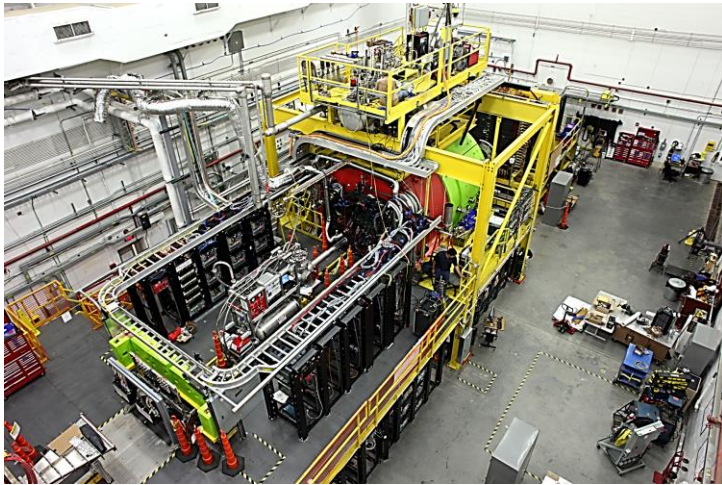


# KPT: Conceptual Design & Radiation Effects

Igor Strakovsky<sup>\*)</sup>, Vitaly Baturin<sup>\*\*)</sup>,  
Moskov Amaryan<sup>\*\*)</sup>, Mikhail Bashkanov<sup>+)</sup>, William J. Briscoe<sup>\*)</sup>, Eugene Chudakov<sup>++)</sup>,  
Pavel Degtyarenko<sup>++)</sup>, Sean Dobbs<sup>#)</sup>, Hovanes Eginyan<sup>++)</sup>, Ilya Larin<sup>##)</sup>,  
Alexander Somov<sup>++)</sup>, & Timothy Whitlatch<sup>++)</sup>

<sup>\*)</sup>The George Washington University, <sup>\*\*)</sup>Old Dominion University, <sup>+)</sup>York University, <sup>++)</sup>TJNAF,  
<sup>#)</sup>Florida State University, & <sup>##)</sup>University of Massachusetts, Amherst



- **ERR-I** charge for **KPT**.
- **Kaon beamline**.
- **Hall D** setting.
- Equivalent prompt dose rate for **Exp Hall**.
- Optimization **KPT**.
- Prompt dose rate for **Collimator Cave**.
- Activation dose rate for **Collimator Cave**.
- Radiation budget above **ground**.

<https://www.overleaf.com/project/6302c989eb137630a435e21c>

Supported by



DE-SC0016583  
DE-FG02-96ER40960



# Experiment Readiness Review Phase I Jefferson Lab, 2023 Charge

From: *Patrizia Rossi*



## Hall D E12-19-001 ERR Phase I Jefferson Lab, 2023 Charge

- What is status of *Kaon Production Target (KPT)*? Specifically:
  - a) Conceptual design.
  - b) Evaluation of produced radiation. In particular, following points should be discussed:
    1. Approximations made in *MC* simulations & which code has been used;
    2. Energy deposition & temperature in *KPT*;
    3. Prompt dose & activation around *KPT* & *Cave*;
    4. Water-cooling system & possible contaminations.
- Will civil constructions be needed in *Cave* to contain radiation?
- What is estimated *annual boundary dose* when running E12-19-001 experiment?
- What is decommissioning plans for *KPT* & activated components?

A brief outline is sufficient.

See Tim's report

See Tim's report

See Tim's report as well

- *Geometry* of *Experimental Hall* & *Collimator Cave* came from *Timothy Whitlatch*.
- *Engineering* design, water cooling, & contamination were done by *Timothy Whitlatch*.
- *RadCon* calculations were under *Pavel Degtyarenko* & *Lorenzo Zana* suggestions.



- Following *codes* were used for *KPT* development:



see pg 15

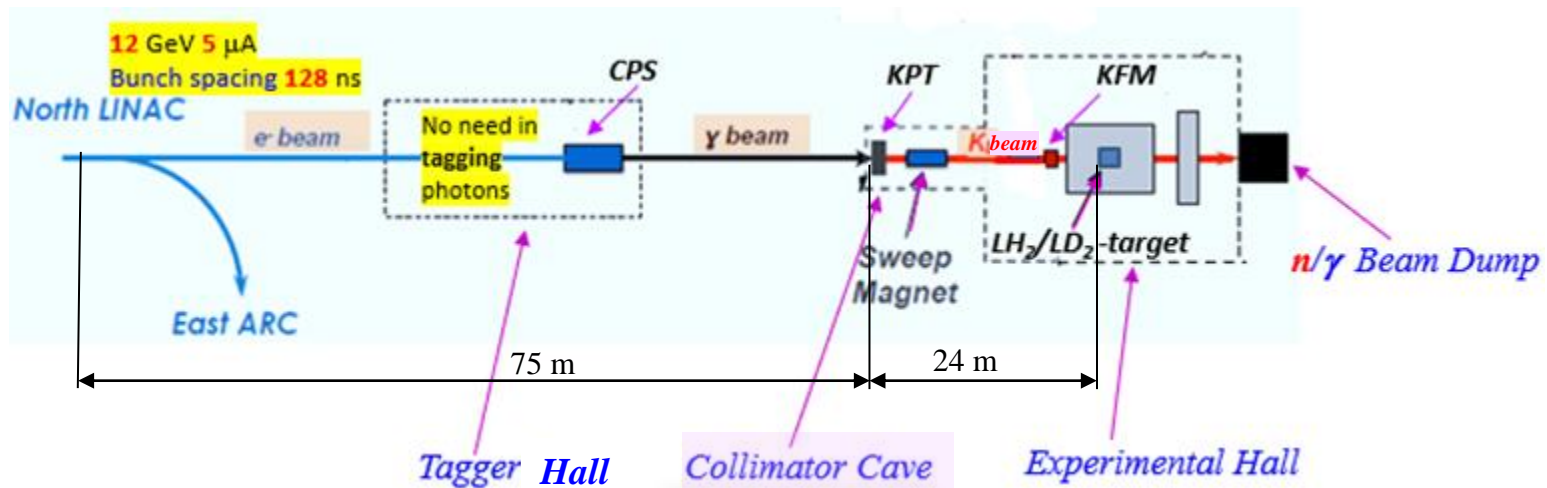


Igor Strakovsky 2



# Hall D: Beam Line for K-long

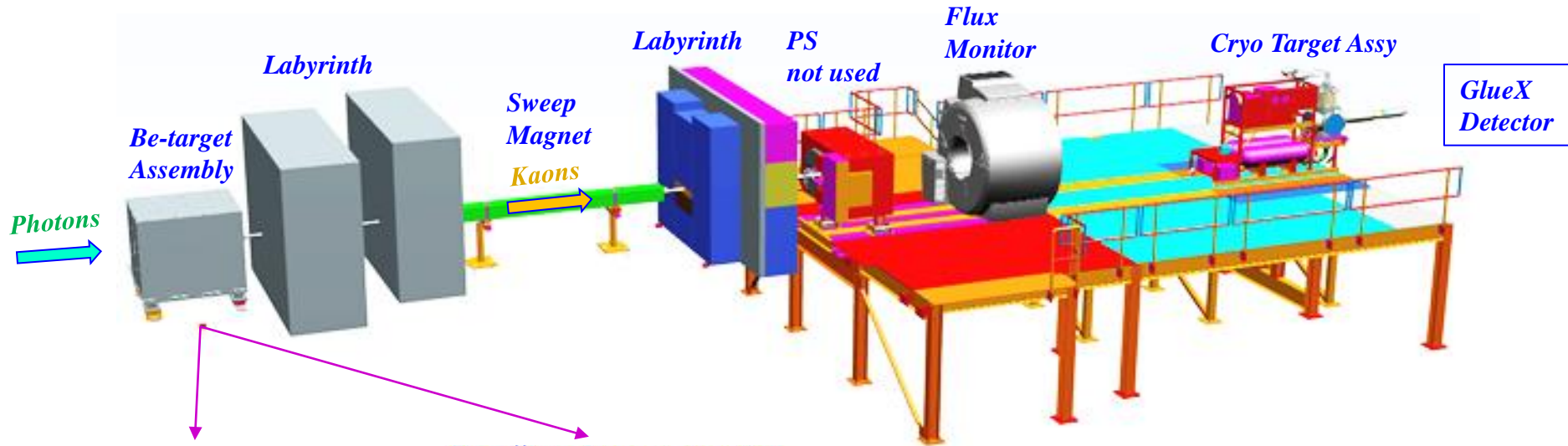
- Electrons ( $3.1 \times 10^{13}$  e/sec) are hitting Cu-radiator [10%  $X_0$ ] @ CPS located in Tagger Hall.
- Photons ( $4.7 \times 10^{12}$   $\gamma$ /sec,  $E_\gamma > 1.5$  GeV) are hitting Be-target located in Collimator Cave.
- $K_L$ s ( $1 \times 10^4$   $K_L$ /sec) are hitting Cryo target within GlueX spectrometer.



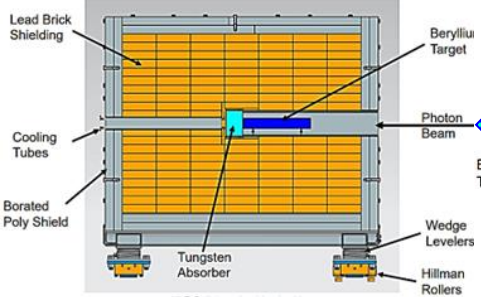
See Tim's report →

## Collimator Cave

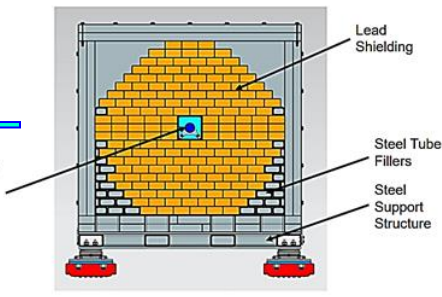
## Experimental Hall



### Beryllium Target Assy



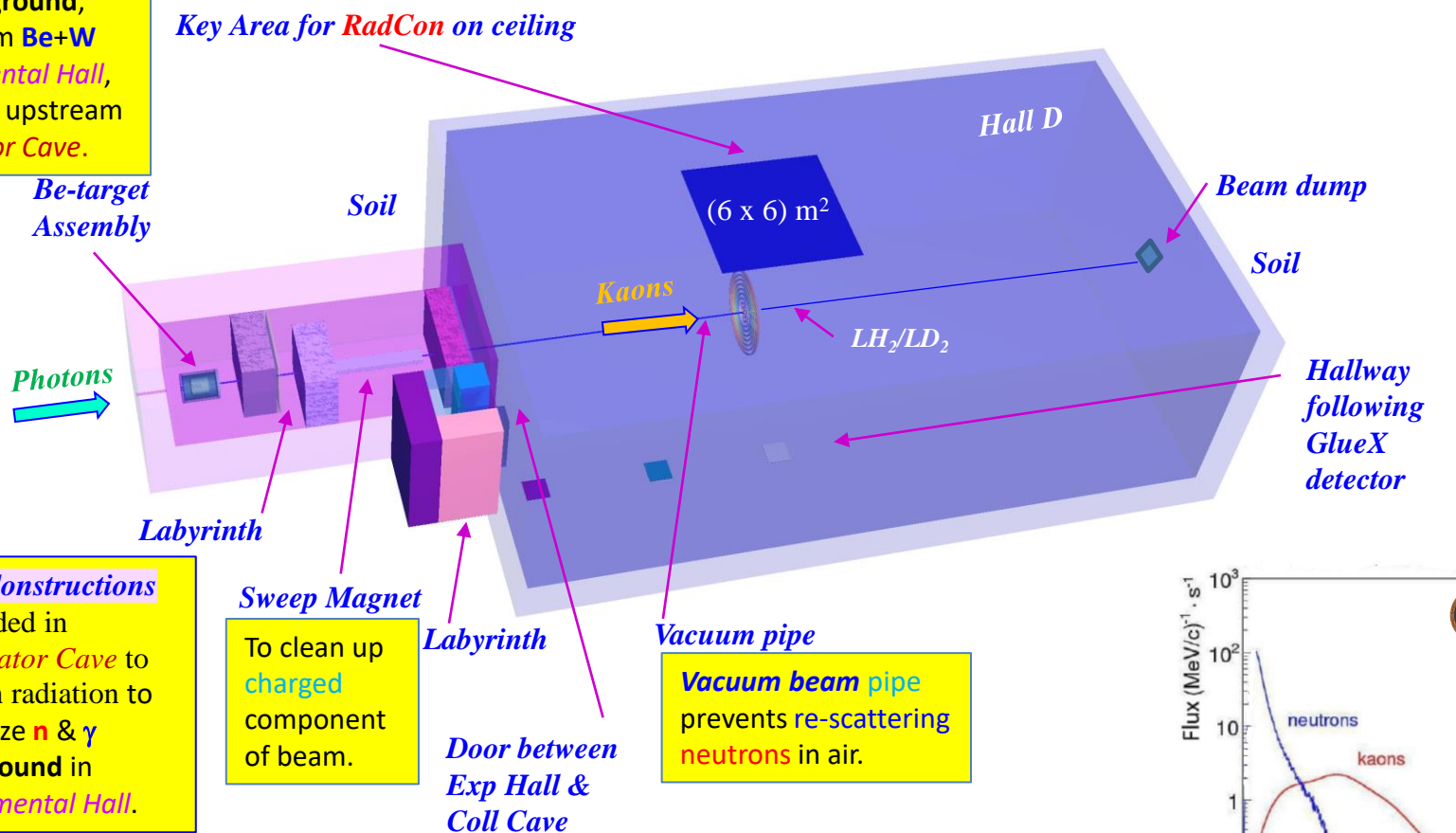
### Beryllium Target Section



RadCon figure-of-merit = 1 mrem/h

@ key area for RadCon on ceiling

To reduce effect of **n** & **γ** background, coming from **Be+W** in *Experimental Hall*, we put **KPT** upstream in *Collimator Cave*.

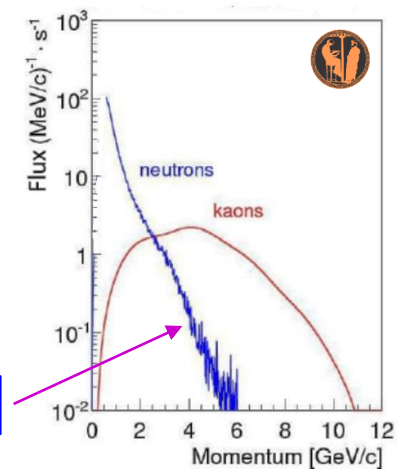


**Civil Constructions** be needed in *Collimator Cave* to contain radiation to minimize **n** & **γ** background in *Experimental Hall*.

To clean up **charged** component of beam.

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

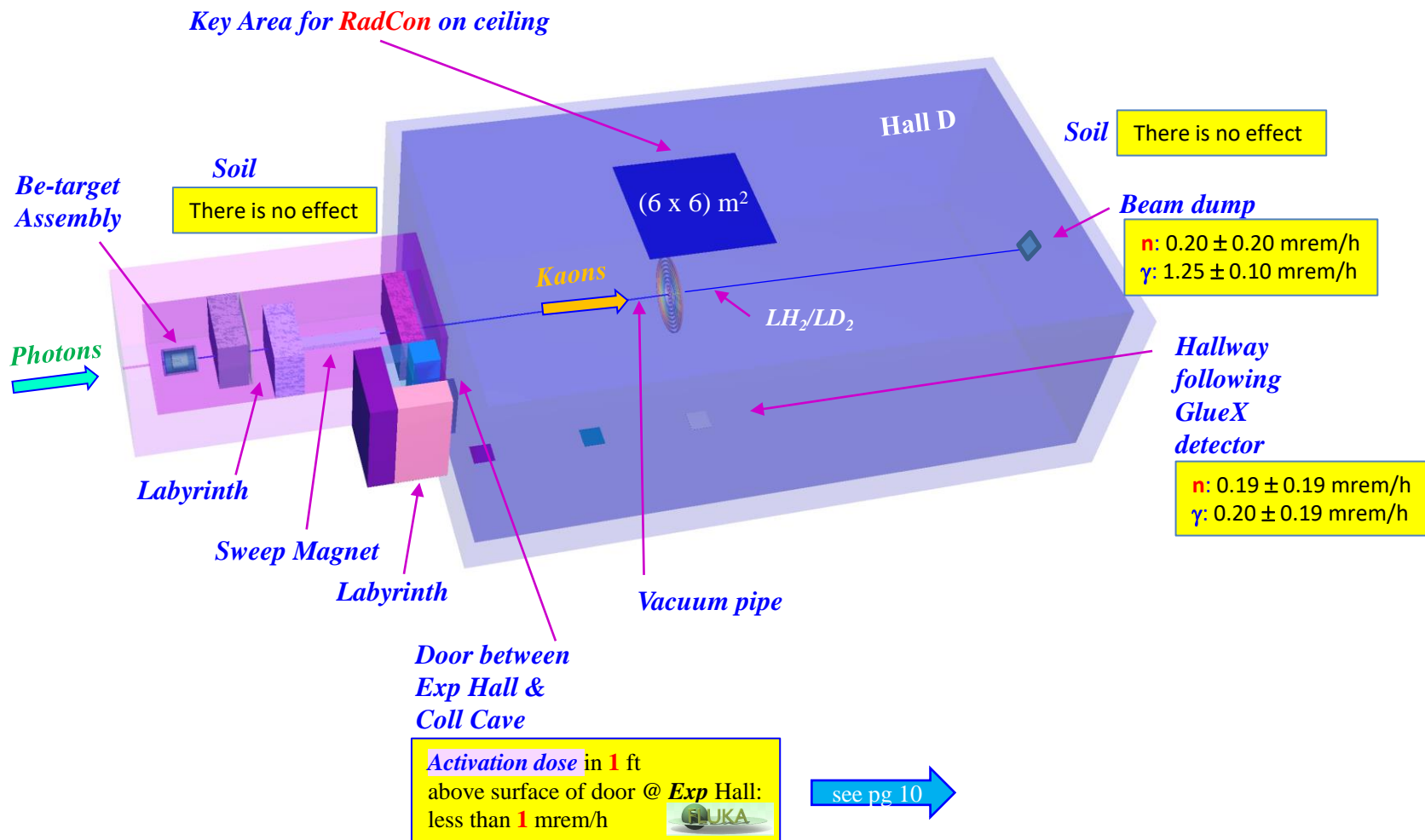
• Most important & unpleasant background for **K<sub>L</sub>** beam comes from **neutrons**.



# Hall D Setting & Equivalent Prompt Dose Rate - 1

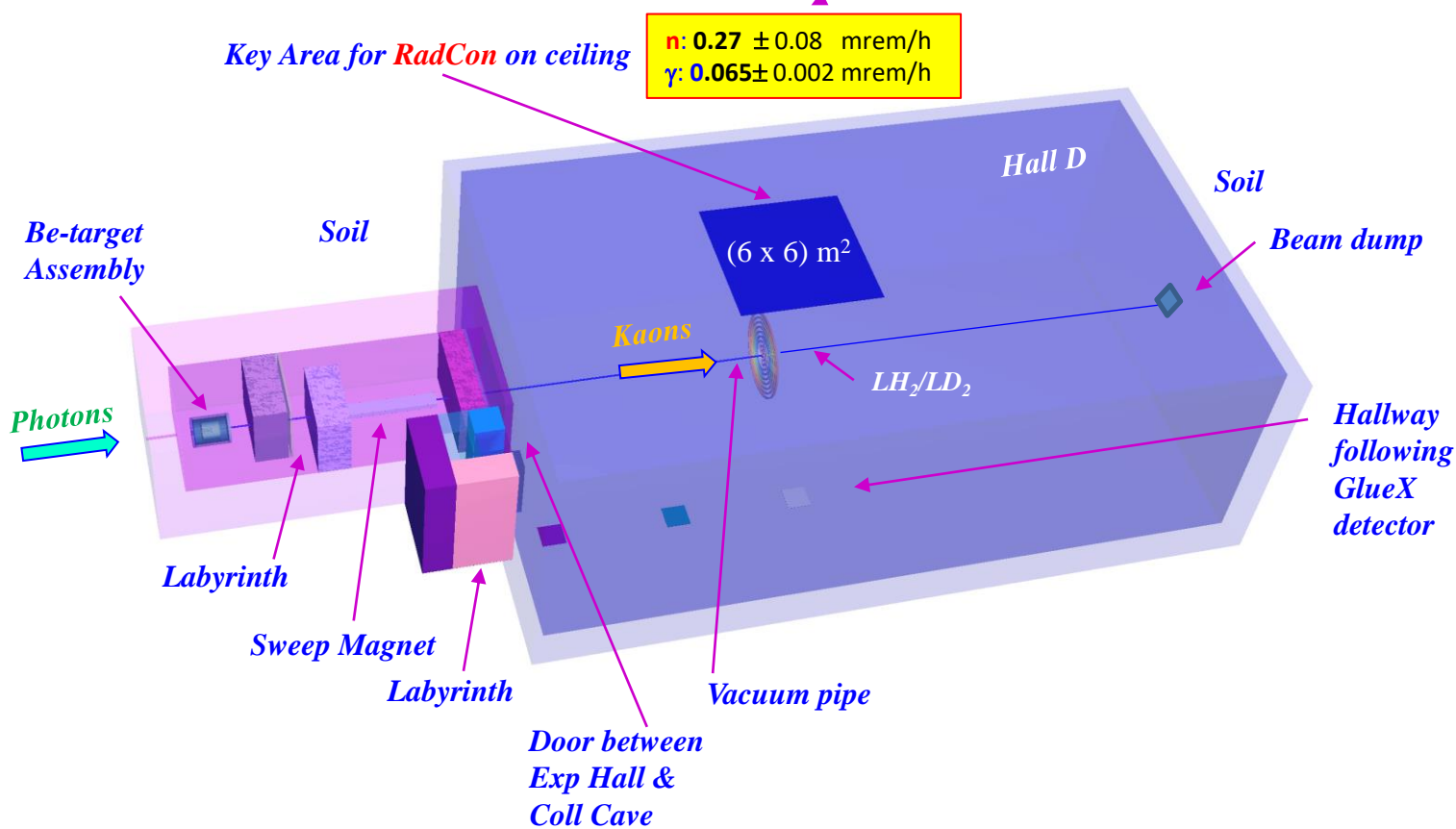
RadCon figure-of-merit = 1 mrem/h

@ key area for RadCon on ceiling



# Hall D Setting & Equivalent Prompt Dose Rate – 2 [Final]

**RadCon figure-of-merit = 1 mrem/h**  
 @ key area for RadCon on ceiling

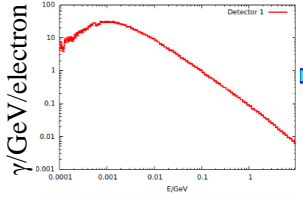


• Prompt radiation in *Experimental Hall* is acceptable.

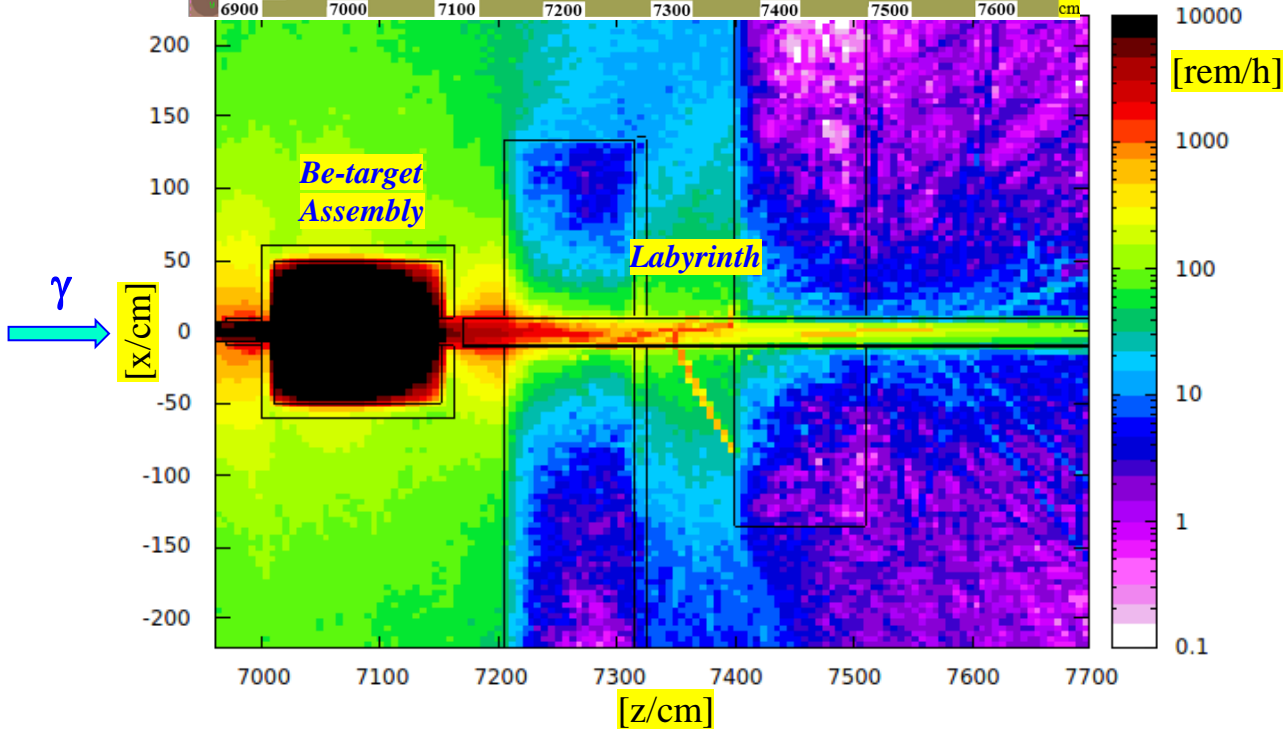
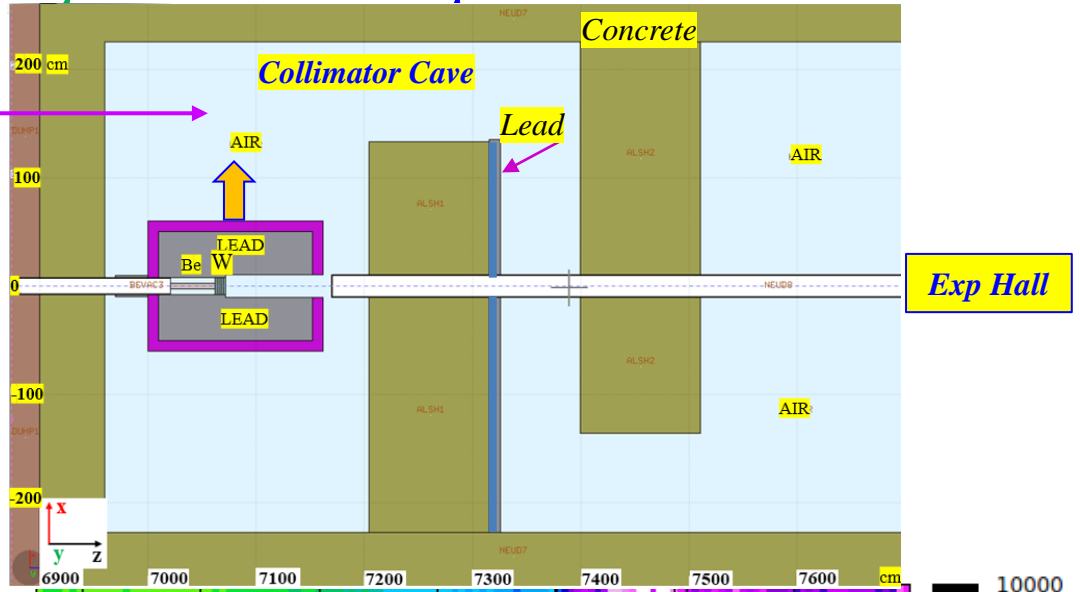
# Equivalent Prompt Dose in Collimator Cave

**Collimator Cave** has enough space (4.52 m width) for **KPT** to remain far enough from beamline.

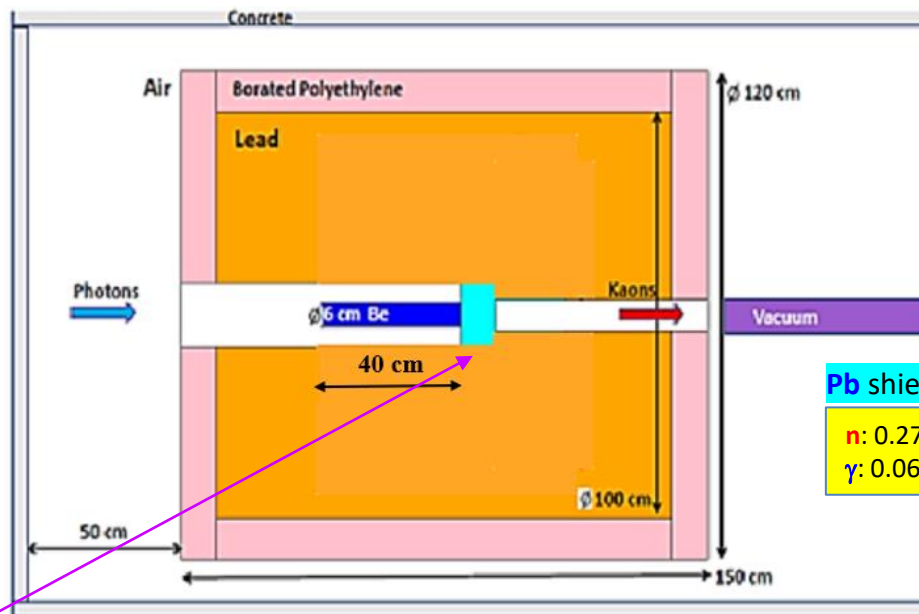
**5  $\mu\text{A}$   $e^-$  of 12 GeV**



$\gamma$







Pb shielding & W-plug

n:  $0.273 \pm 0.083$  mrem/h  
 $\gamma$ :  $0.065 \pm 0.002$  mrem/h

Concrete walls are out of scale

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:  $0.77 \pm 0.33$  mrem/h  
 $\gamma$ :  $0.074 \pm 0.002$  mrem/h

15 cm in length: n:  $0.16 \pm 0.06$  mrem/h  
 $\gamma$ :  $0.003 \pm 0.001$  mrem/h

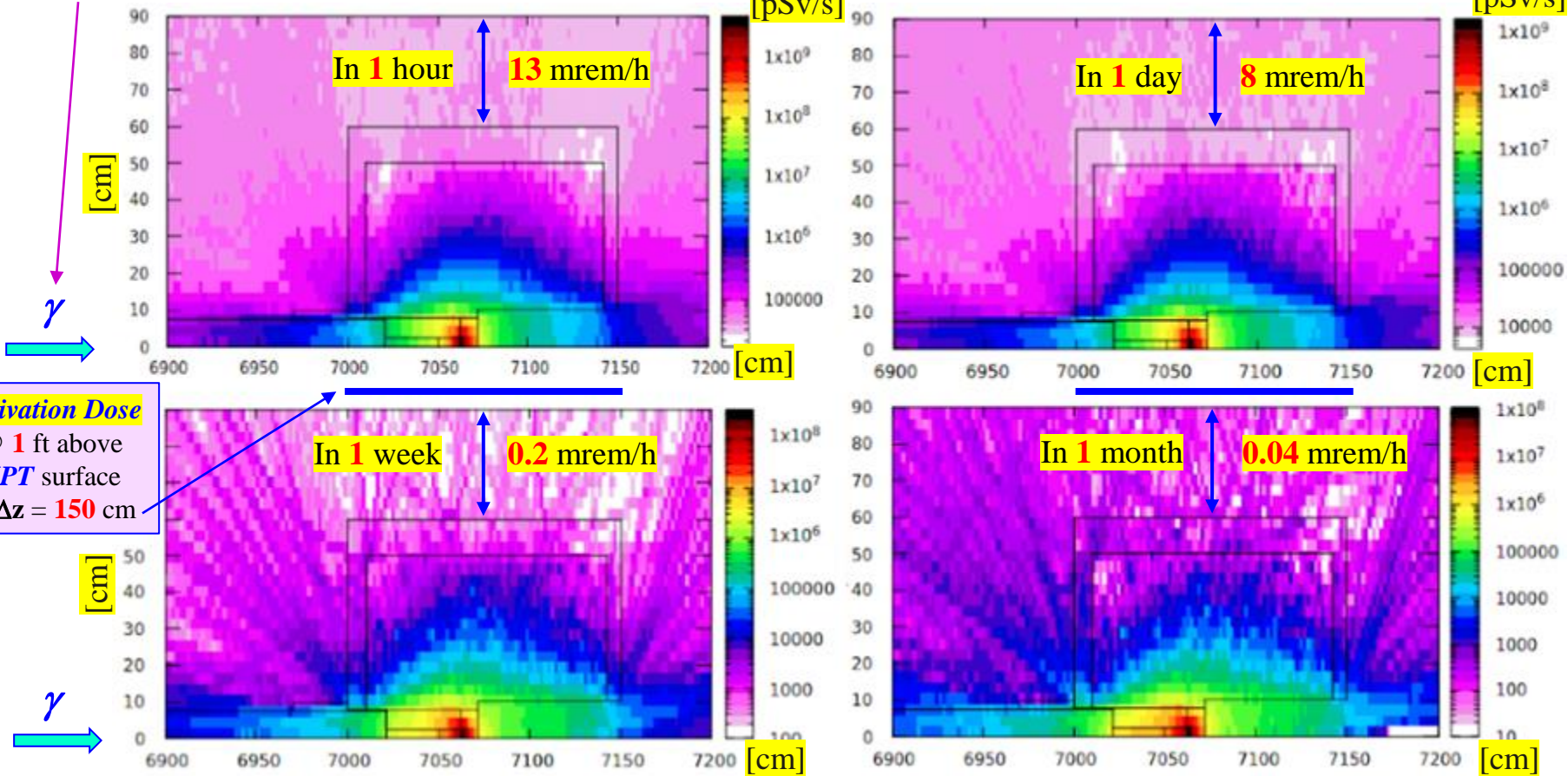
Corresponds to loss of 70% of kaons



• Prompt radiation in Exp Hall due to Be-target & W-plug is acceptable.

RadCon figure-of-merit = 1 mrem/h

1000 h of operation with 5  $\mu\text{A e}^-$  of 12 GeV



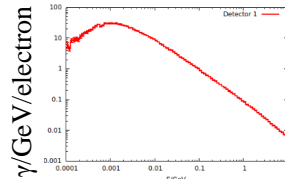
Activation Dose  
@ 1 ft above  
KPT surface  
&  $\Delta z = 150$  cm

Equivalent dose:  
 $10^5$  pSv/s = 36 mrem/h

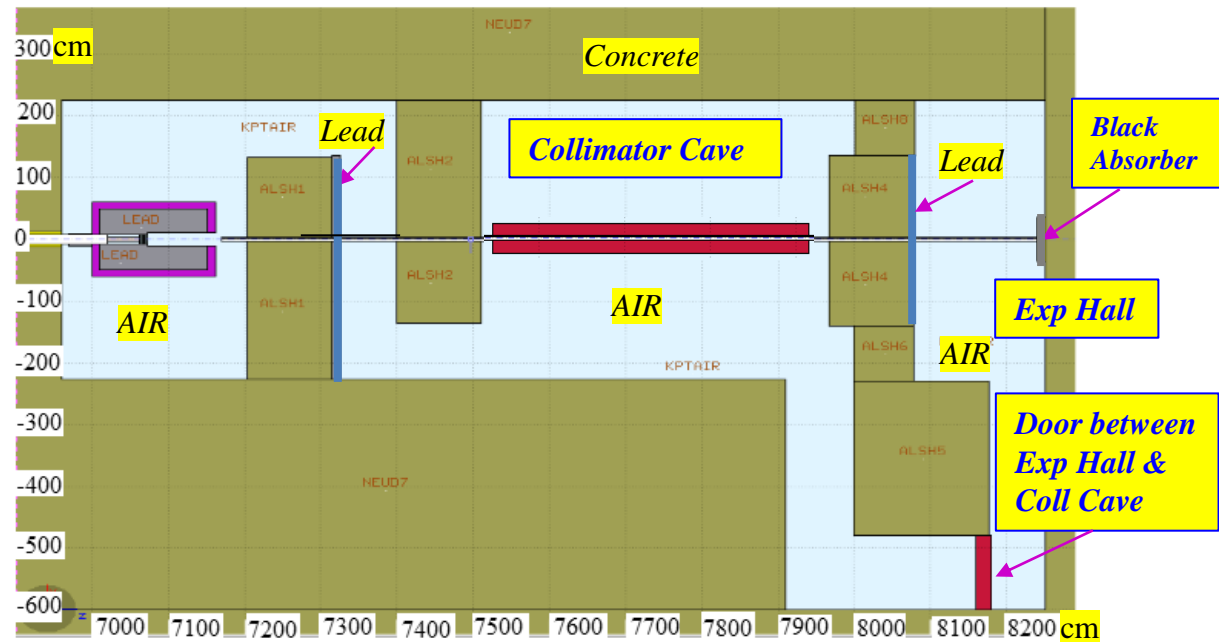
- KPT is kept in Cave & moved sideways.
- All other modifications in Cave are restored to .

# Activation Dose for Door between Exp Hall & Coll Cave

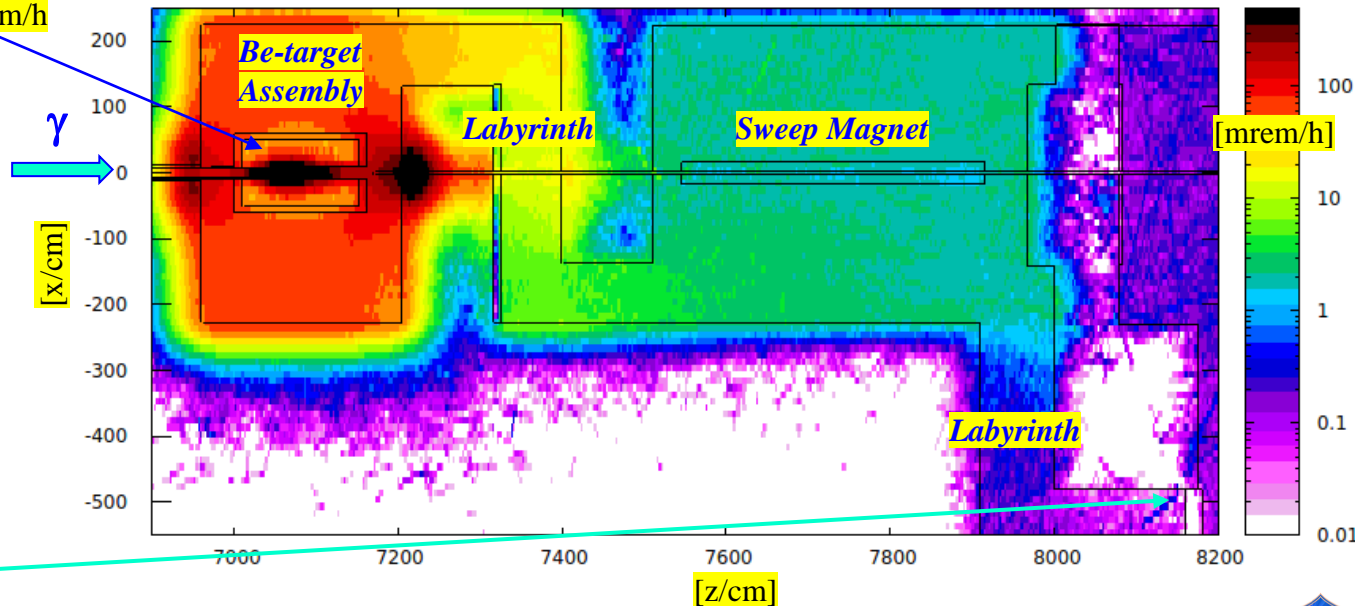
**5  $\mu\text{A e}^-$   
of 12 GeV**



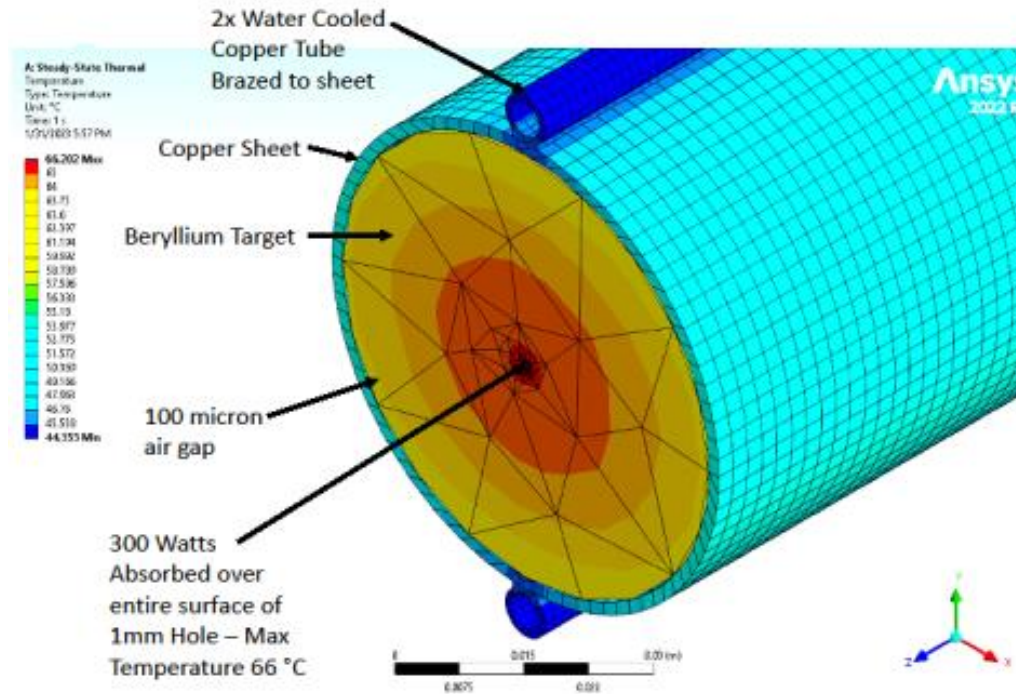
$\gamma$



**Black > 500 mrem/h**



**Activation dose** in 1 ft above surface of door @ *Exp Hall* [in 1 h of 1000 h of operation with 5  $\mu\text{A e}^-$  of 12 GeV @  $-80 < y/\text{cm} < +80$ ]: less than **0.1 mrem/h** which is acceptable.



- Since there is concern with *air contamination* from Be if air is blown onto surface for cooling, it is decided to use *water cooling* for this target.
- Maximum temperature of 66°C was found in Be.
- Target is wrapped with 0.065 in thick copper sheet in which 0.25 in cooling tubes are brazed on to.
- Inner surface of water-cooling tube is assumed to have a convection coefficient of 5 kW/m<sup>2</sup> K & water temperature of 40°C on average.
- This is very conservative since there will be some actual contact.



# SUMMARY


- Report addressed to ##5,6,7, & partly 12 of ERR-I charge.
  - Radiation in *Experimental Hall* & *Collimator Cave*, & *ground* is acceptable.
  - We have been working closely together to *Pavel Degtyarenko* & *Lorenzo Zana*.
  - Civil constructions be needed in *Collimator Cave*.
  - Decommissioning of *Collimator Cave* does not require long time.
- Design for *Be-target Assembly* & *Collimator Cave* completed – drawings finalizing.
- Thermal analysis of *Beryllium Target Tungsten Absorber* completed.  
Designer from Engineering Group loan.



See Tim's report



See Tim's report



Do you have any  
questions to  
speaker?



# Codes Used for MC Simulations



is general MC N-particle transport *code*.

T. Goorley *et al*, Nucl Tech **180**, 298 (2012); <https://mcnp.lanl.gov/>



is general purpose MC *code* simulating interaction & transport of hadrons, heavy ions, & EM particles.

T.T. Boehlen *et al*, Nucl Data Sheets **120**, 211 (2014)

G. Battistoni *et al*, Annals Nucl Energy **82**, 10 (2015)



**Pythia** is *code* for generation of high-energy physics collision events.

T. Sjostrand *et al*, Comput Phys Commun **191**, 159 (2015)



is *software* which is flexible & powerful integrated solution that helps to deliver better products faster & more efficiently.



is *workbench* 2022 R2 finite element program.

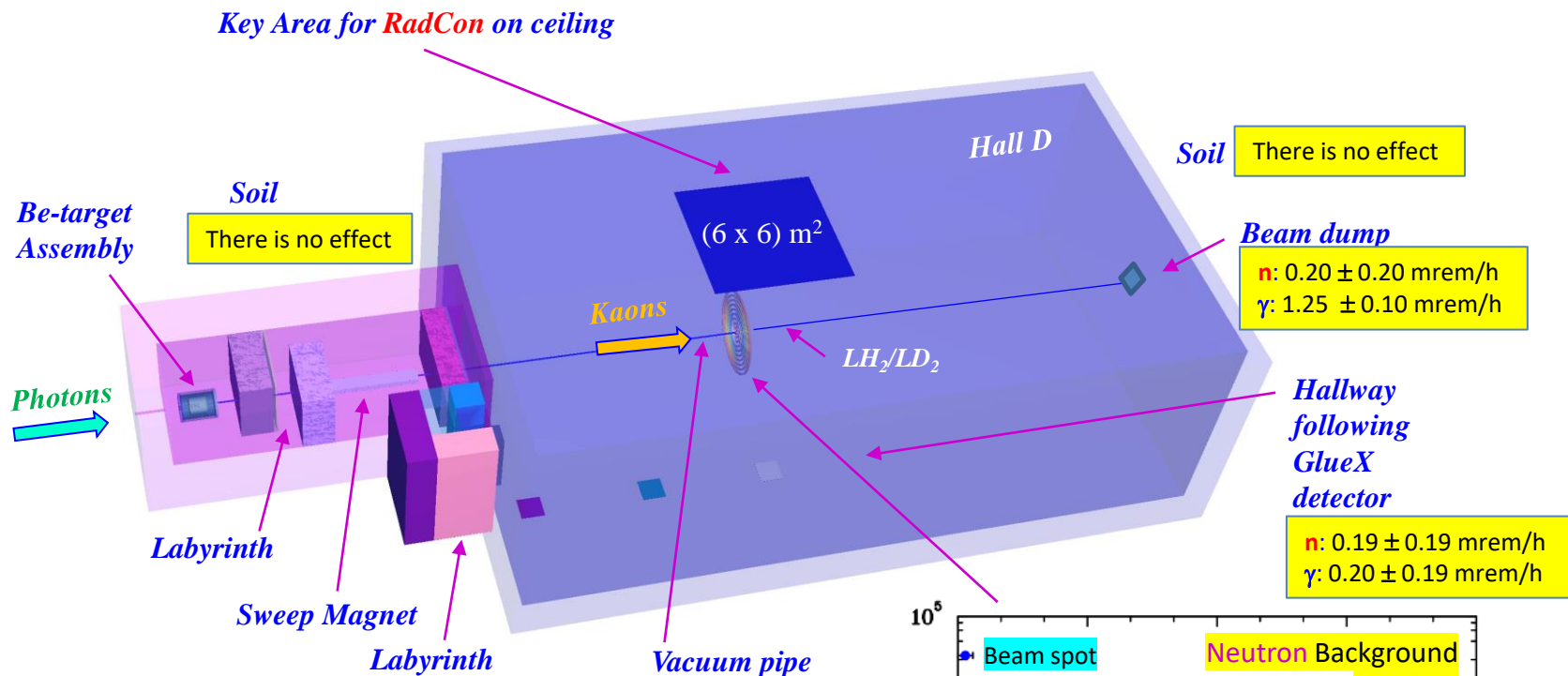
ANSYS inc. Workbench 2022 R2 Finite Element Program



# Hall D Setting & Equivalent Prompt Dose Rate

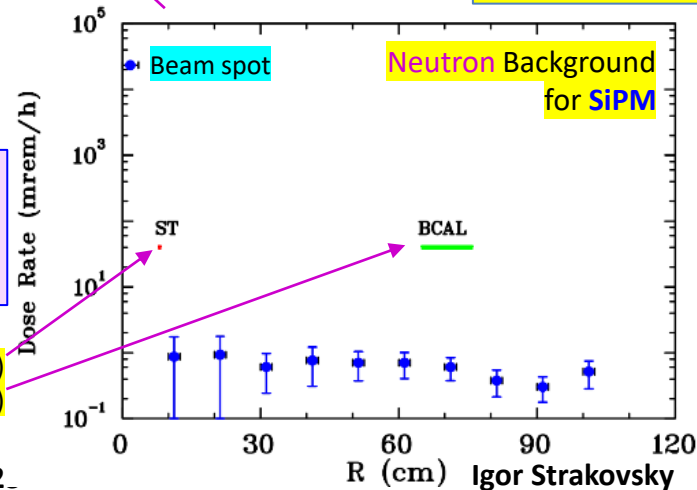
RadCon figure-of-merit = 1 mrem/h

At key area for RadCon on ceiling



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

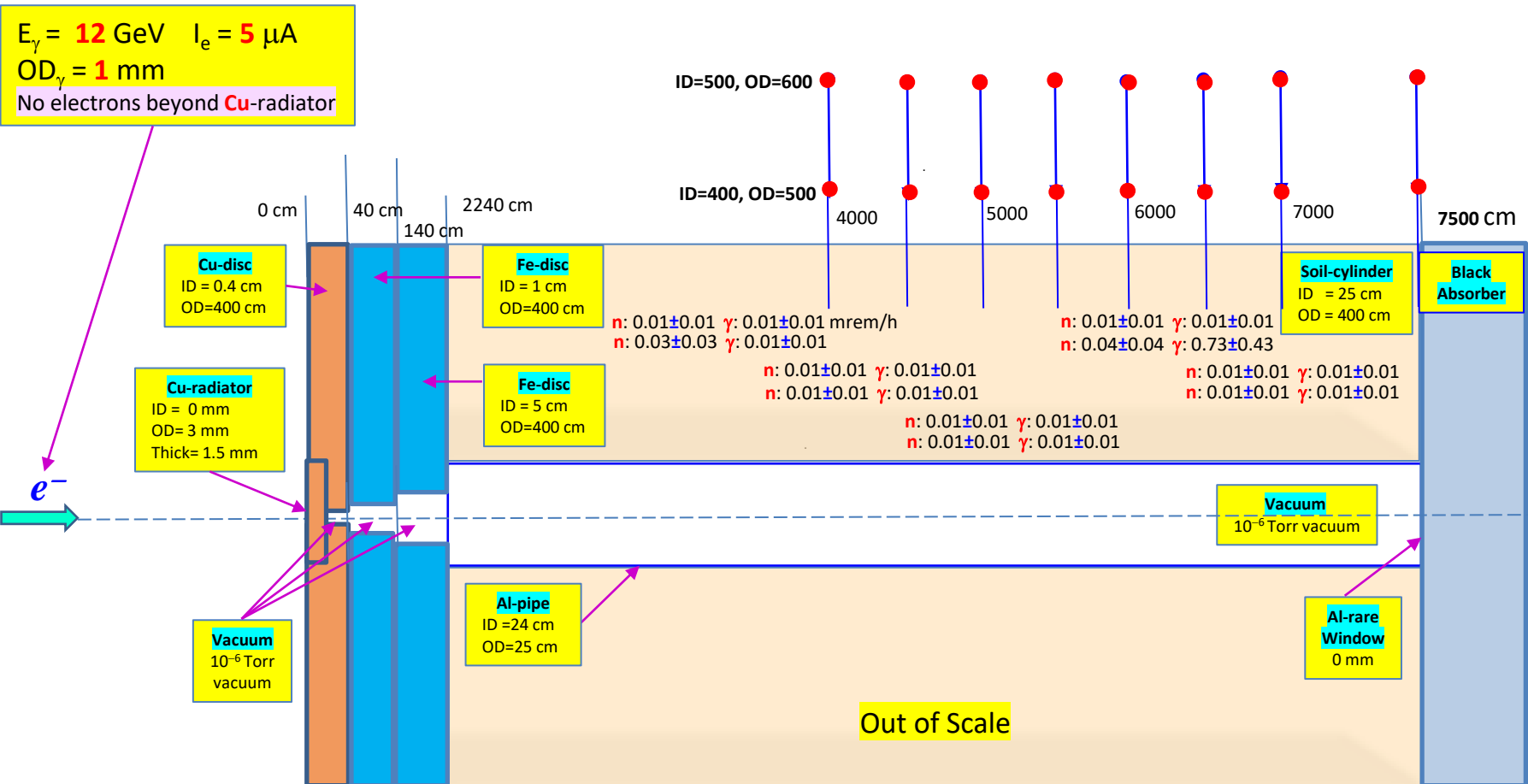
ST: E. Pooser *et al*, Nucl Instrum Meth A 927, 330 (2019)  
 BCAL: T.D. Beattie *et al*, Nucl Instrum Meth A 896, 24 (2018)





# Radiation Budget on Ground above Tagger Cave

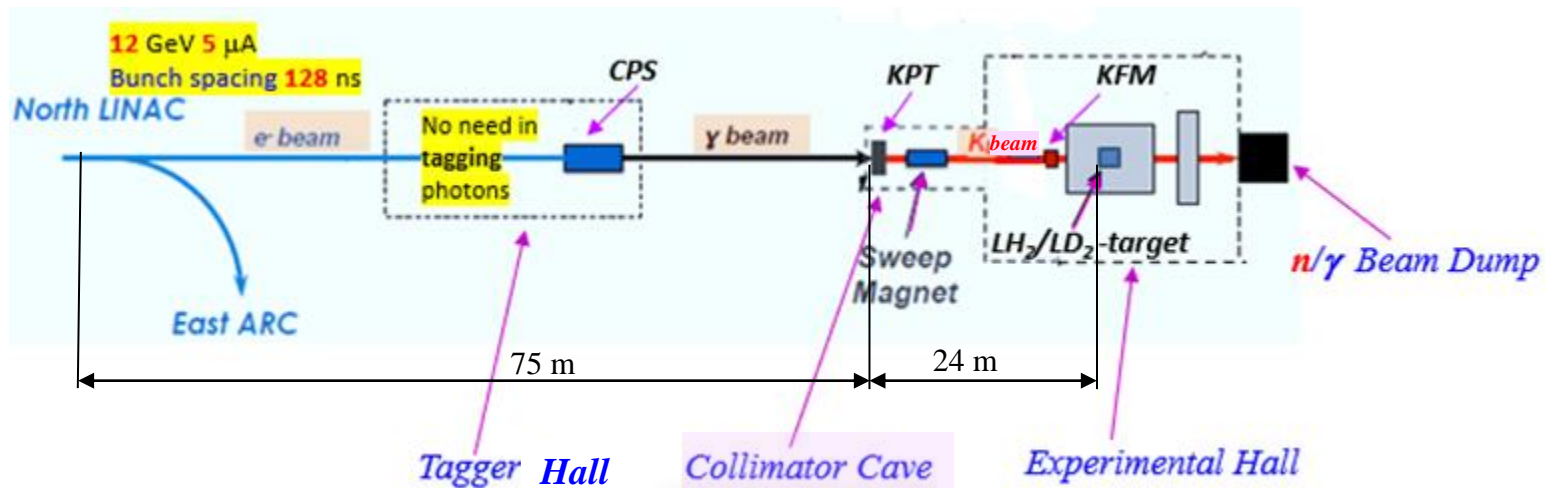
RadCon figure-of-merit = 1 mrem/h



• Radiation on ground above Tagger Cave is acceptable.

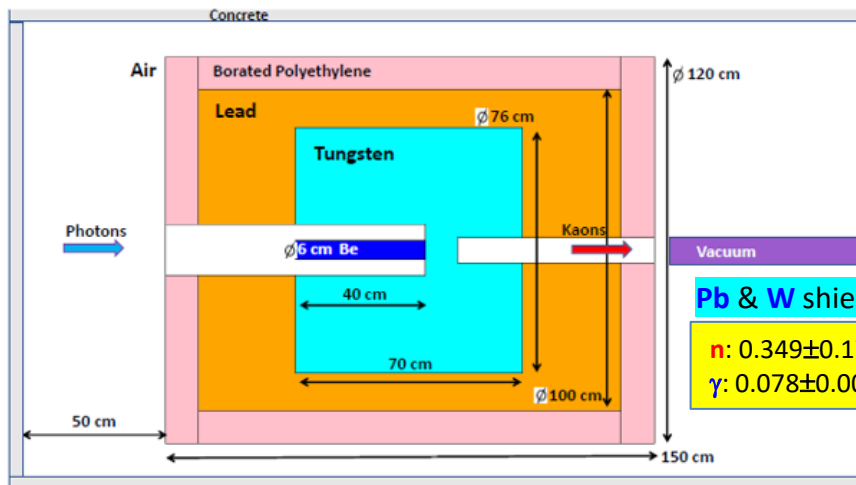
# Hall D: Beam Line for K-long

- Electrons ( $3.1 \times 10^{13}$  e/sec) are hitting Cu-radiator [10%  $X_0$ ] @ CPS located in Tagger Hall.
- Photons ( $4.7 \times 10^{12}$   $\gamma$ /sec,  $E_\gamma > 1.5$  GeV) are hitting Be-target located in Collimator Cave.
- $K_L$ s ( $1 \times 10^4$   $K_L$ /sec) are hitting Cryo target within GlueX spectrometer.
- Neutrons ( $6.6 \times 10^5$  n/sec) are hitting Cryo target within GlueX spectrometer.
- Photons ( $6.5 \times 10^5$   $\gamma$ /sec,  $E_\gamma > 100$  MeV) are hitting Cryo target within GlueX spectrometer.

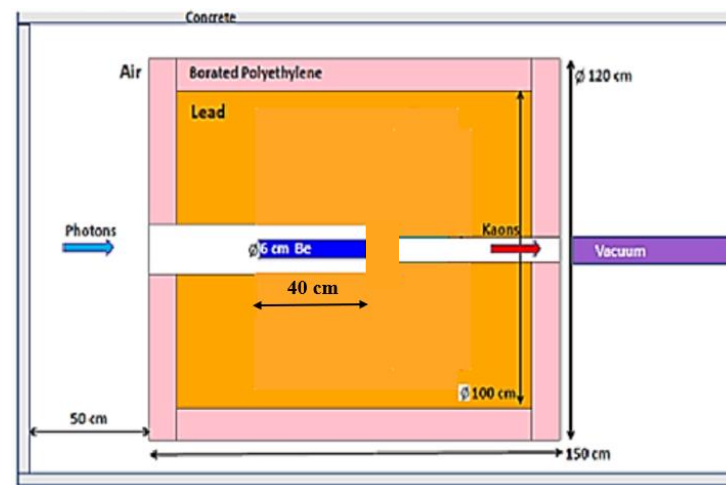


RadCon figure-of-merit = 1 mrem/h

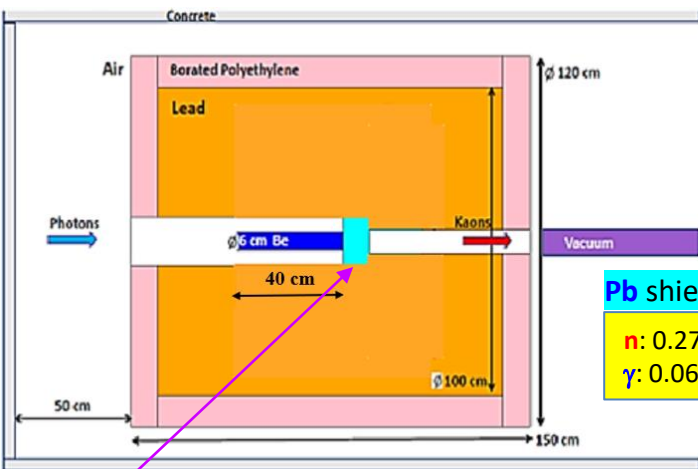
@ key area for RadCon on ceiling



**Pb & W shielding**  
 $n: 0.349 \pm 0.172$  mrem/h  
 $\gamma: 0.078 \pm 0.005$  mrem/h



**Pb & no W shielding**  
 $n: 0.614 \pm 0.246$  mrem/h  
 $\gamma: 0.527 \pm 0.006$  mrem/h



**Pb shielding & W-plug**  
 $n: 0.273 \pm 0.083$  mrem/h  
 $\gamma: 0.065 \pm 0.002$  mrem/h

Concrete walls are out of scale

• Prompt radiation in Exp Hall due to Be-target & W-plug is acceptable.

**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:**  $n: 0.77 \pm 0.33$  mrem/h  
 $\gamma: 0.074 \pm 0.002$  mrem/h

**15 cm in length:**  $n: 0.16 \pm 0.06$  mrem/h  
 $\gamma: 0.003 \pm 0.001$  mrem/h

Corresponds to lost of 70% of kaons

