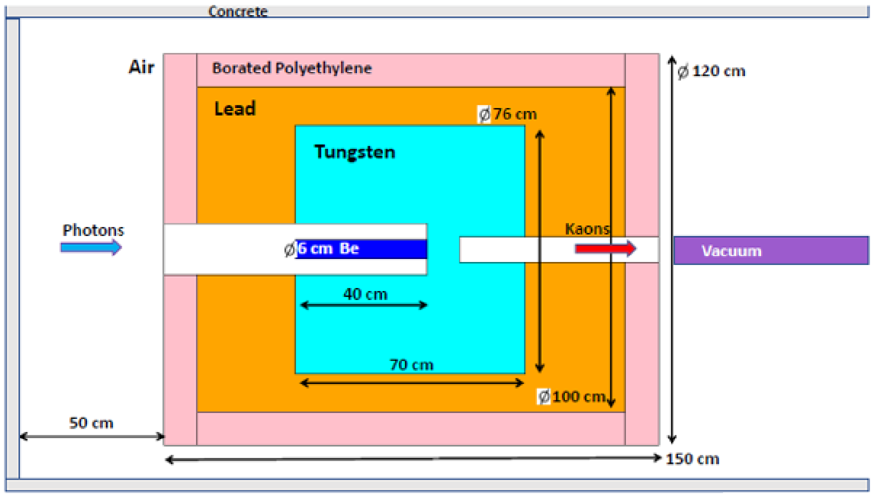

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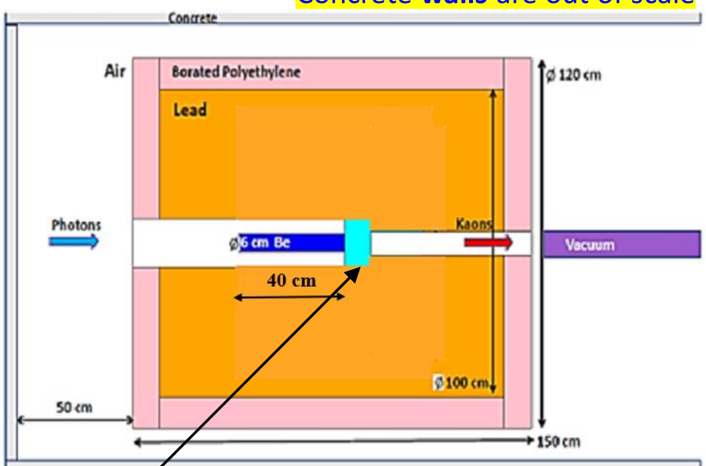


W-plug
16 cm in diam
10 cm in length

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

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

24 cm in **diam**: **n**: 0.77 ± 0.33 mrem/h
γ: 0.074±0.002 mrem/h

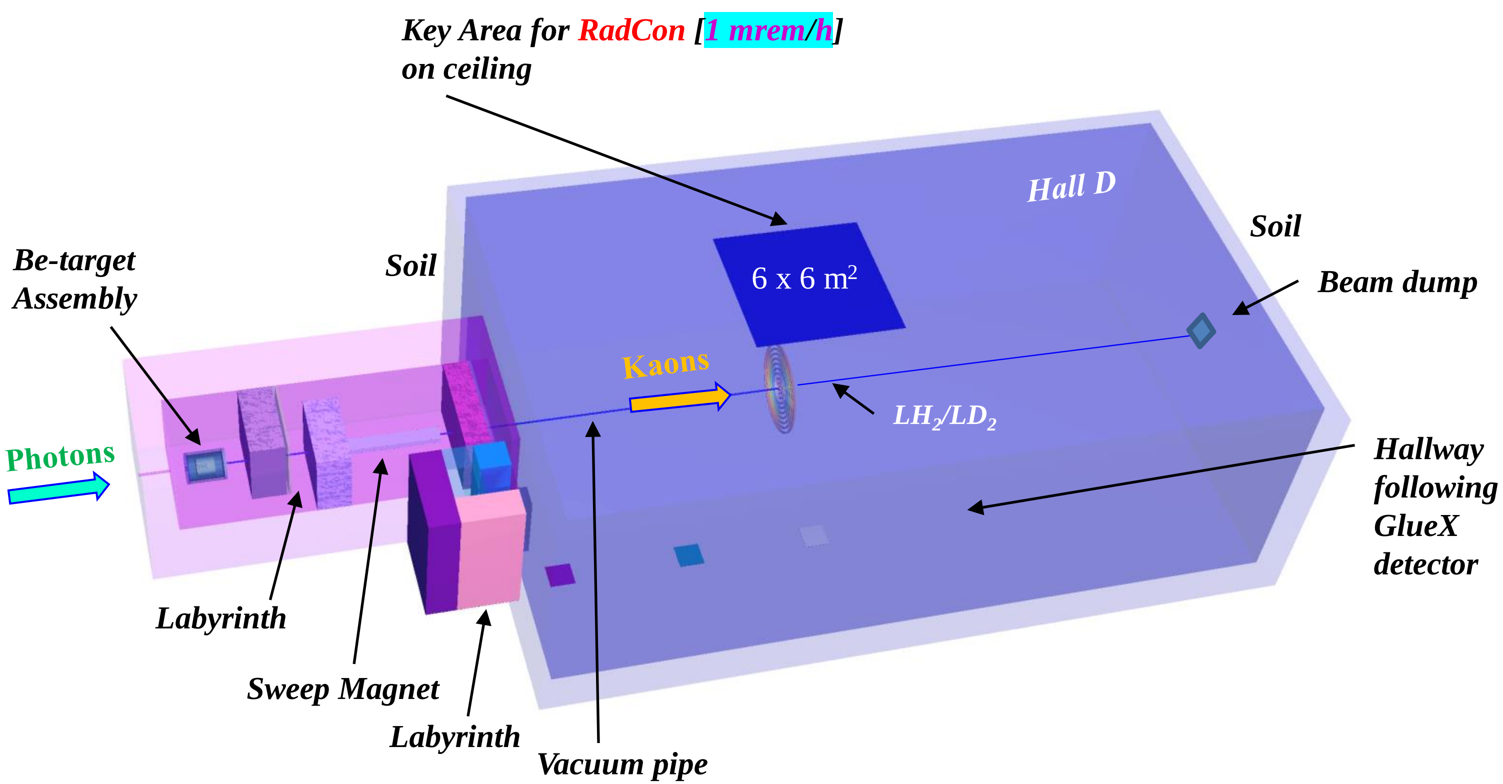
15 cm in **length**: **n**: 0.16 ± 0.06 mrem/h
γ: 0.003±0.001 mrem/h

Corresponds to lost of **70%** of **kaons**

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

Hall D Setting & Dose Rate

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



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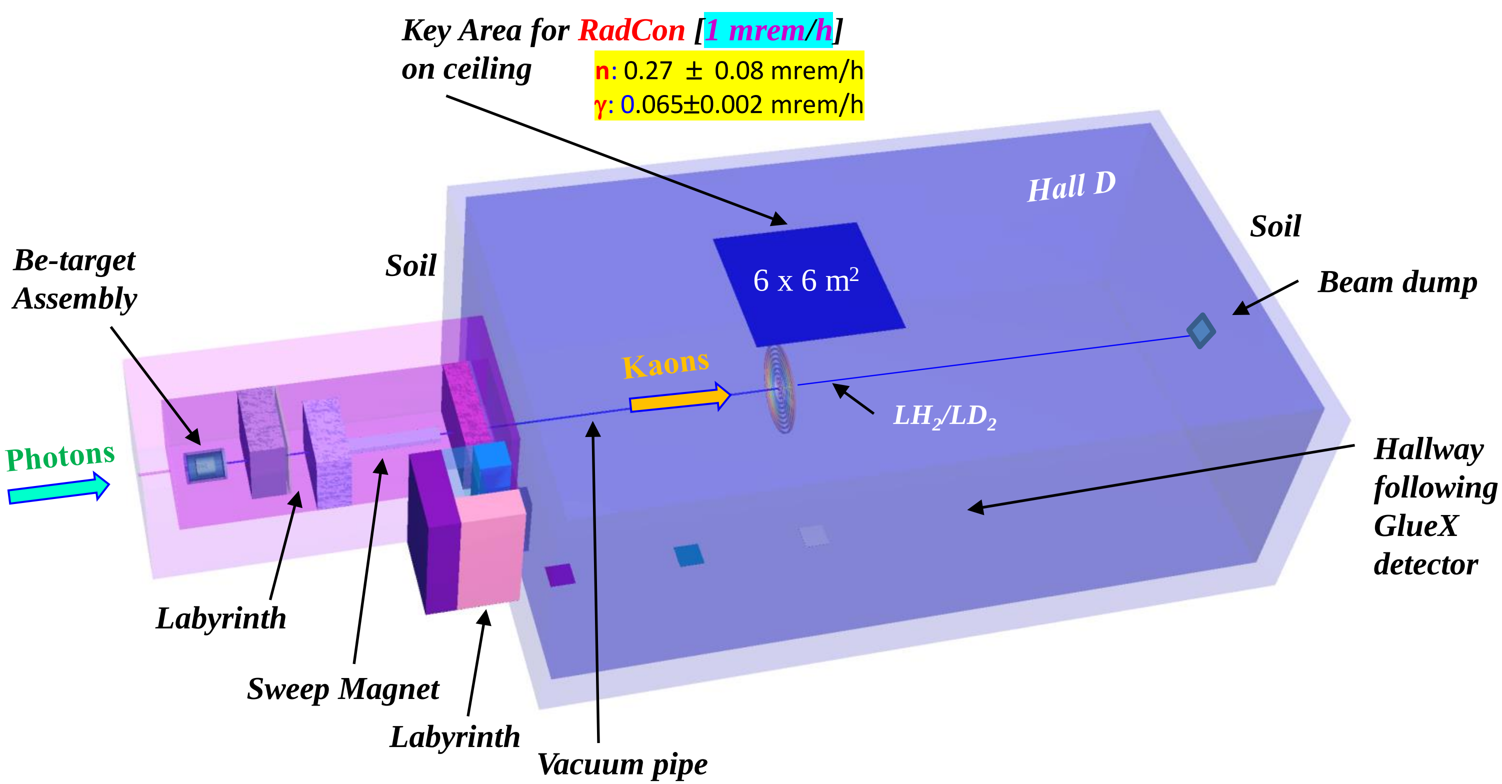

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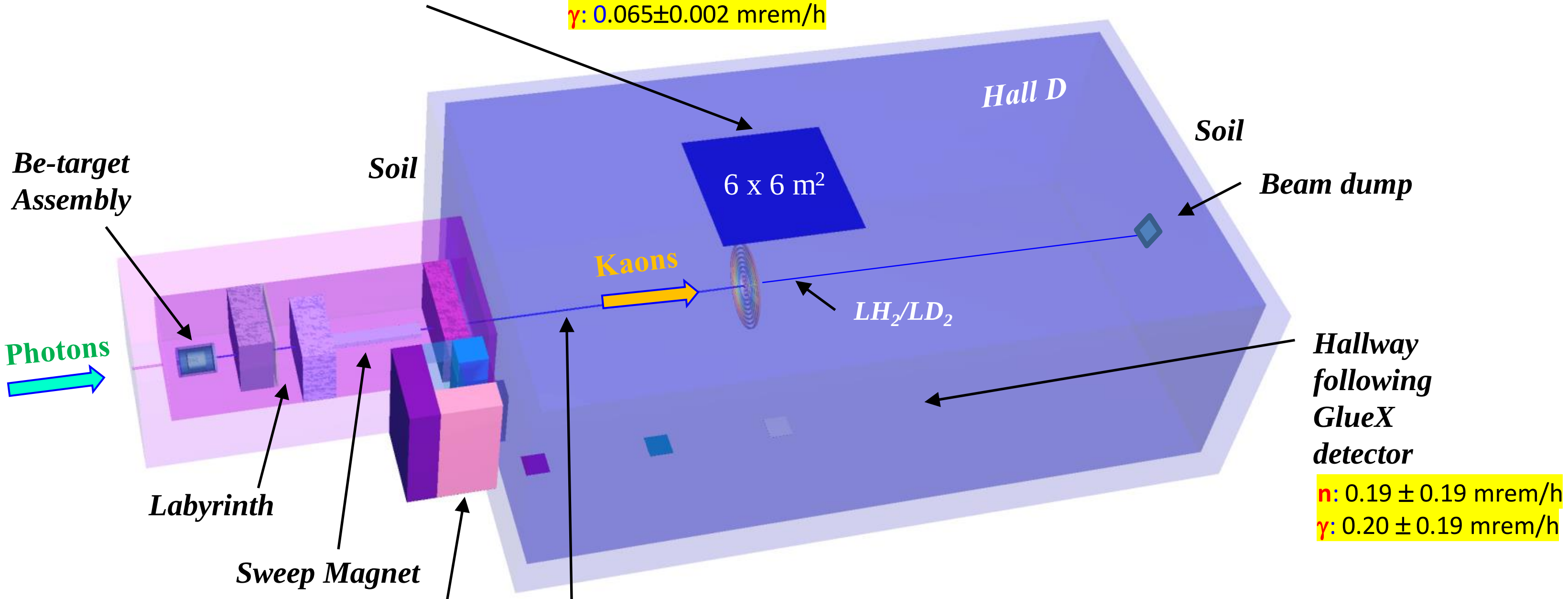

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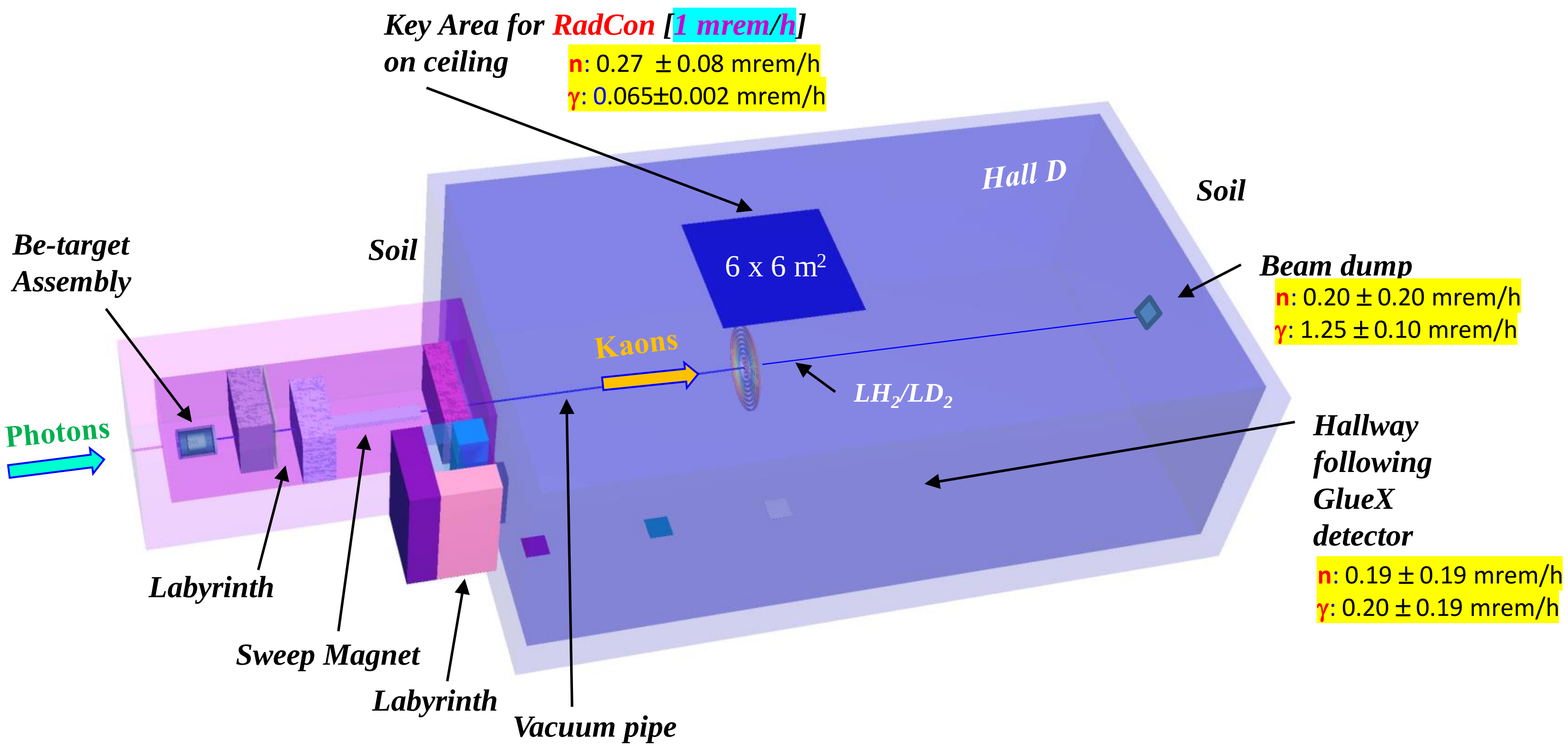

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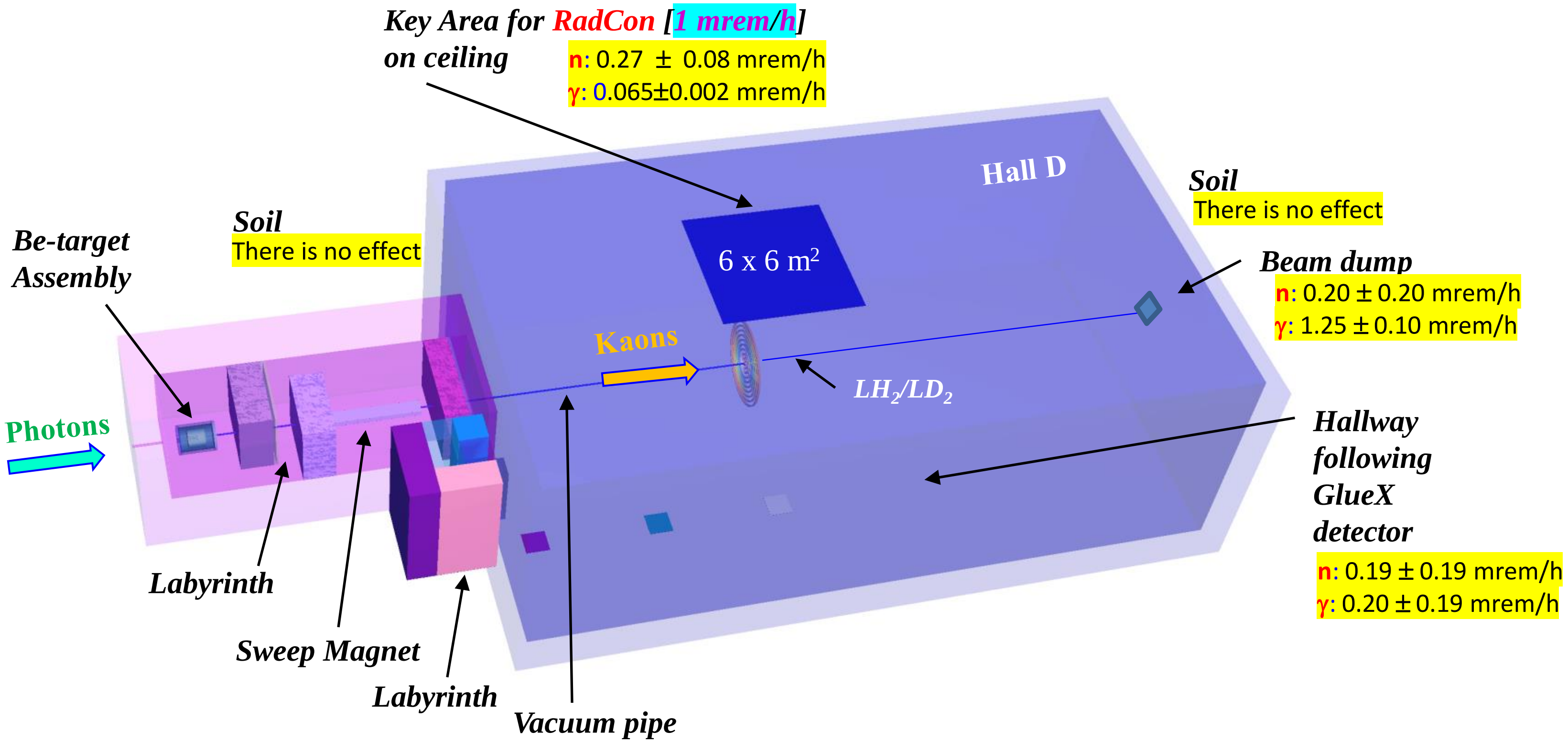

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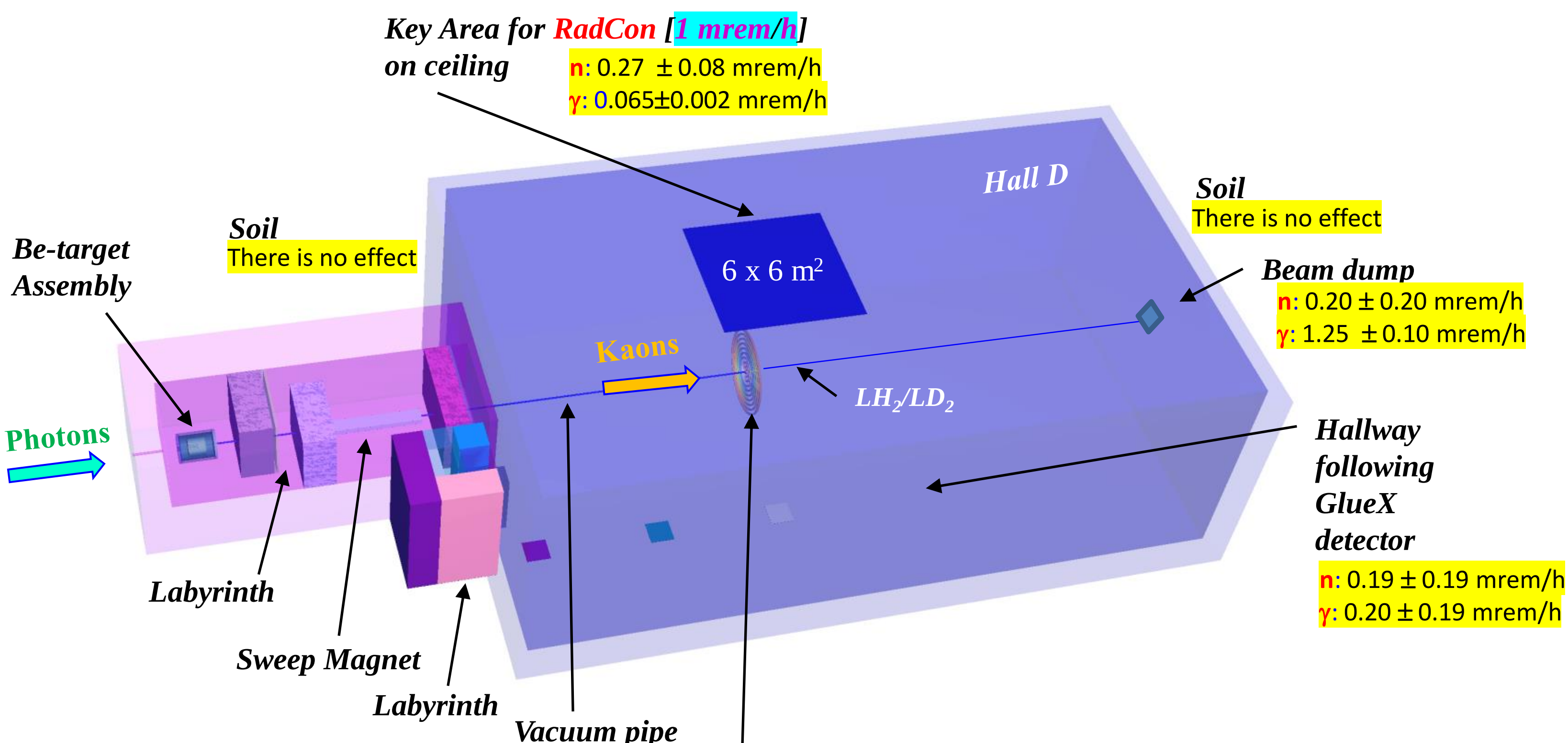
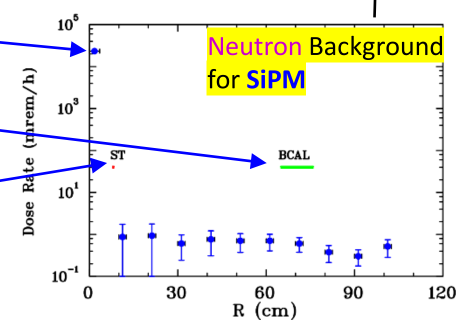


Beam spot



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)

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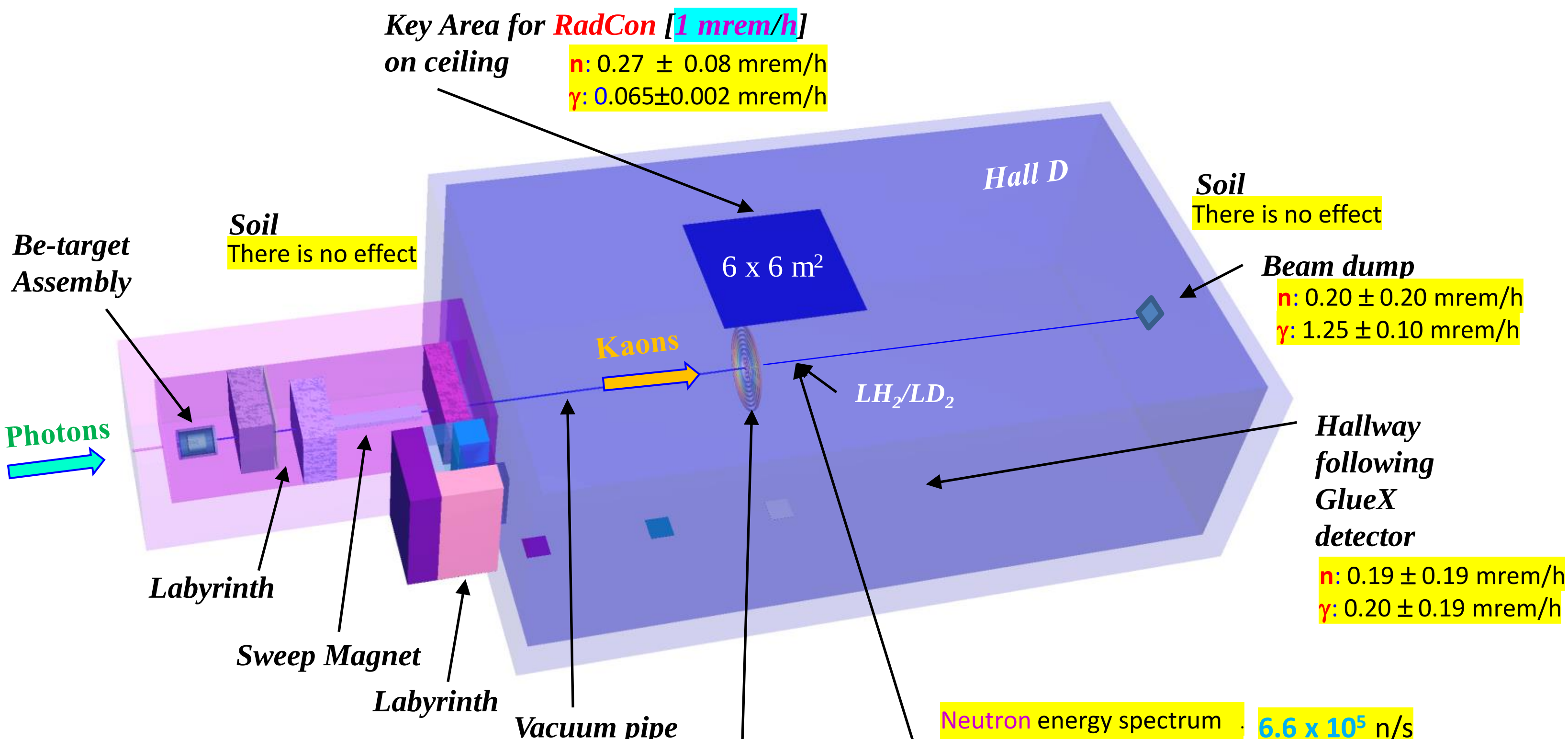

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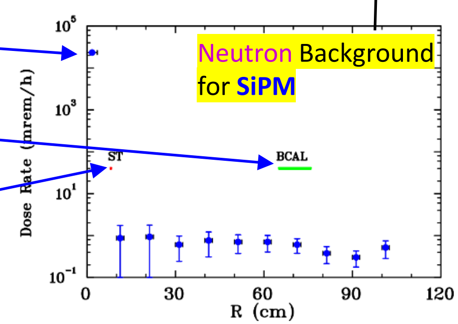

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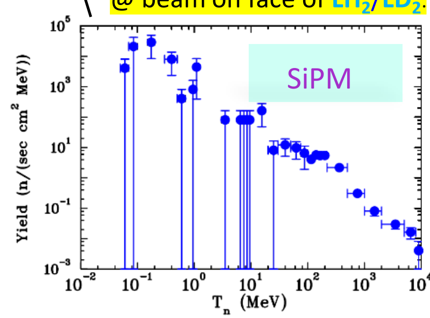
Neutron energy spectrum @ beam on face of LH_2/LD_2.

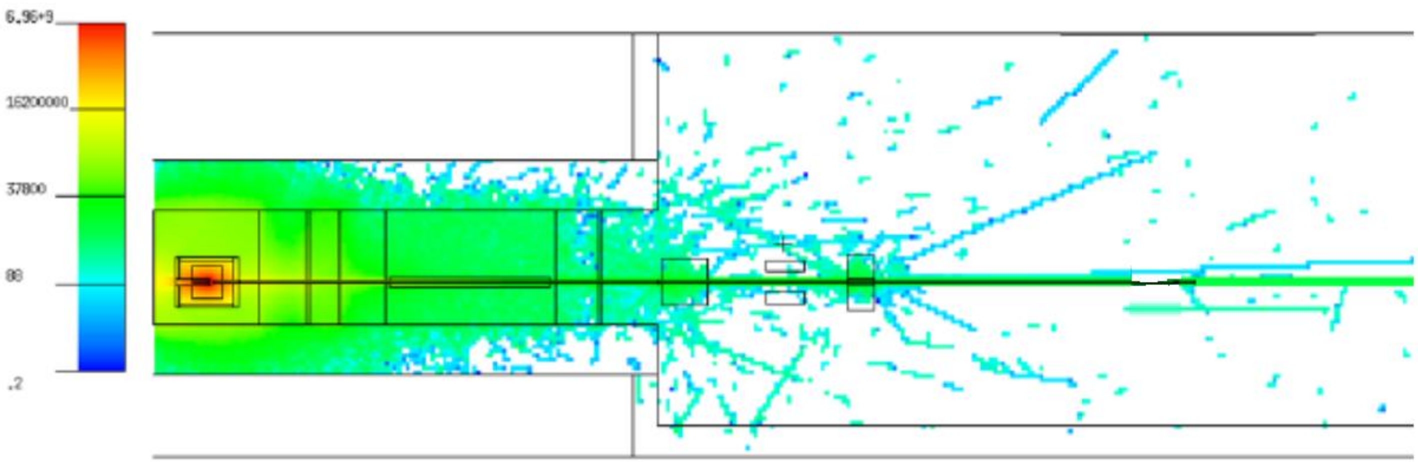
6.6 x 10^5 n/s



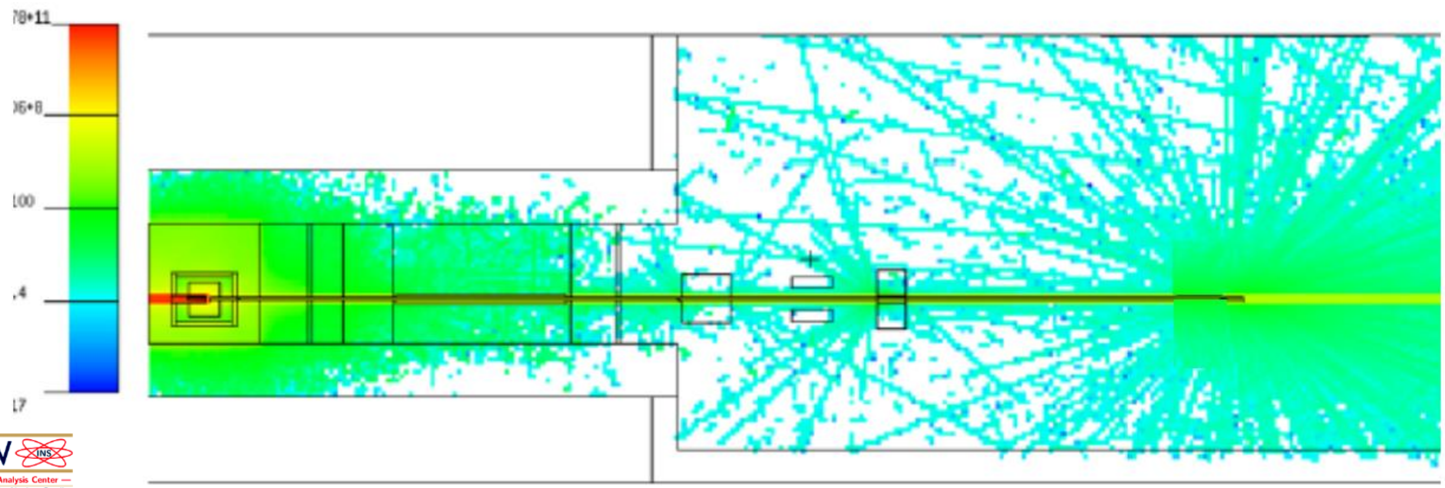
Previous studies stand that dose rate of **30** mreh/h increases dark current @ **SiPM** by factor of **5** after **75** days of running period.

Prompt Plots

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

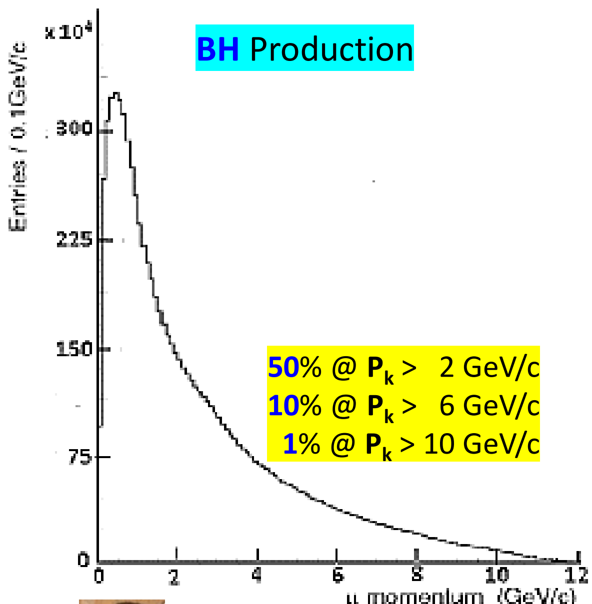


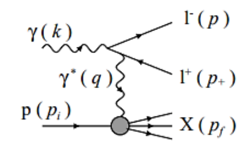
- **Vertical** cross section of **gamma** flux calculated using MCNP6.



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**.
- 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 KLF 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.

Mikhail Bashkanov's Talk

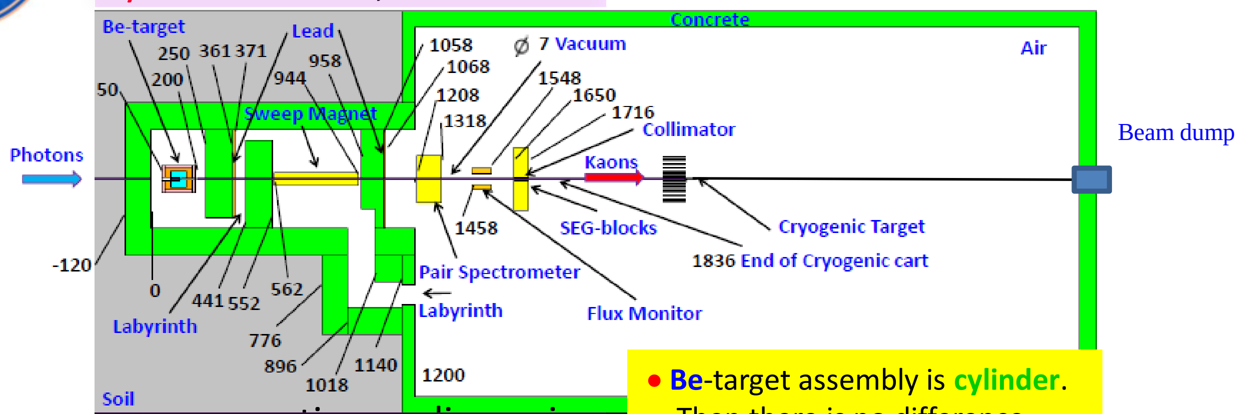
- SiPMs of SC & BCAL are expected to tolerate expected **neutron** background.
- Engineering design is in order ?

Any Questions ?

Collimator Alcove & Experimental Hall

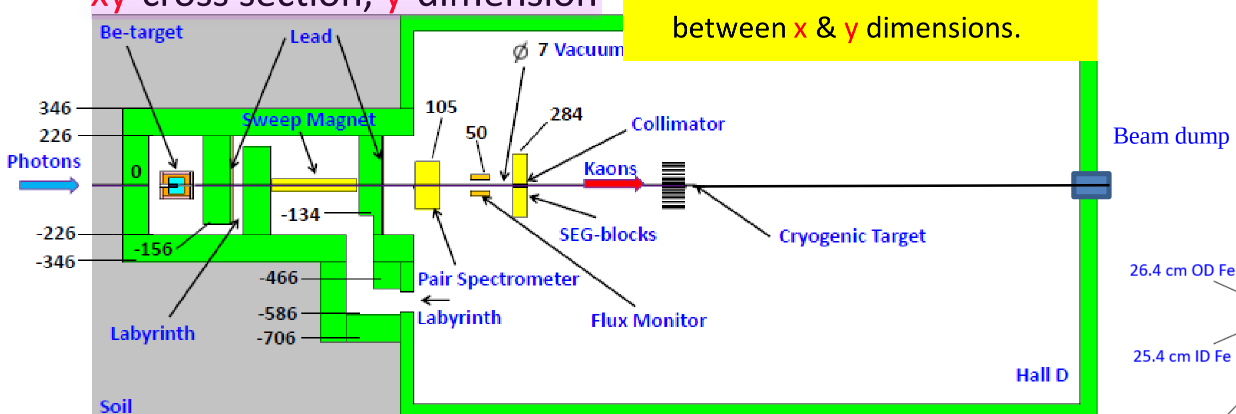
[**29.5** m long **x** **17.2** m wide]

xy-cross section, x-dimension

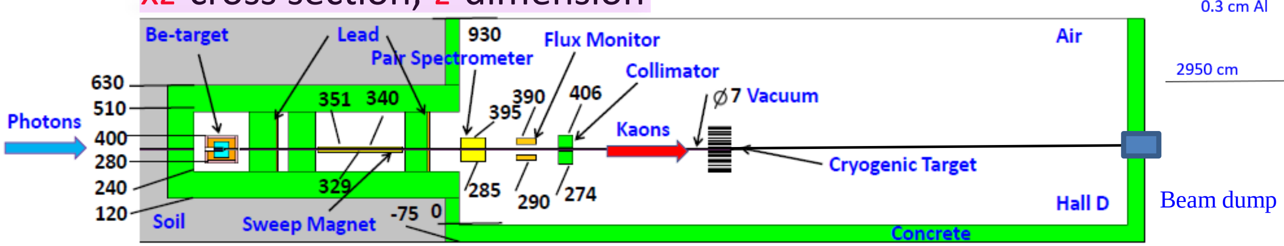


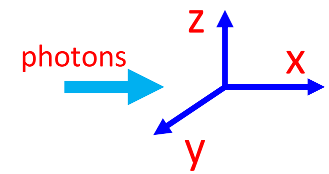
- **Be**-target assembly is **cylinder**. Then there is no difference between x & y dimensions.

xy-cross section, y-dimension



xz-cross section, z-dimension





Beam dump