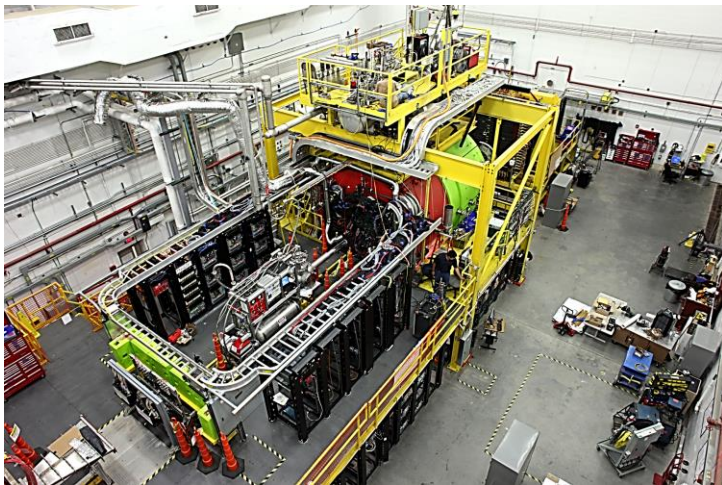


KPT: Conceptual Design & Radiation Effects

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Pavel Degtyarenko⁺⁺⁾, Sean Dobbs^{#)}, Hovanes Eginyan⁺⁺⁾, Ilya Larin^{##)},
Alexander Somov⁺⁺⁾, & Timothy Whitlatch⁺⁺⁾

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^{#)}Florida State University, & ^{##)}University of Massachusetts, Amherst



- **ERR-I** charge for **KPT**.
- **Kaon** beamline.
- **Hall D** setting.
- Equivalent prompt dose rate for **Exp Hall**.
- Prompt dose rate for **Collimator Cave**.
- **KPT** Assembly.
- Activation dose rate for **Collimator Cave**.
- **KPT** cooling.
- **Summary**.

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

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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

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



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



see pg 15

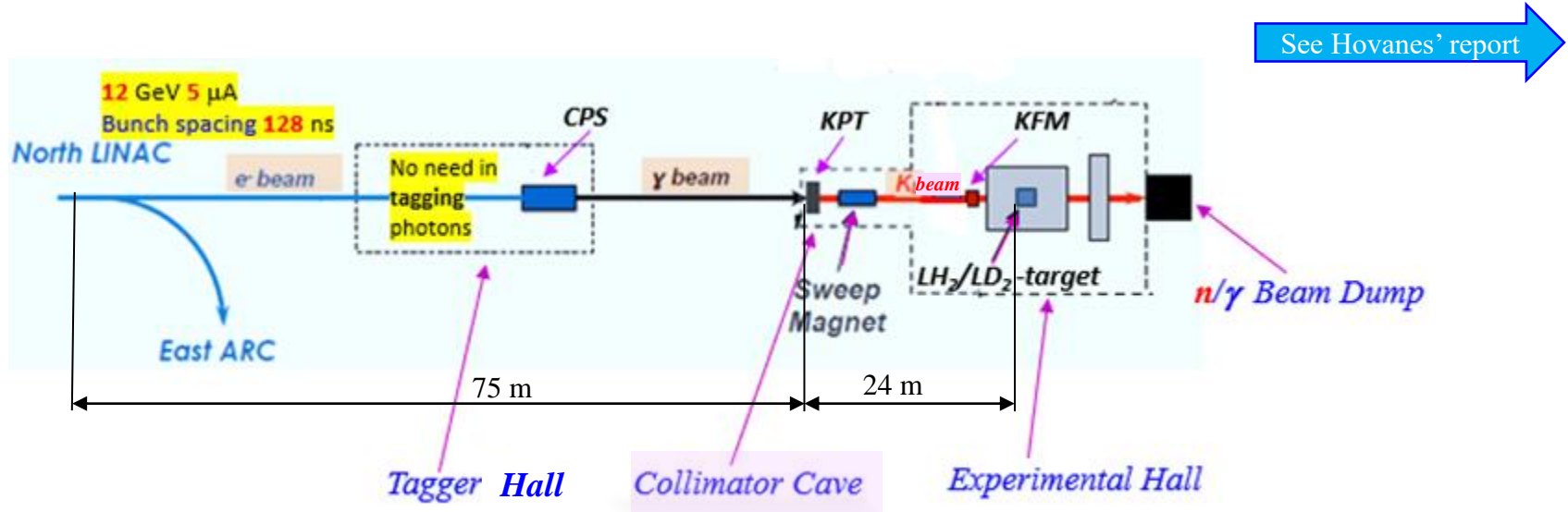


Igor Strakovsky 2



Hall D: Beam Line for K-long

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

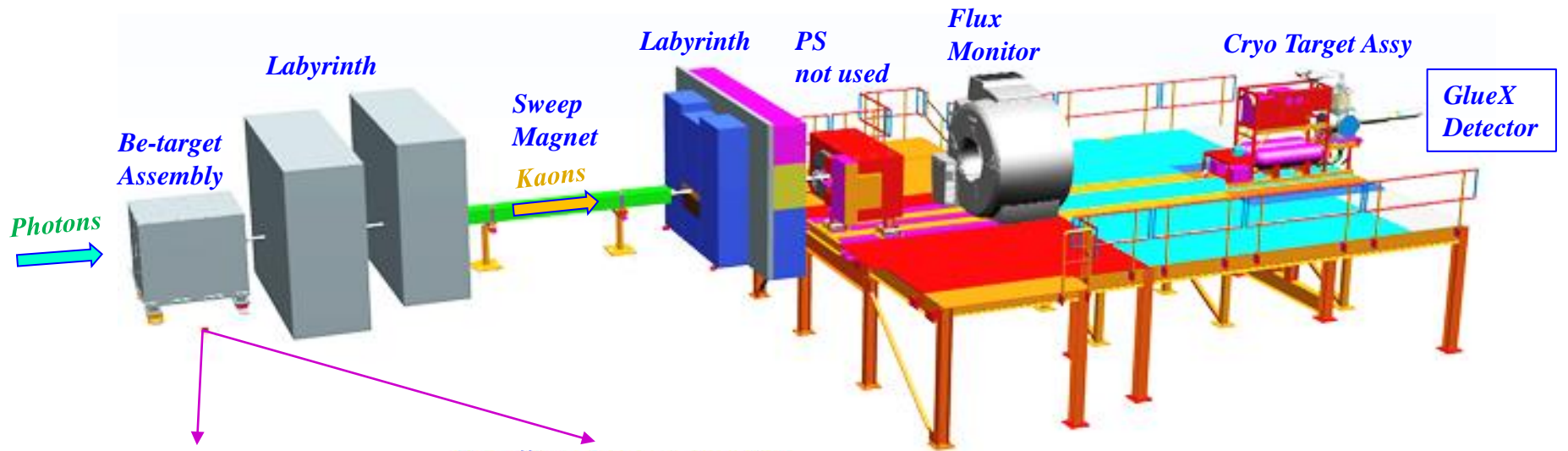


See Tim's report 

See Mikhail's report 

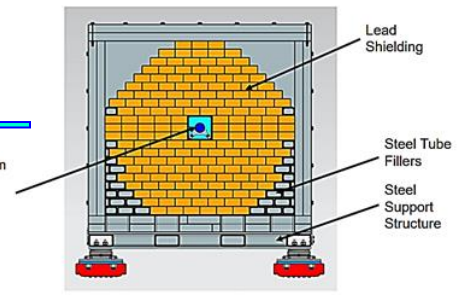
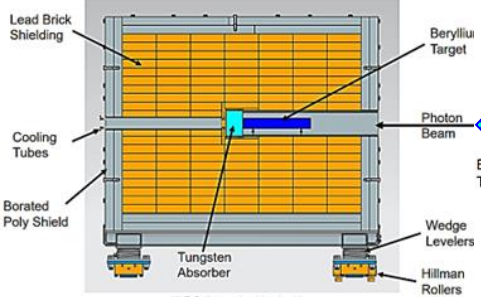
Collimator Cave

Experimental Hall



Beryllium Target Assy

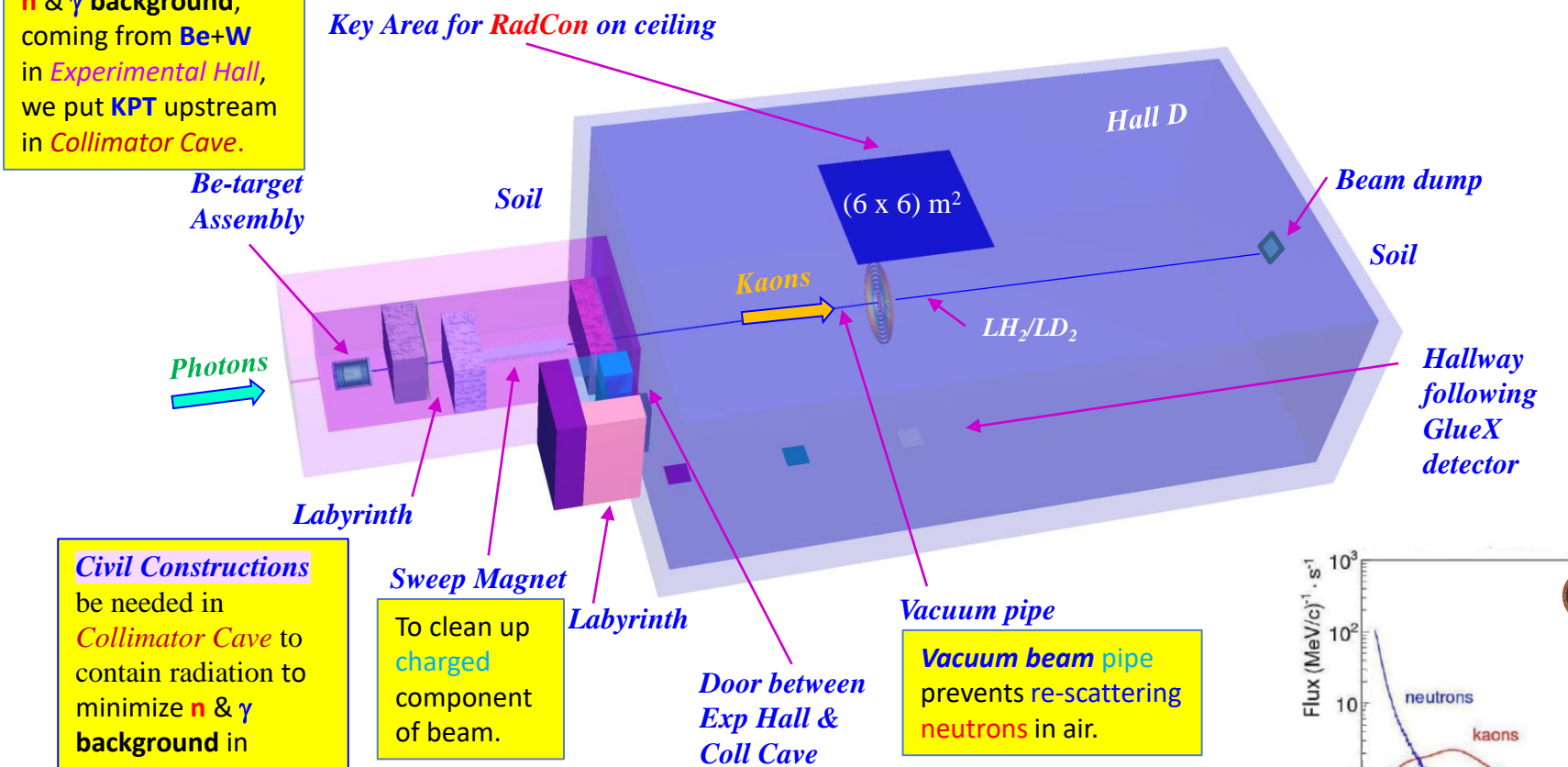
Beryllium Target Section



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*.



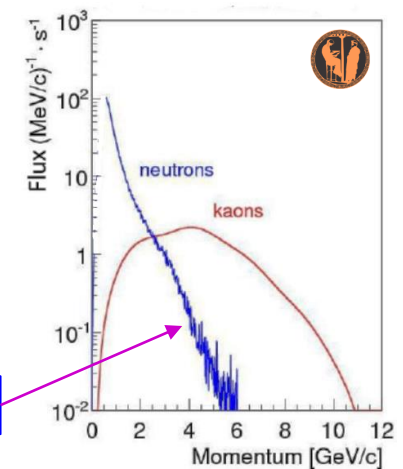
Civil Constructions be needed in *Collimator Cave* to contain radiation to minimize **n** & **γ** background in *Experimental Hall*.

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

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

See Tim's report

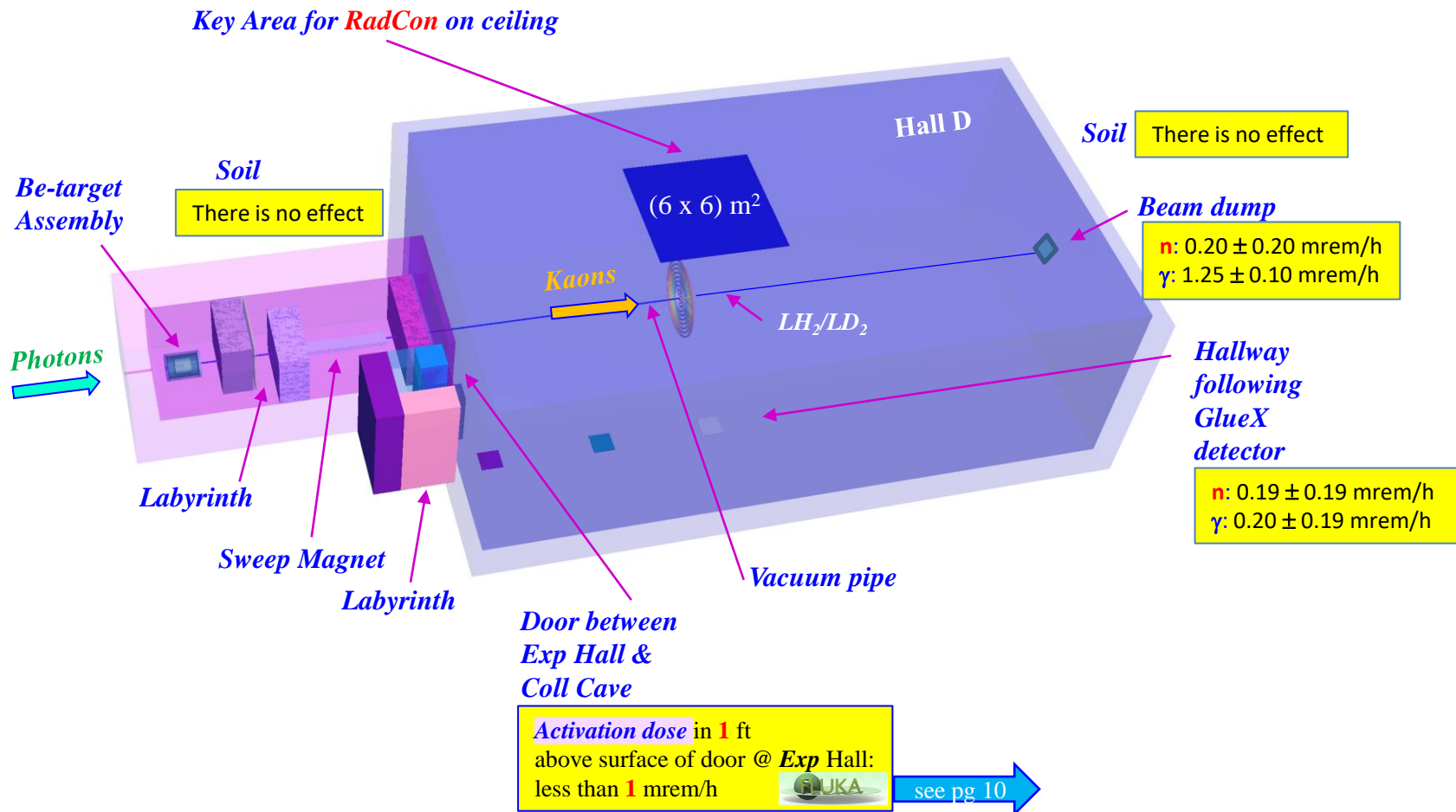
• Most important & unpleasant *background* for **K_L** beam comes from **neutrons**.



Hall D Setting & Equivalent Prompt Dose Rate - 1

RadCon figure-of-merit = 1 mrem/h

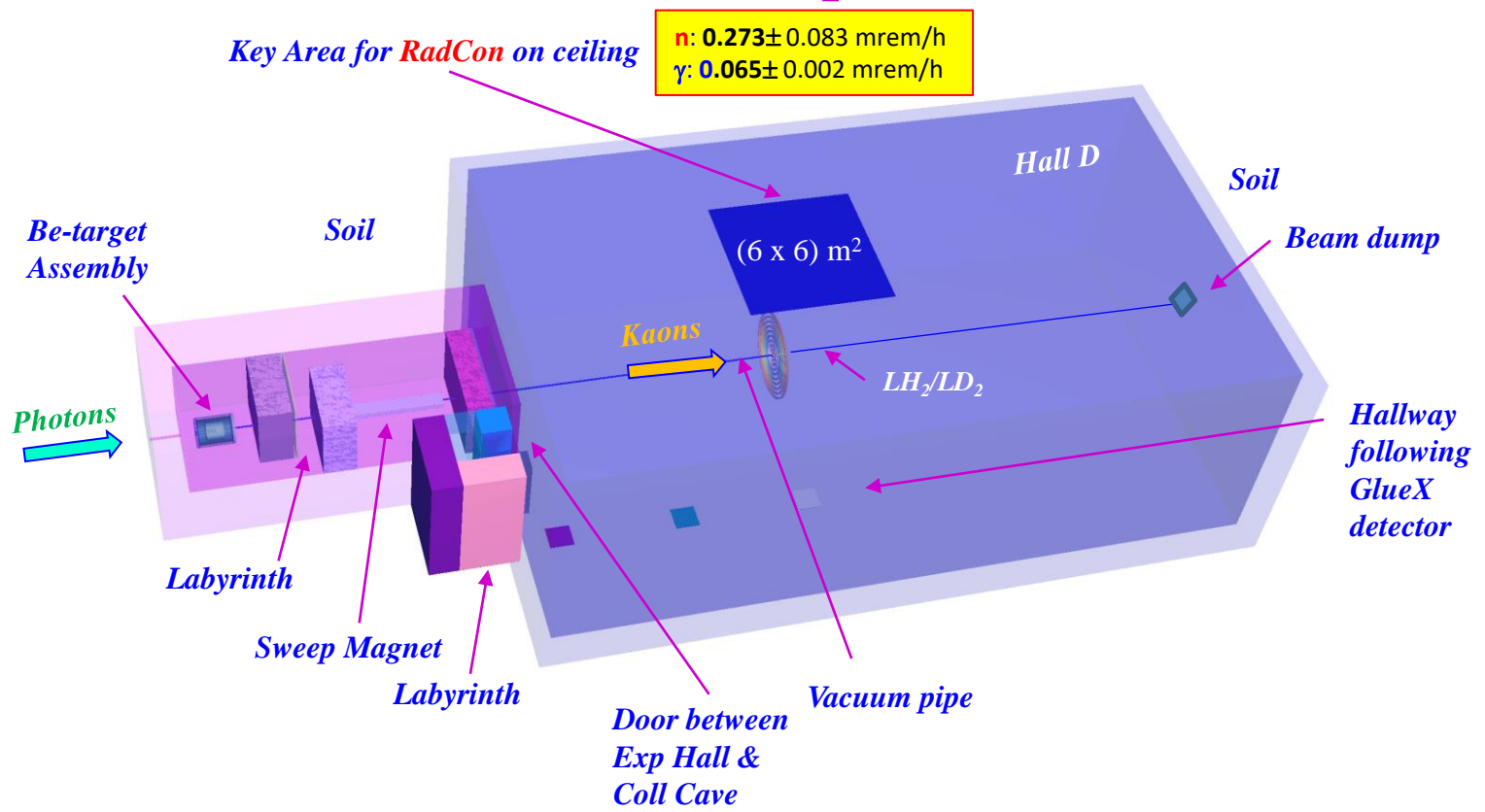
@ key area for RadCon on ceiling



see pg 10

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

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

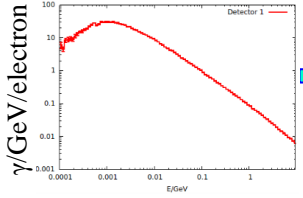


• Prompt radiation in *Experimental Hall* is acceptable.

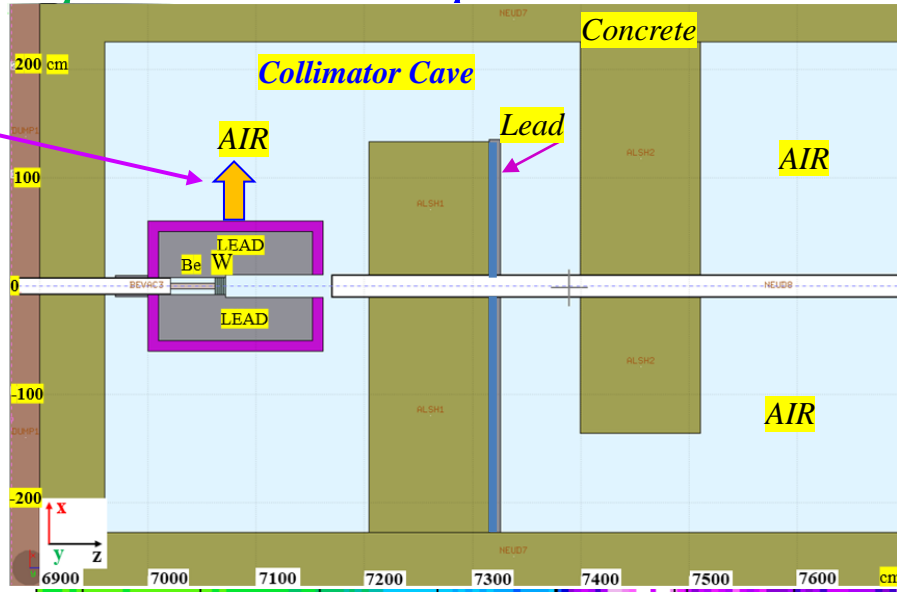
Equivalent Prompt Dose in Collimator Cave

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

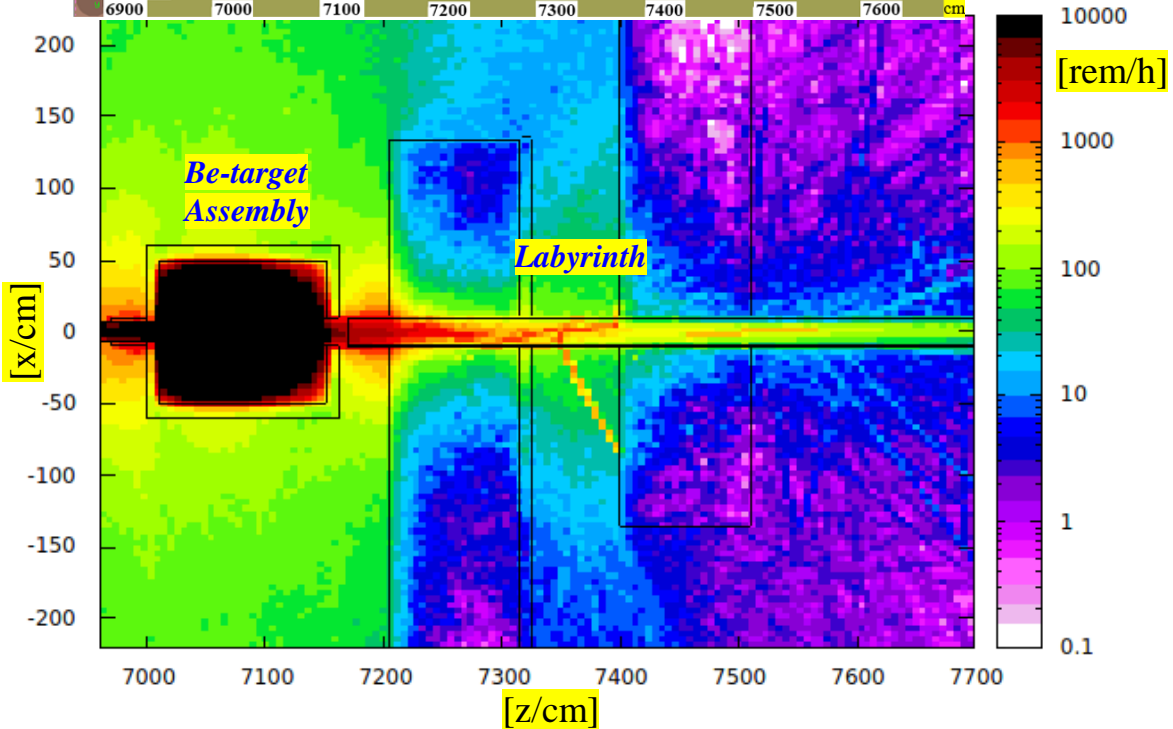


γ

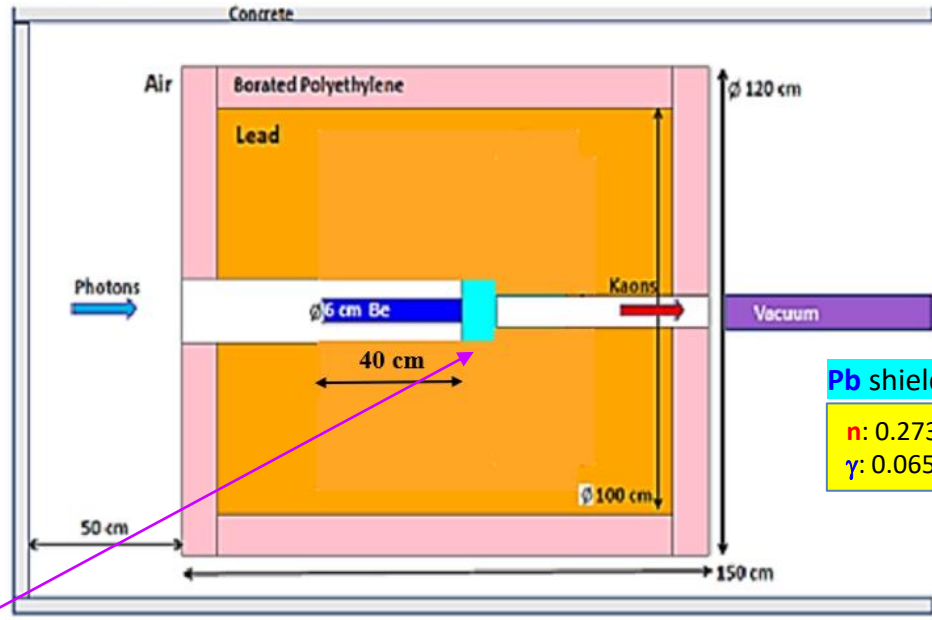


Exp Hall

γ



Prompt radiation in Collimator Cave is acceptable.



Pb shielding & W-plug
 n: 0.273 ± 0.083 mrem/h
 γ : 0.065 ± 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.

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

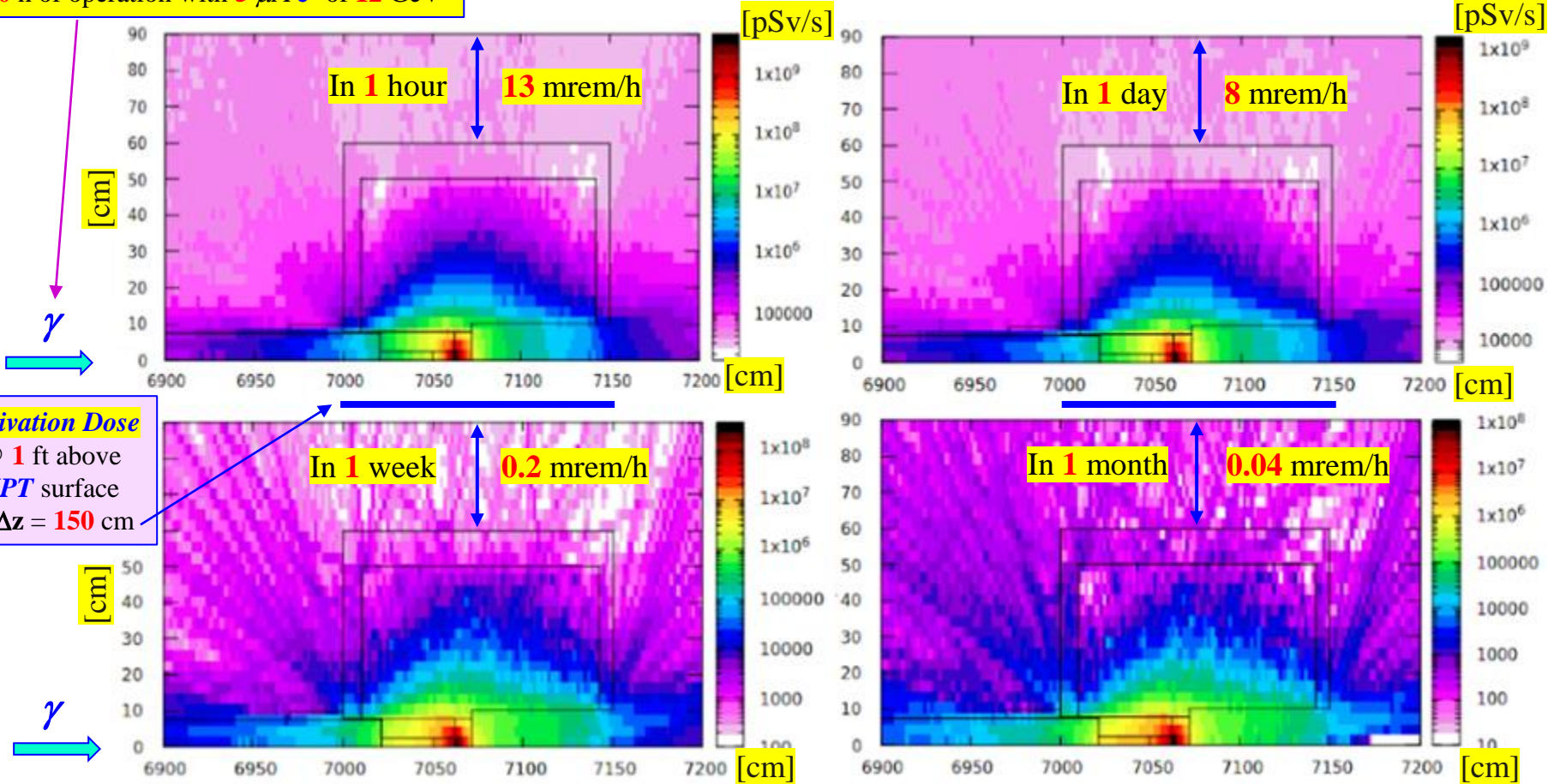
Corresponds to lost of **70% of kaons**



• 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

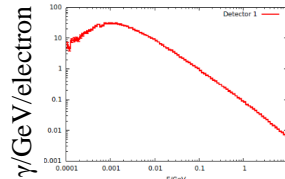


Equivalent dose:
10⁵ pSv/s = 36 mrem/h

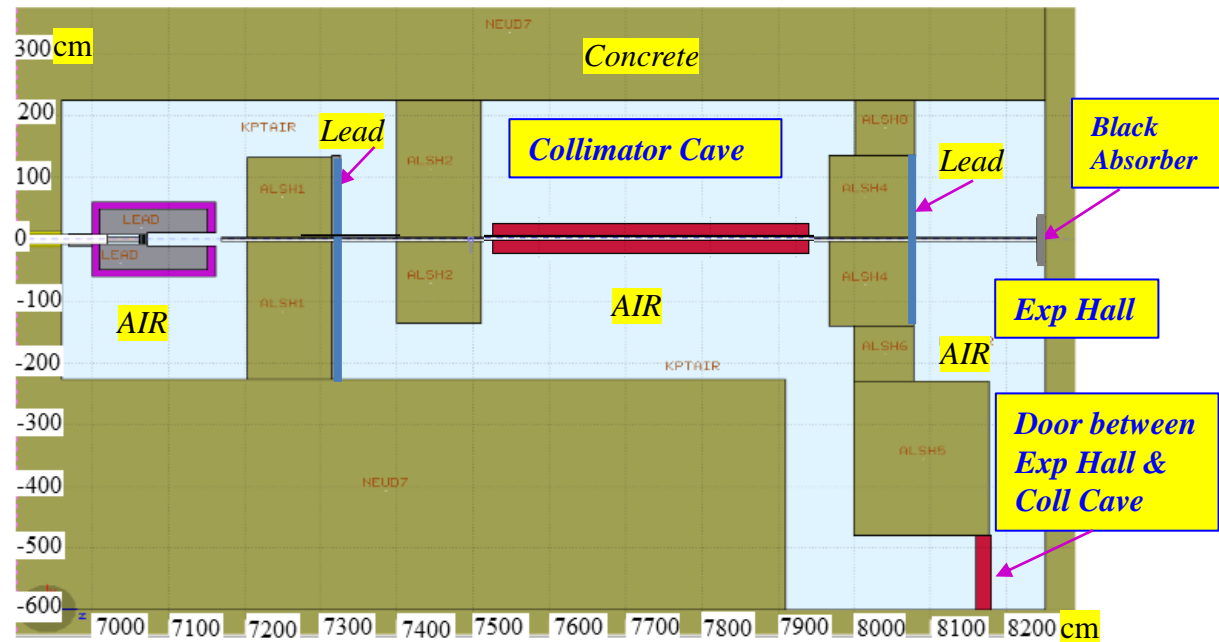
- KPT is kept in Cave & moved sideways.
- All other modifications in Cave are restored to .

Activation Dose for Door between Exp Hall & Coll Cave

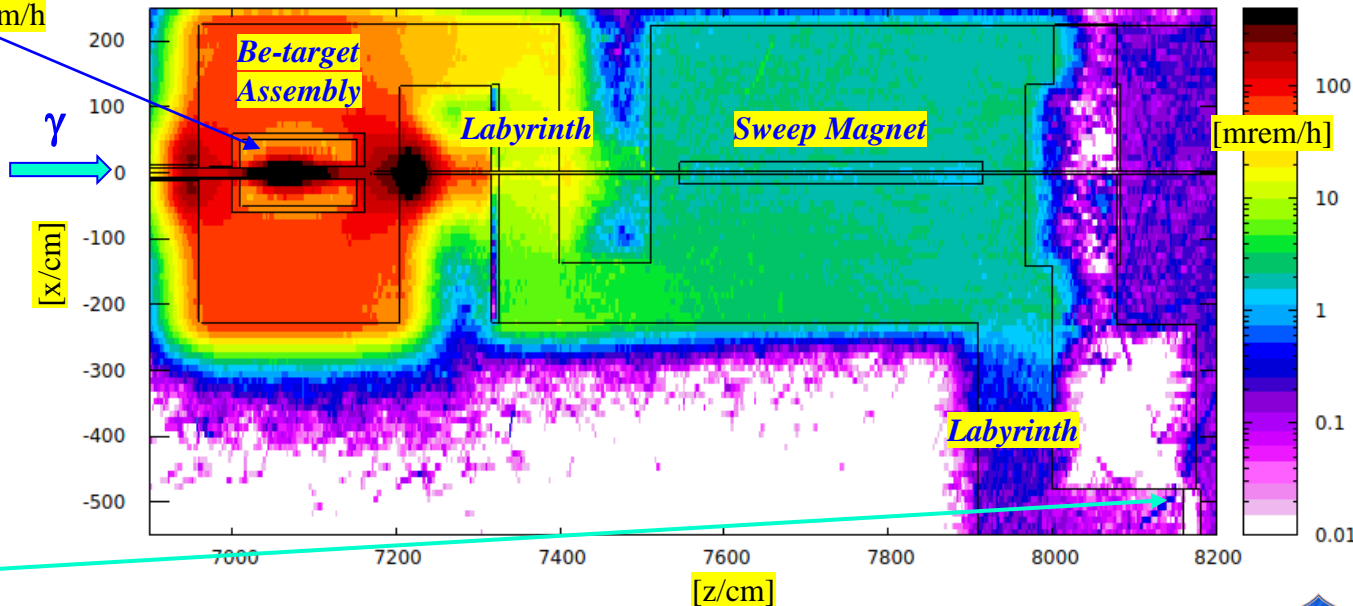
**5 $\mu\text{A e}^-$
of 12 GeV**



γ

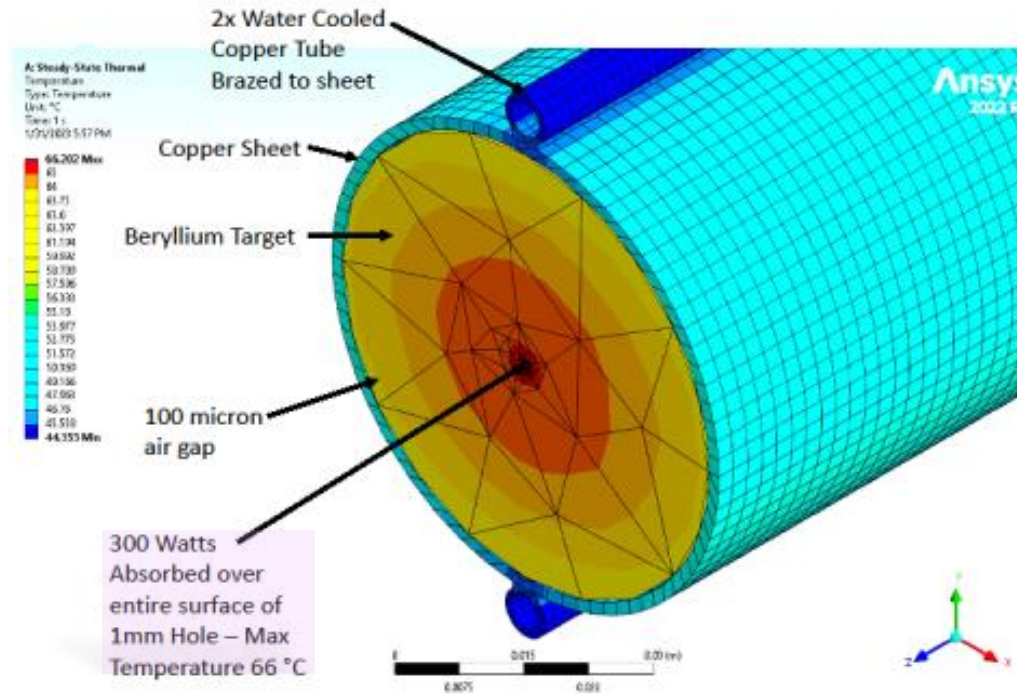


Black > 500 mrem/h



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.

See Tim's report



- 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 Be 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/m² K & water *temperature* of 40°C on average.
- This is *conservative* since there will be some actual contact.



SUMMARY

- *KPT* is ready to be assembled and installed in *Hall D beamline*.
- 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.



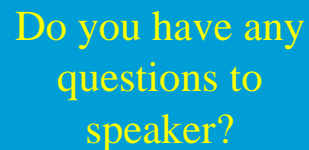
See Tim's report



See Tim's report



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 *workbench* 2022 R2 finite element program.

ANSYS inc. Workbench 2022 R2 Finite Element Program



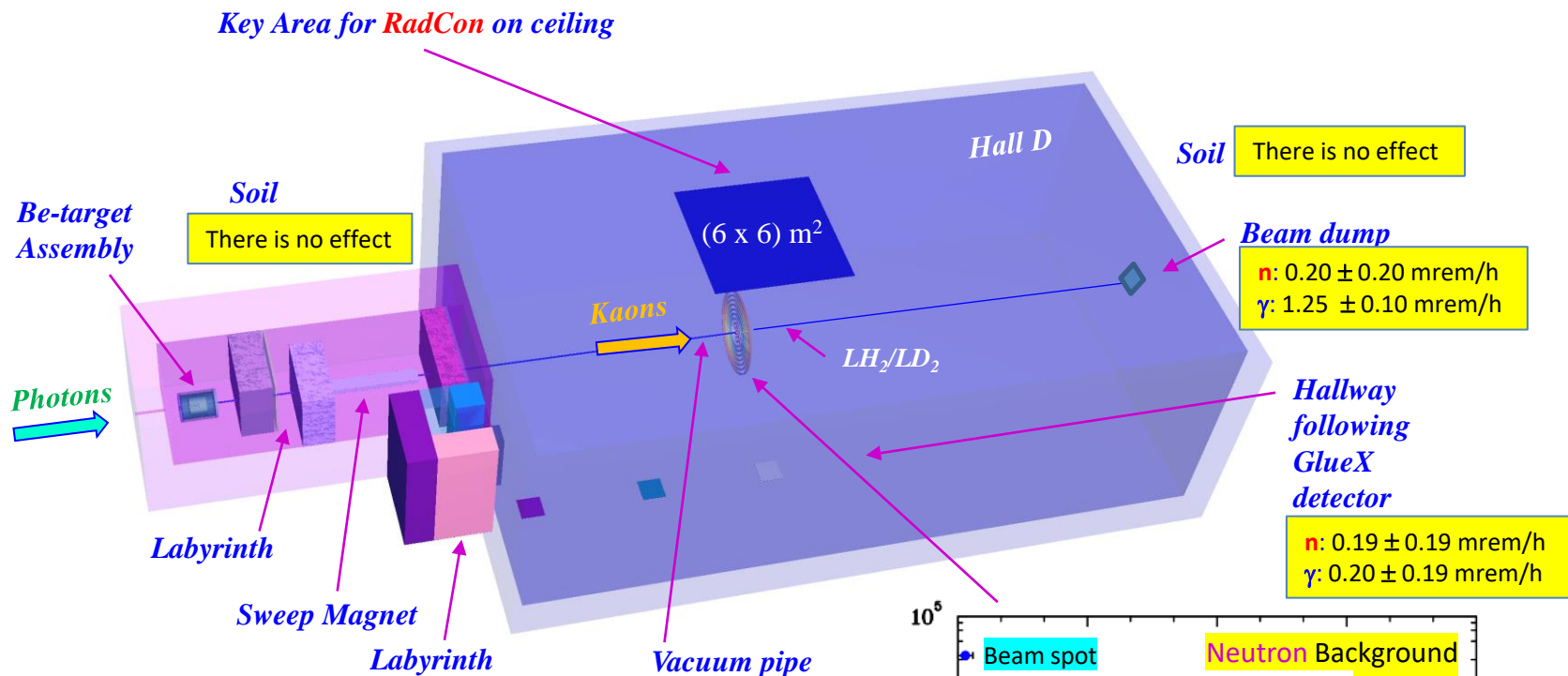
is *software* which is flexible & powerful integrated solution that helps to deliver better products faster & more efficiently.



Hall D Setting & Equivalent Prompt Dose Rate

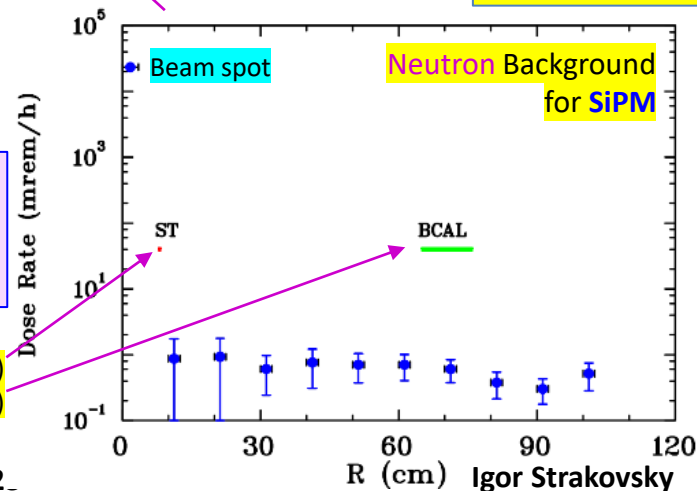
RadCon figure-of-merit = 1 mrem/h

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.

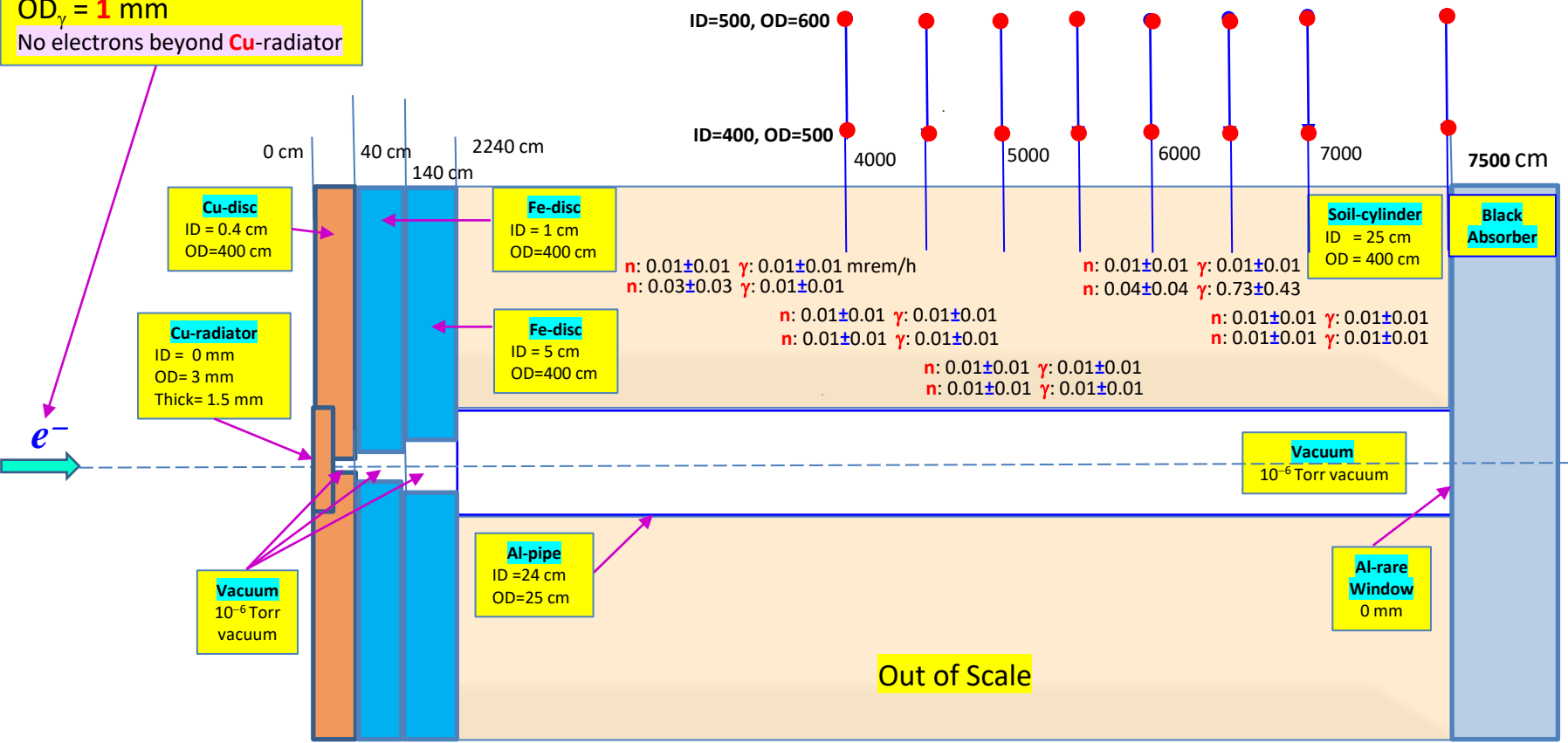
ST: E. Pooser *et al*, Nucl Instrum Meth A 927, 330 (2019)
 BCAL: T.D. Beattie *et al*, Nucl Instrum Meth A 896, 24 (2018)



Radiation Budget on Ground above Tagger Cave

RadCon figure-of-merit = 1 mrem/h

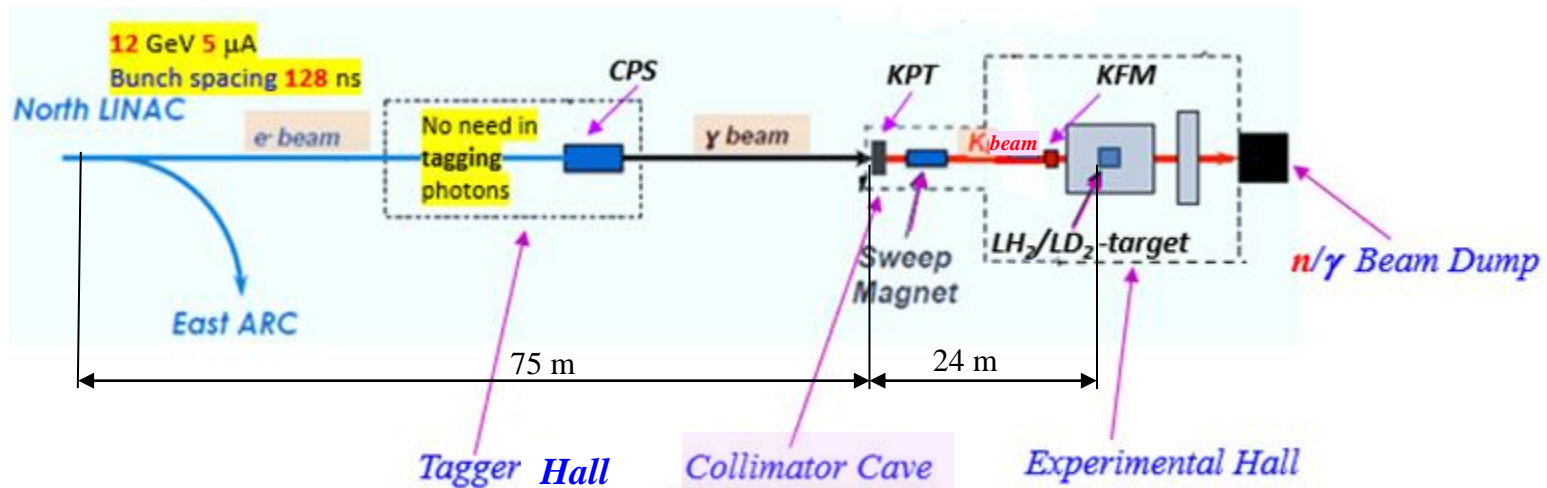
$E_\gamma = 12 \text{ GeV}$ $I_e = 5 \mu\text{A}$
 $OD_\gamma = 1 \text{ mm}$
 No electrons beyond Cu-radiator



• Radiation on ground above Tagger Cave is acceptable.

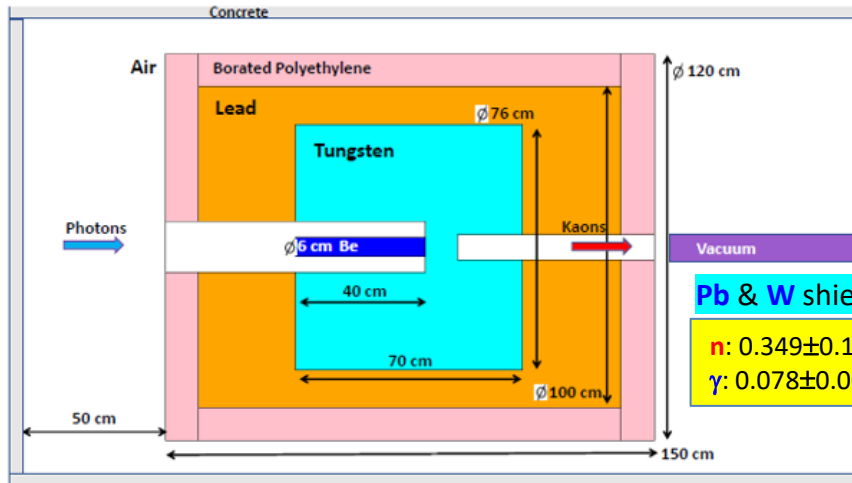
Hall D: Beam Line for K-long

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

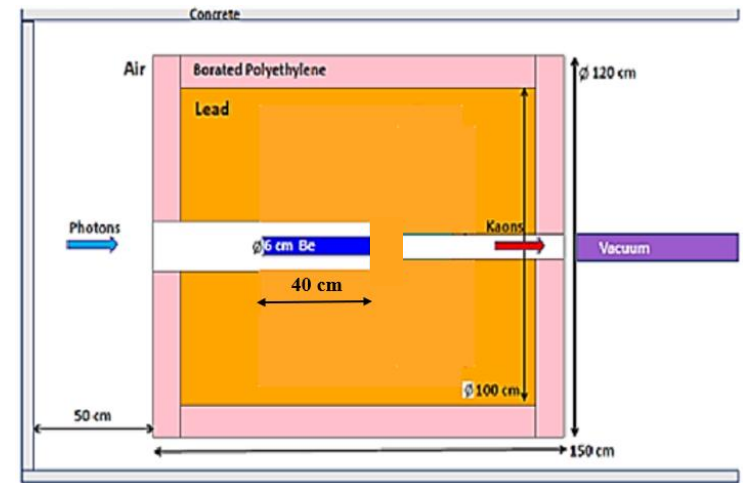


RadCon figure-of-merit = 1 mrem/h

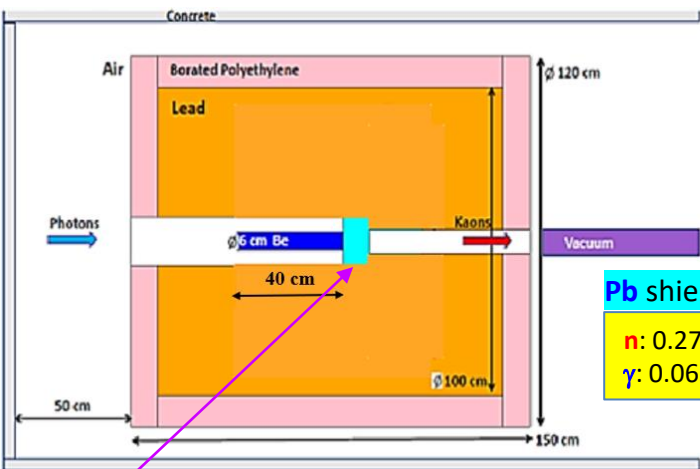
@ key area for RadCon on ceiling



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

