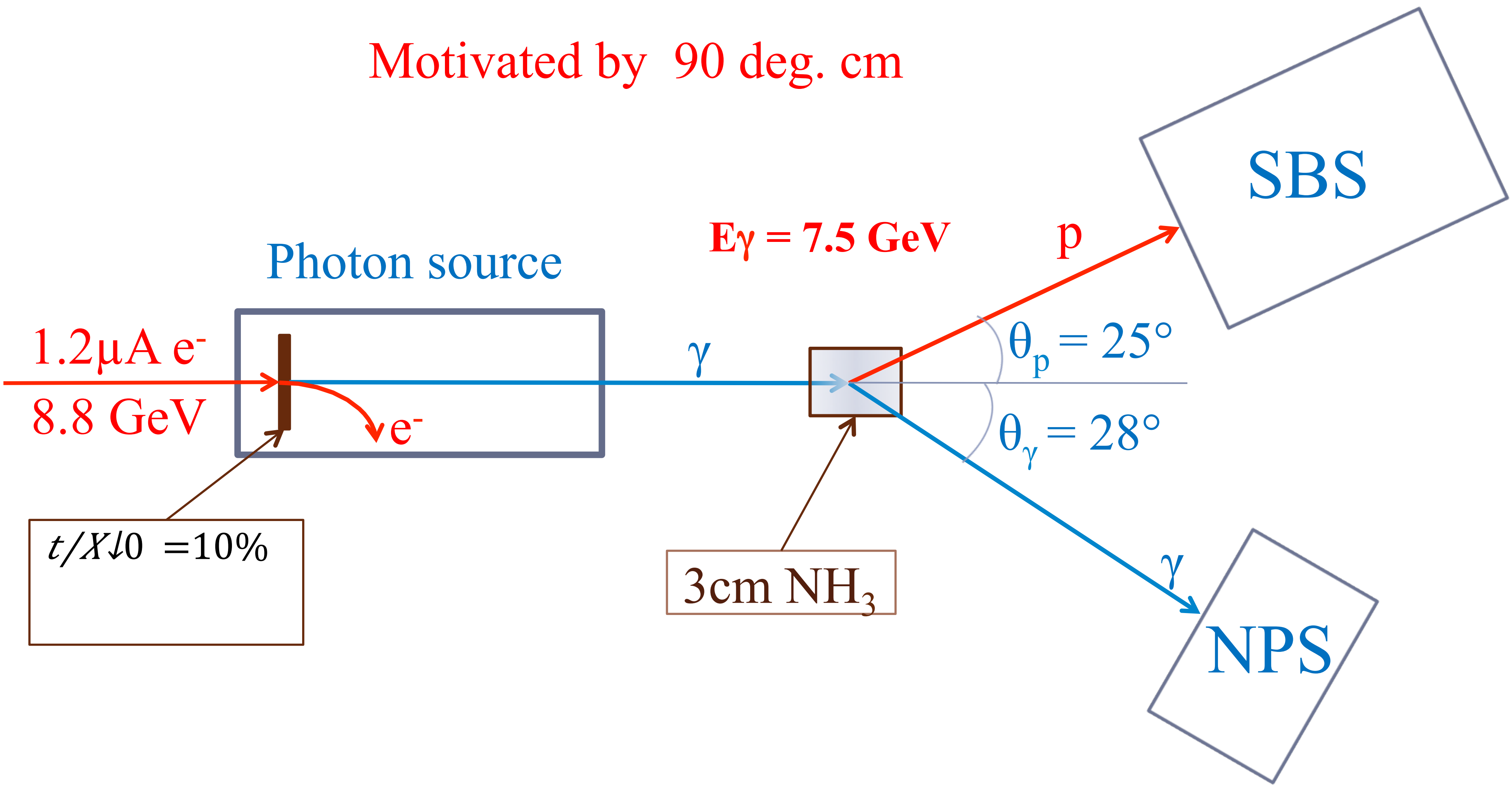
Large Acceptance Wide-Angle Compton Scattering Experiment

Bogdan Wojtsekhowski,

Thomas Jefferson National Accelerator Facility,

Experimental Setup, as shown in 11/2014



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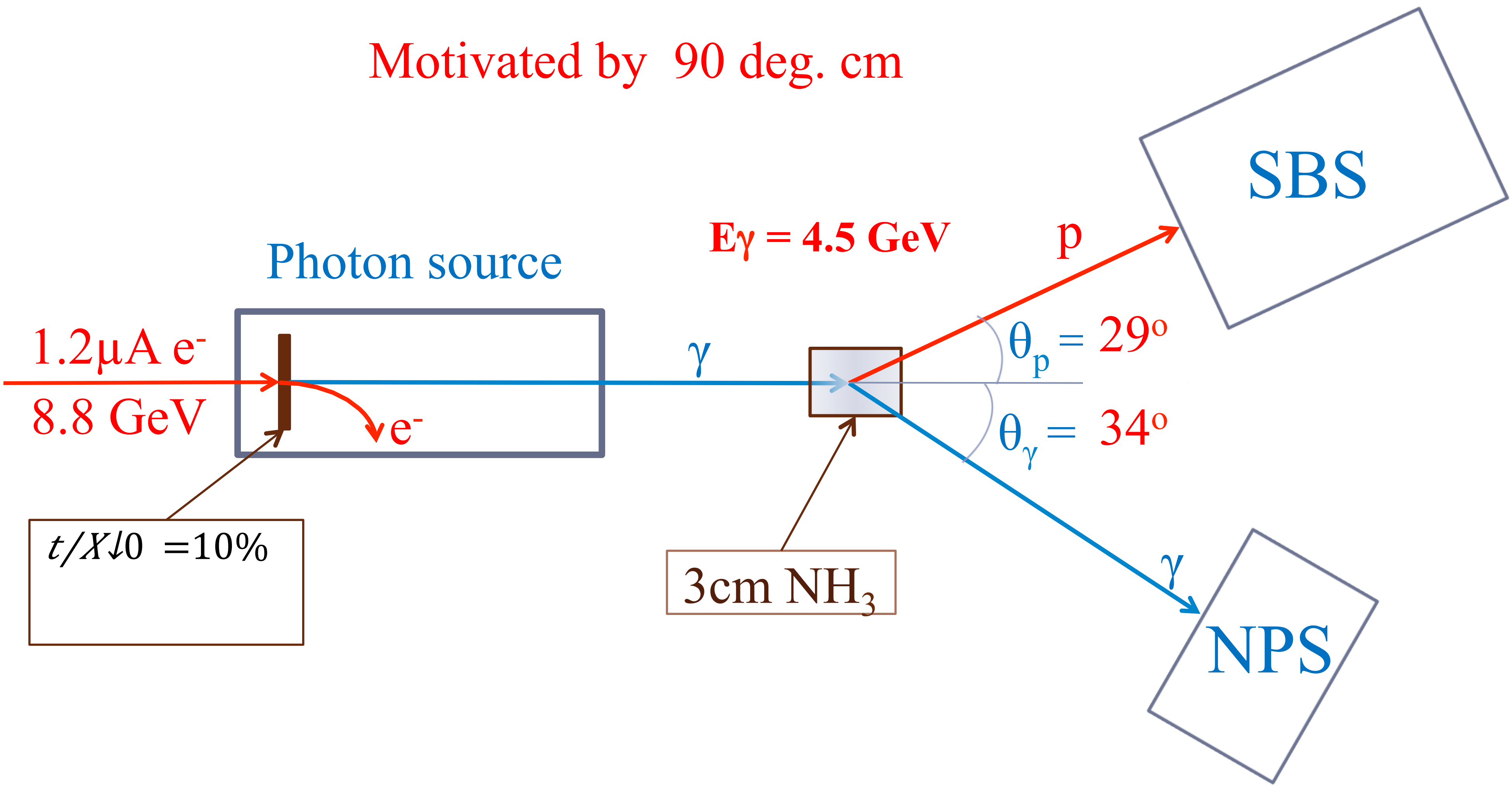
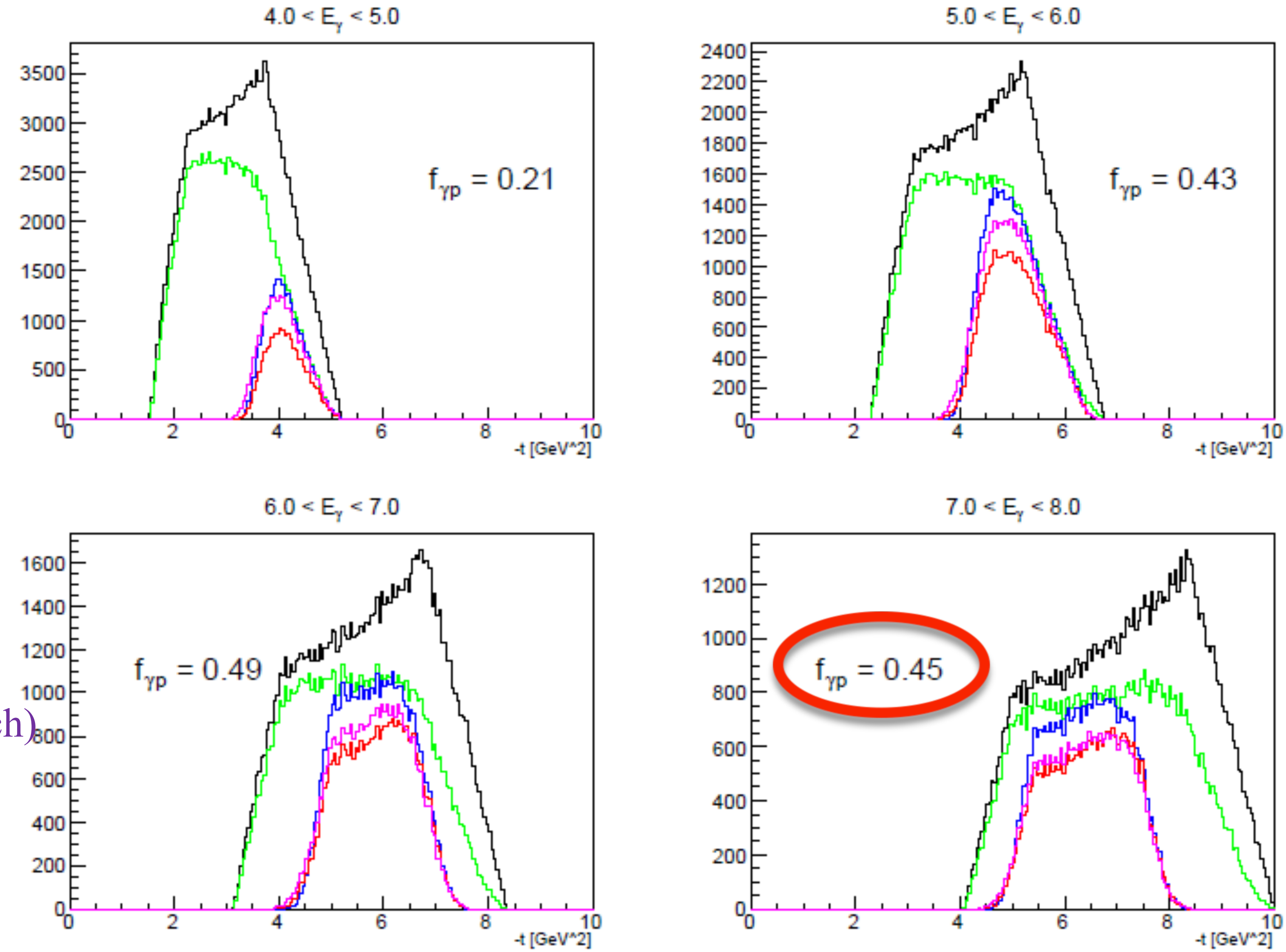


Solid angle

$$N_{RCS} = \frac{d\sigma}{dt}\frac{\left(E'_{\gamma}\right)^2}{\pi}\cdot\Delta\Omega_{\gamma} f_{\gamma p}\cdot N_p\cdot N_{\gamma}$$

- NPS acceptance
- SBS acceptance (no field)
- SBS acceptance (with SBS and target fields)
- SBS acceptance (with SBS and target fields, NPS shifted to match)



Initial State Helicity Correlation in Wide Angle Compton Scattering

Proposal 05-101

Donal Day and Bogdan Wojtsekhowski,
co-spokespersons

PAC 28

August 24, 2005

Figure 10: The simulated photon spectra for the proposed kinematics for a) for $\theta_\gamma^{cm} = 70°$ and b) for $\theta_\gamma^{cm} = 140°$. The photon spectra, in coincidence with the proton in the HMS, are indicated by the hashed area. The double hashed area corresponds to statistics used for our estimate of the expected results from the energy interval 3.9 – 4.7 GeV.

$$N_{RCS} = \frac{d\sigma}{dt}_{RCS} \left(\frac{(E_\gamma^f)^2}{\pi} \Delta\Omega_p \frac{d\Omega_\gamma}{d\Omega_p}\right) f_{\gamma p} \left(\frac{\Delta E_\gamma^f}{E_\gamma^f} \frac{t_{rad}}{X_o}\right) \mathcal{L}_{e\vec{p}}$$

where $\frac{d\sigma}{dt}_{RCS}$ is the RCS cross section (see Table 2); the factor $\left(\frac{(E_\gamma^f)^2}{\pi} \Delta\Omega_p \frac{d\Omega_\gamma}{d\Omega_p}\right)$ is the range of Δt for the given kinematics, expressed through the energy of the scattered photon and the solid angle of the proton detector; $f_{\gamma p} = 0.5 - 0.7$ is the fraction of events detected for given range of photon energy E_γ^f; $\left(\frac{\Delta E_\gamma^f}{E_\gamma^f} \frac{t_{rad}}{X_o}\right) = 0.8/4.3 \cdot 0.128$ is the number of photons per incident electron, including the photons produced in the target and virtual photons; $\mathcal{L}_{e\vec{p}} = 7.7 \cdot 10^{34}$ cm^{-2}Hz is the electron-proton polarized luminosity with the NH_3 target, including a correction for the extra heat load from the radiator.

The simulated photon spectra for the proposed kinematics is shown in Figure 10.

A test of a handbag mechanism in exclusive photon-proton reaction

A_{LL} or K_{LL} – does not matter, we need just better data to constrain the GPD models

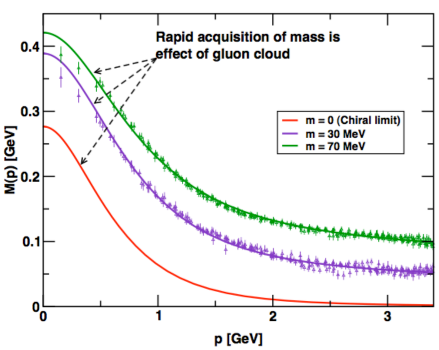
However, one can test of the handbag dominance more using the result: $A_{LL} = K_{LL}$

- In reality, the WACS K_{LL} data has a modest accuracy ~ 0.09

Selection	$K_{\rm LL}$	$K_{\rm LS}$
$\rm WACS_{this\ experiment}$	$0.645 \pm 0.059 \pm 0.048$	$-0.089 \pm 0.059 \pm 0.040$
$\rm WACS_{E99-114}$	$0.678 \pm 0.083 \pm 0.04$	$0.114 \pm 0.078 \pm 0.04$

from PRL paper

- Projected accuracy: A_{LL} - K_{LL} would be +/- 0.12; can not exclude 10% admixture



Better test of a handbag mechanism in exclusive photon-proton reaction

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However, we can test of the handbag dominance more using the result: $A_{LL} = K_{LL}$

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$\text{WACS}_{\text{E99}-114}$	$0.678{\pm}0.083{\pm}0.04$	$0.114{\pm}0.078{\pm}0.04$
$\text{Pion}_{\text{this experiment}}$	$-0.082{\pm}0.007$	$-0.296{\pm}0.007$
$\text{Pion}_{\text{E99}-114}$	$0.532{\pm}0.006$	$0.480{\pm}0.006$

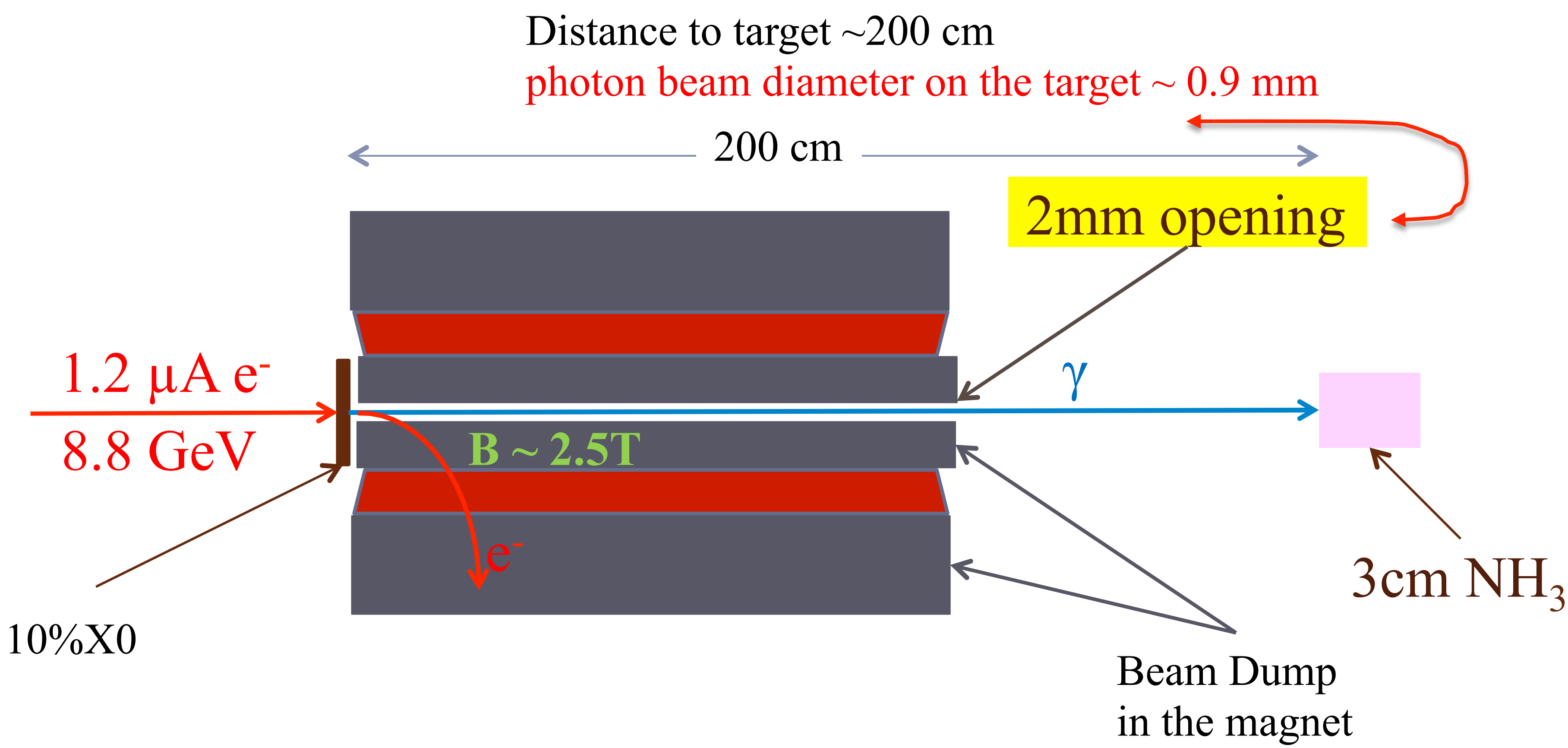
from PRL paper

◆ A new suggestion: A_{LL} - K_{LL} , a prediction in the pion photo production, an experiment needs 1% accuracy for A_{LL} , a problem of systematic error

A new comment from P. Kroll:

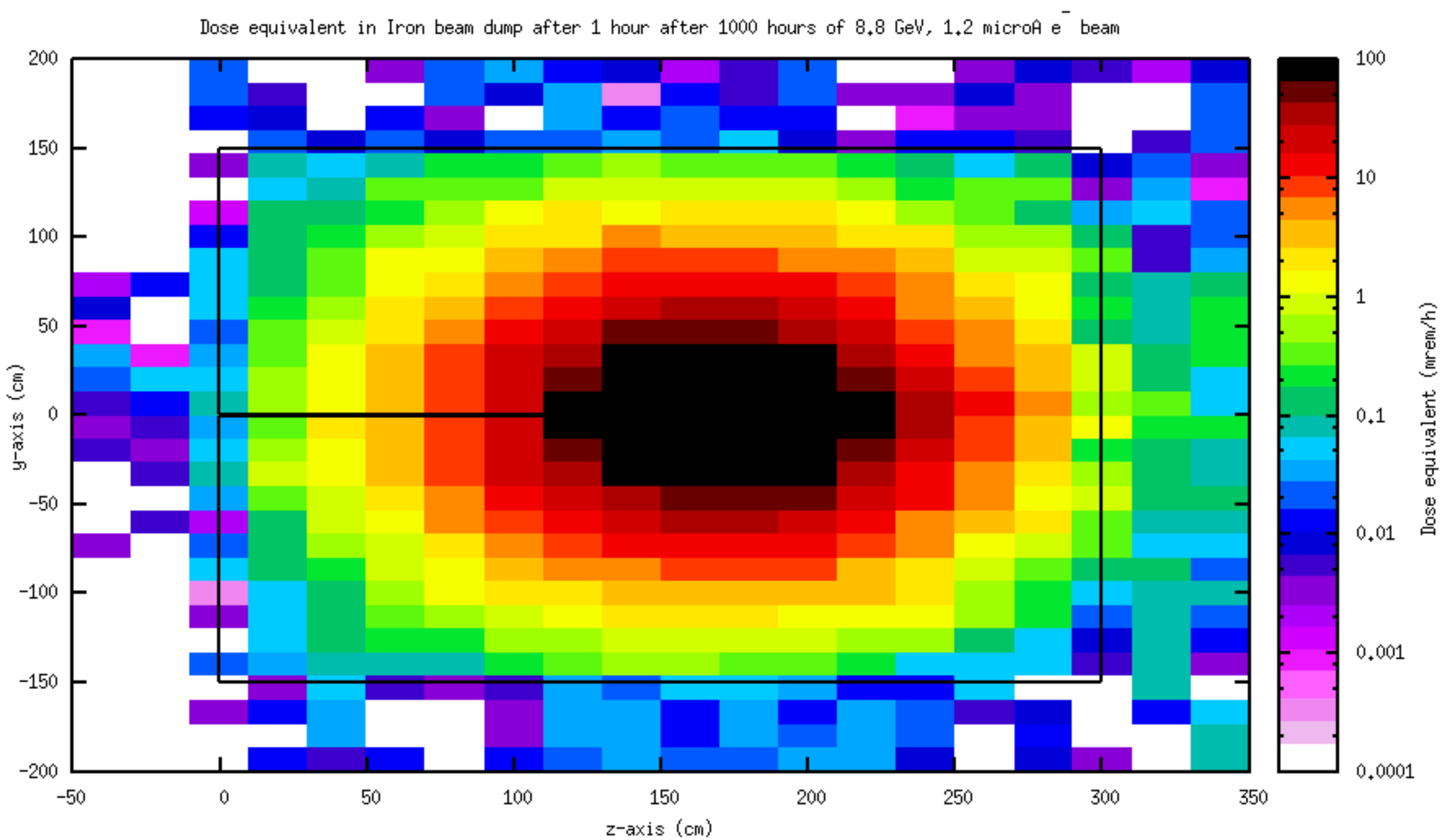
Twist-3 would be important for K_{LL}- A_{LL} in the pion photo-production process

Hermetic Compact Photon Source

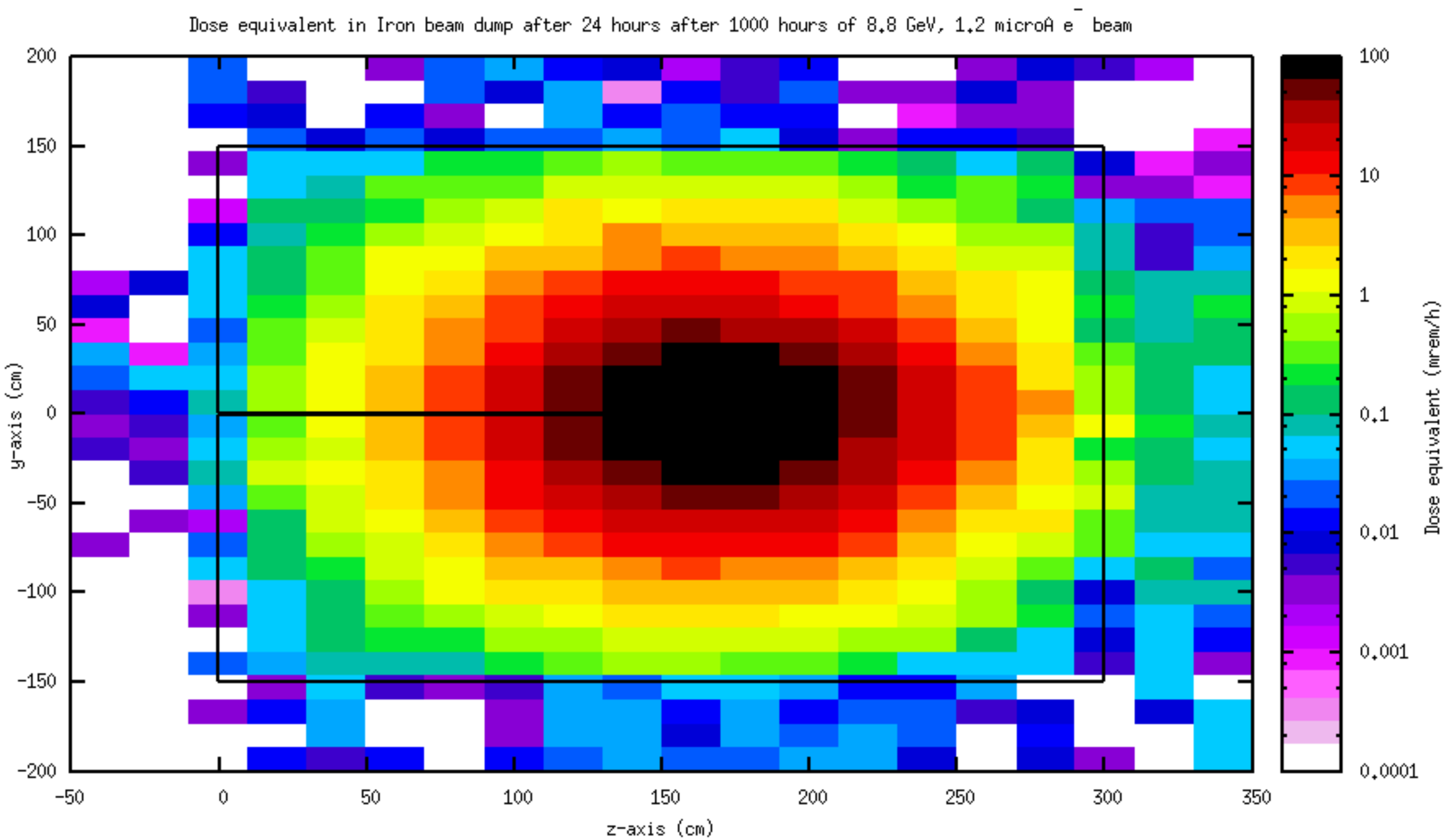


Novel concept allows high photon intensity and low radiation in the hall

1000 hours HCPS run (1.2 mA, 8.8 GeV) after 1 hour cool down. 3x3x3 m^3 Fe box

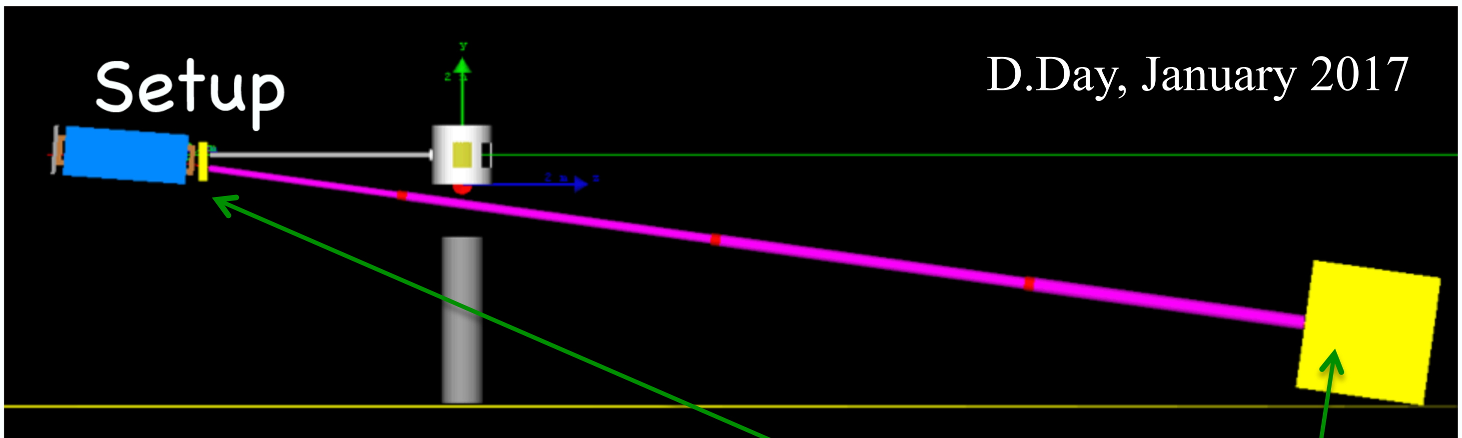


1000 hours HCPS run (1.2 mA, 8.8 GeV) after 24 hours cool down. 3x3x3 m^3 Fe box



Regarding a traditional "beam dump" scheme

The shielding a "Separated Function Pure Photon Source" would be difficult and expensive due to the large size of the area which requires shielding and a wide electron energy spectrum.



~ 20 m

25%   75%

Power in the tail is defined by the integral

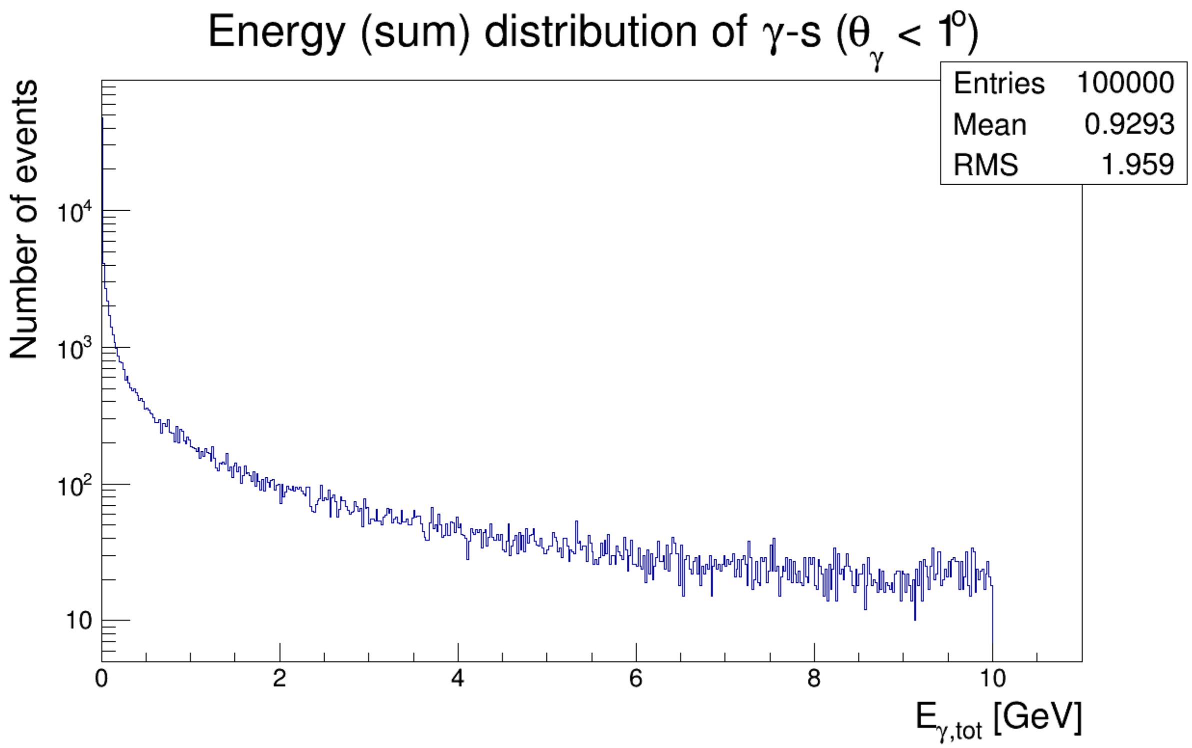
$$P_b \cdot t_{rad} \cdot \int_{0.03E_b}^{E_b} \frac{E_b - E_\gamma}{E_b} \frac{dE_\gamma}{E_\gamma}$$

7.5 kW

GEANT4 MC simulation for 10 GeV beam on 10% radiator

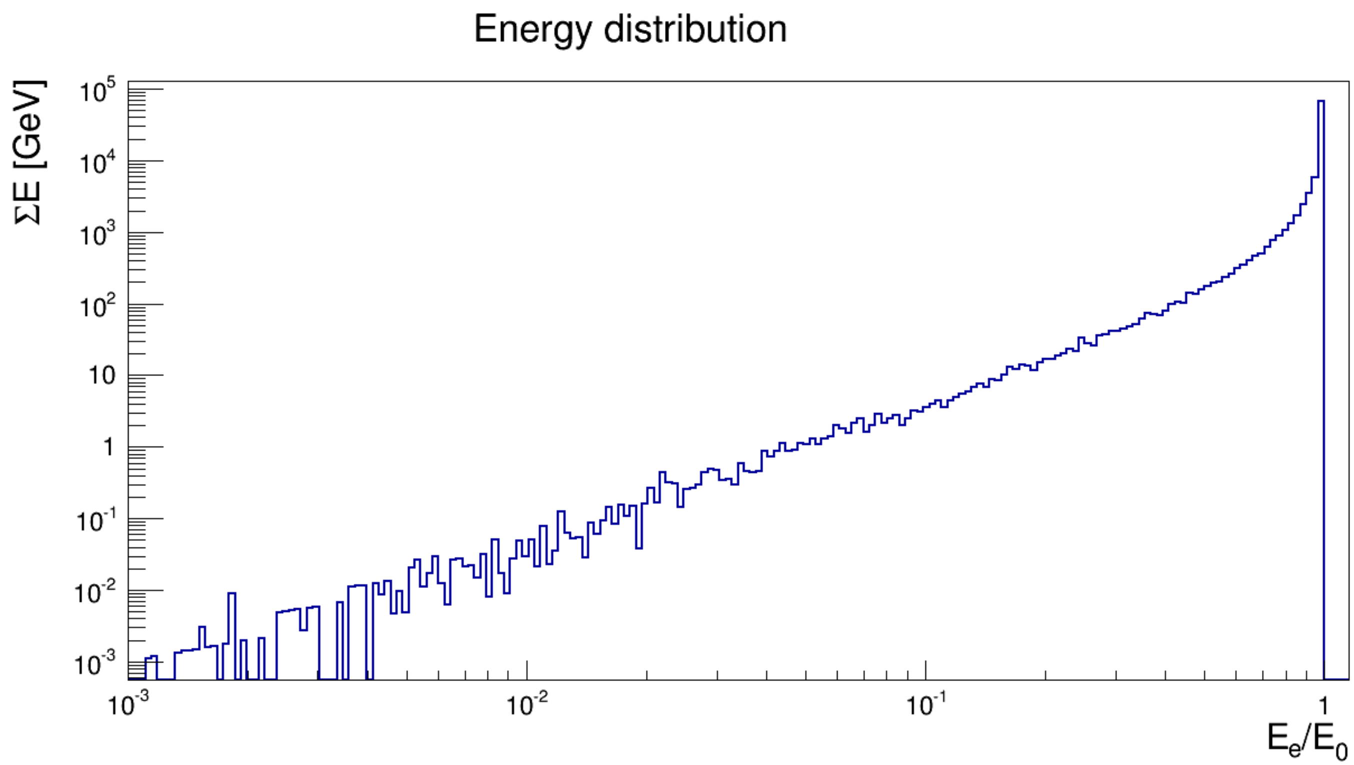
Photon energy spectrum

Average gamma energy = 0.929342 GeV,
average electron energy = 9.03508 GeV



GEANT4 MC simulation for 10 GeV beam on 10% radiator

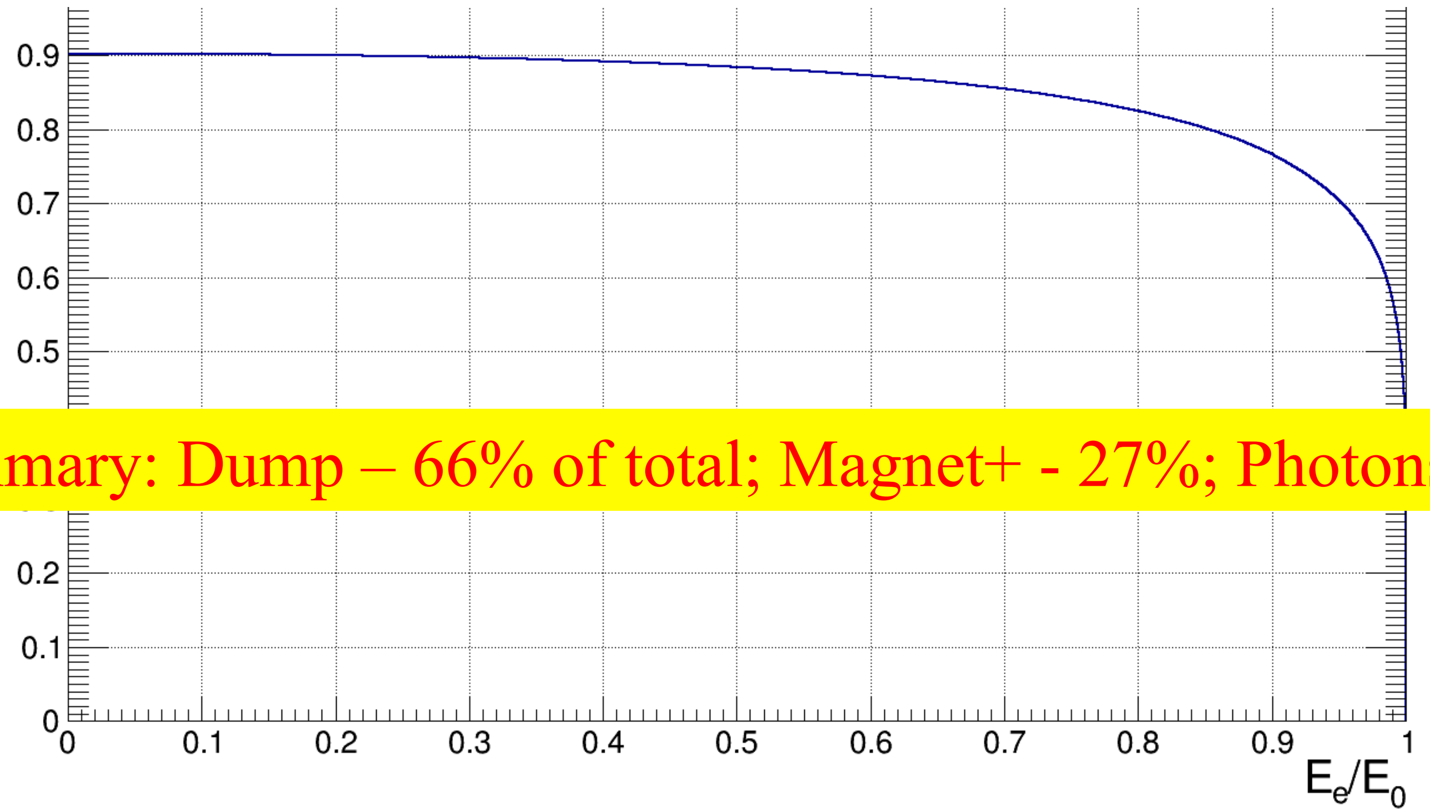
Electron energy spectrum



E/E_0=0.01, I=0.902542
E/E_0=0.70, I=0.85509
E/E_0=0.80, I=0.825077
E/E_0=0.90, I=0.766518
E/E_0=0.95, I=0.704204
E/E_0=0.97, I=0.660163

At $(1-E/E_0)$= 0.03 - cut value
The "main" beam has only 66% of total power
Photon beam take up to 10% (in 1 degree col.)
Resulting in 24% + 3(4)% are in the magnet and …

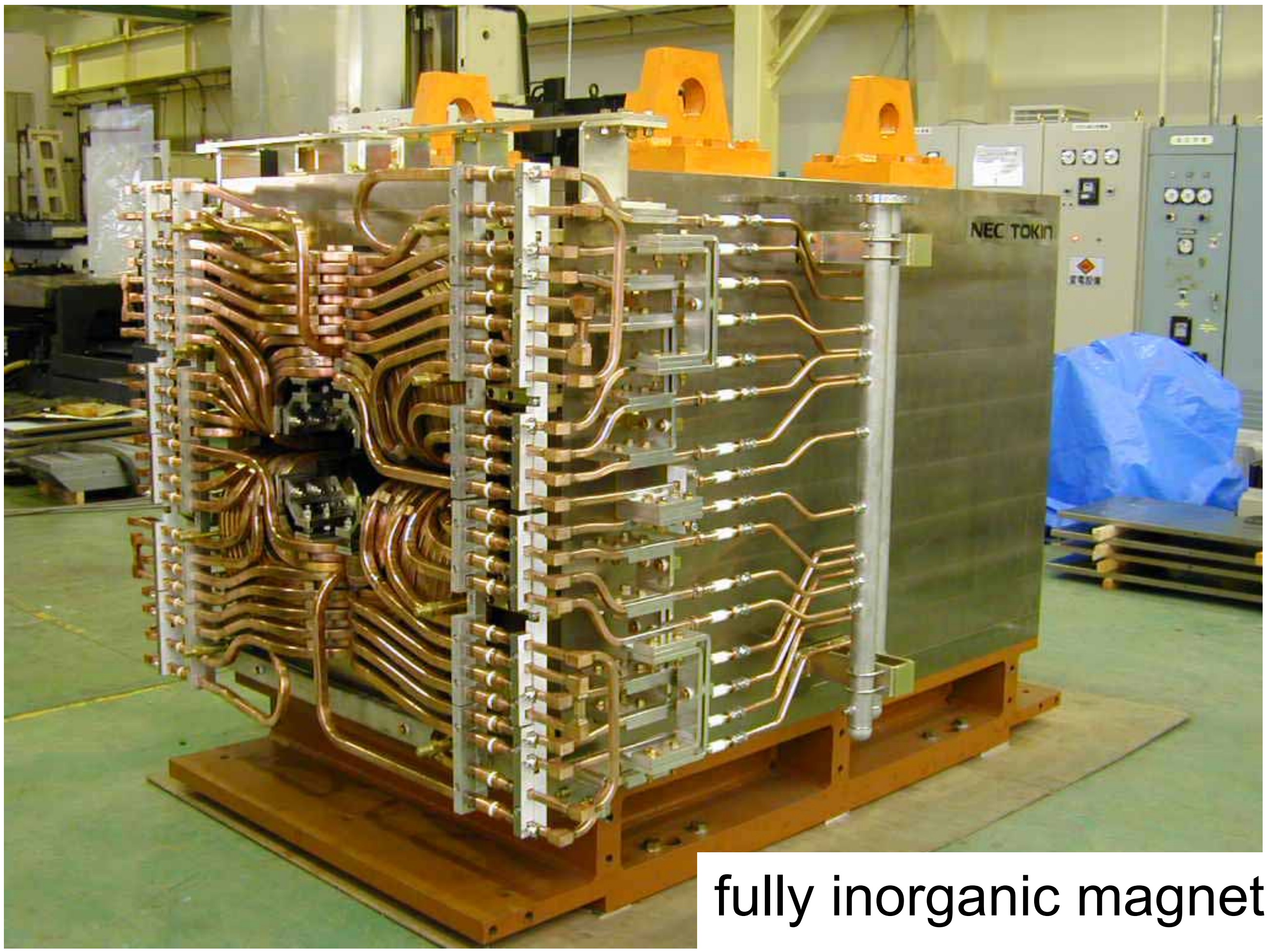
Fraction of incident power in the electrons vs. lower energy cut



Summary: Dump – 66% of total; Magnet+ - 27%; Photons – 7%

Radiation Hard Magnet

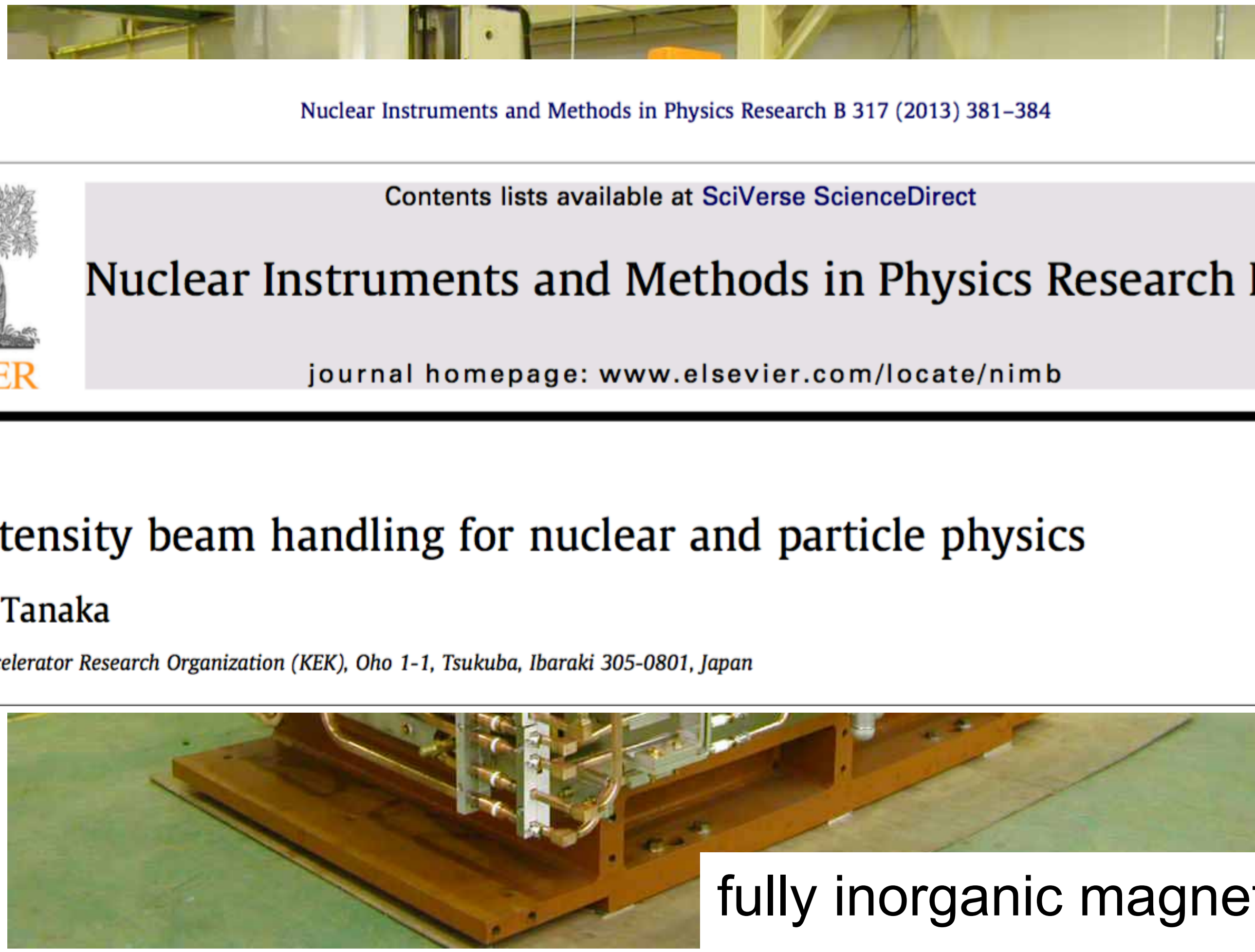
❖ J-PARC – warm magnet



fully inorganic magnet

Radiation Hard Magnet

❖ J-PARC – warm magnet



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BEAM INTERACTIONS WITH MATERIALS AND ATOMS

High intensity beam handling for nuclear and particle physics

CrossMark

Kazuhiro Tanaka

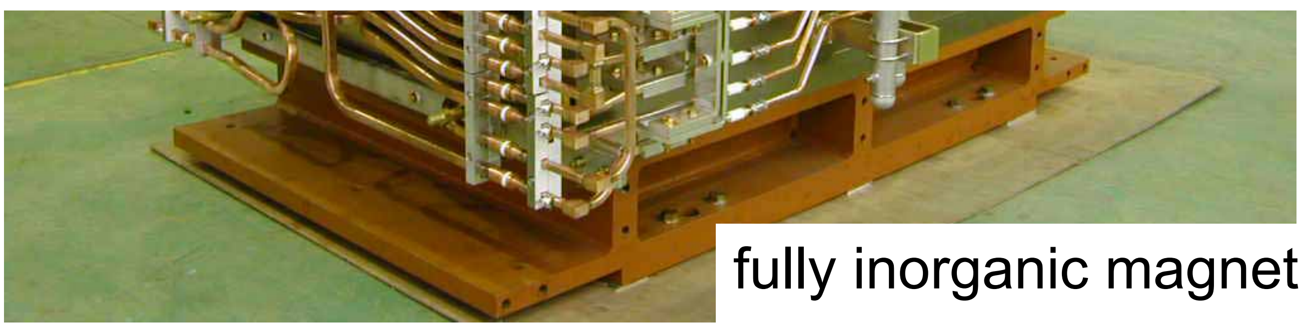
High Energy Accelerator Research Organization (KEK), Oho 1-1, Tsukuba, Ibaraki 305-0801, Japan

fully inorganic magnet

Radiation Hard Magnet

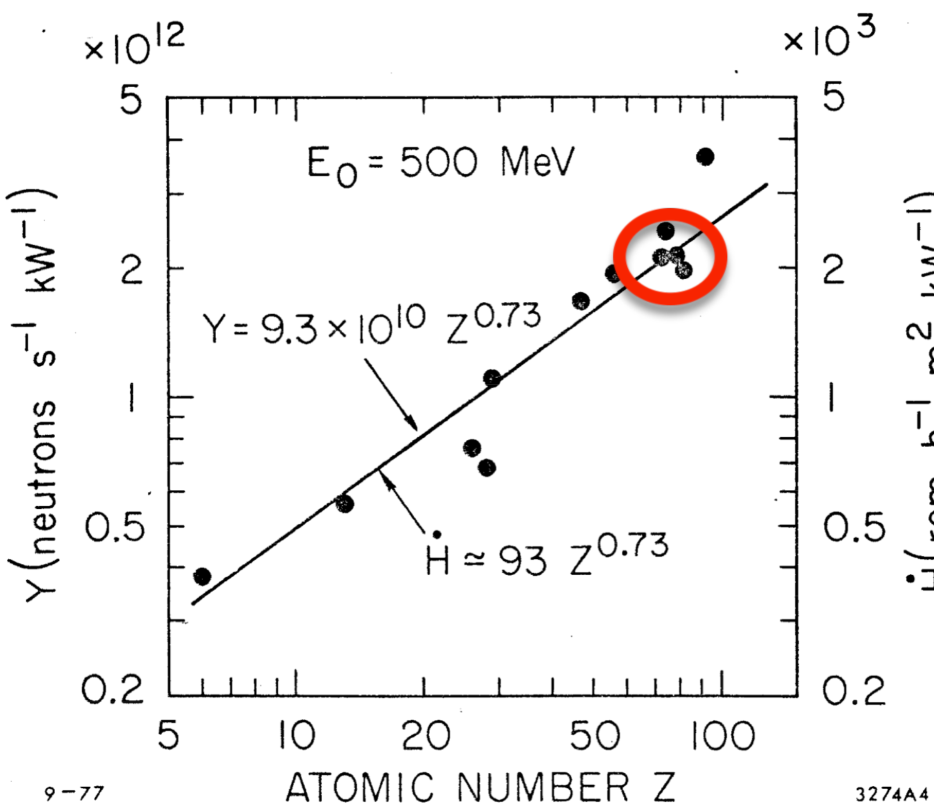
❖ J-PARC – warm magnet

```
100 kRad/hour = 1K Gy/hour = 5M Gy/year (assuming 5000h operation/year)
-> 5x10e7 Gy/10 years.

This radiation dose is not very serious if you select appropriate
insulation resin.
Some epoxy resin can survive well against 5x10e7 Gy.  However, if you select
BT resin, magnet will be much stronger against the radiation dose.

There are several manufacturer of electromagnets in Japan.  I can ibtroduce
some of companies for you.
```



fully inorganic magnet

The neutron shielding

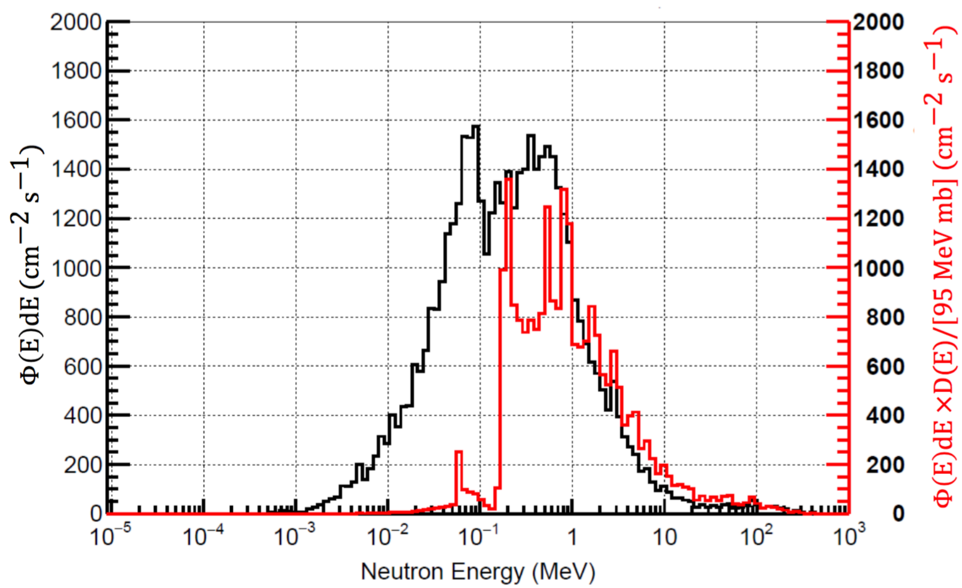


$2x10^{12}$ n/kW x 10 kW = 2 x 10^{13} n/s

1 millirem = 27,000 n/cm^2 (T= 1 MeV)

< 3 rem/hour during beam ON at 2 meters is required for the target magnet

a shielding factor needs to be ~ 1 x 10^3



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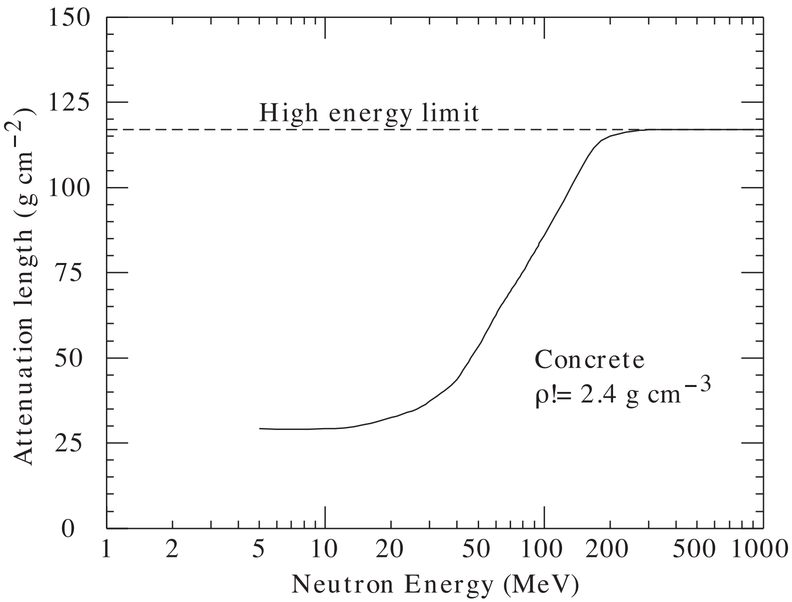


$2\text{x}10^{12}$ n/kW x 10 kW = 2 x 10^{13} n/s

1 millirem = 27,000 n/cm^2 (T= 1 MeV)

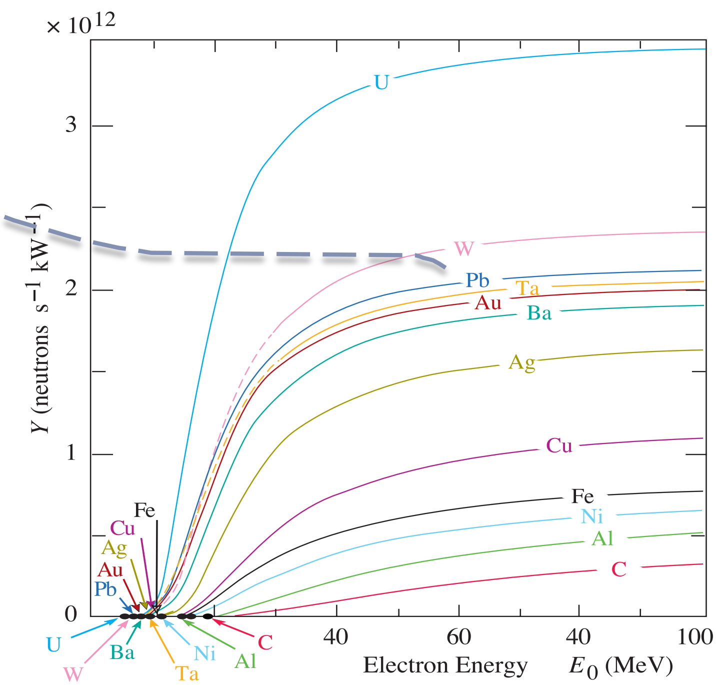
3000 millirem/hour at 2 meters is required

a shielding factor needs to be ~ 1 x 10^3

An estimate

Factor e requires 30 g/cm^2 ->
12.5 cm of concrete or 4 cm iron

A factor 1 x 10^3 needs the thickness of 25 cm of iron
We have 150 cm of iron in the HCPS proposal
However, the rad. source is long: 20 X0 => 35 cm



Material cost

Market cost, quotation, density, length atten. (factor 100)

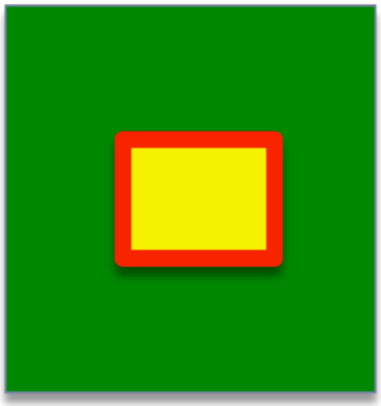
	Tungsten	Copper	Lead	Iron
Cost	\$11.4/lbs	\$2.7/lbs	\$1.0/lbs	\$0.31/lbs
Type	powder, \$60 /lbs			slab, \$1-2/lbs
Quotations	\$16-18/lbs			
Density	15 g/cm^3 (<18.3)	8.9 g/cm^3	11.3 g/cm^3	7.8 g/cm^3
Att. length	30 cm			60 cm
comment	need a container			magnetic

The shielding factor and cost

Shielding factor, $A_0 = 2 \times 10^4 \sim R \times \rho$

Sphere cost $\sim R^3 \times C \times \rho$

$\sim A_0^3 \times C / \rho^2$



Outside shielding volume of 3x3x3 m^3 total:

tungsten (15 g/cm^3)~7.5 m^3, 112 tons

lead (11.3 g/cm^3) ~ 12 m^3, 136 tons

iron (7.8 g/cm^3) ~ 26 m^3, 200 tons

Tungsten option cost is \$4.0M

Lead option cost is \$1.5M

Iron option cost is \$0.7M

Material cost

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Lot Title	Event	Lot	Qty.	Lot Price
 104,800 lbs Approx. Lead scrap, to include but not limited to Bagged shielding. This sale is located at Ft. Lewis, WA....	40702	8600	104,800 lbs.	**Sealed Bid**

48 tons ~ 4.2 m^3

Material cost

will be used in
NPS magnet
27 tons

The shielding factor and cost

Shielding factor, A_0 = 1 x 10^3 ~ R x ρ

Sphere cost ~ R^3 x C x ρ

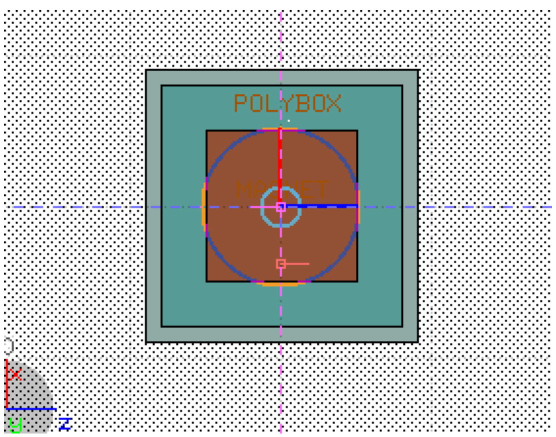
~ A_0^3 x C / ρ^2

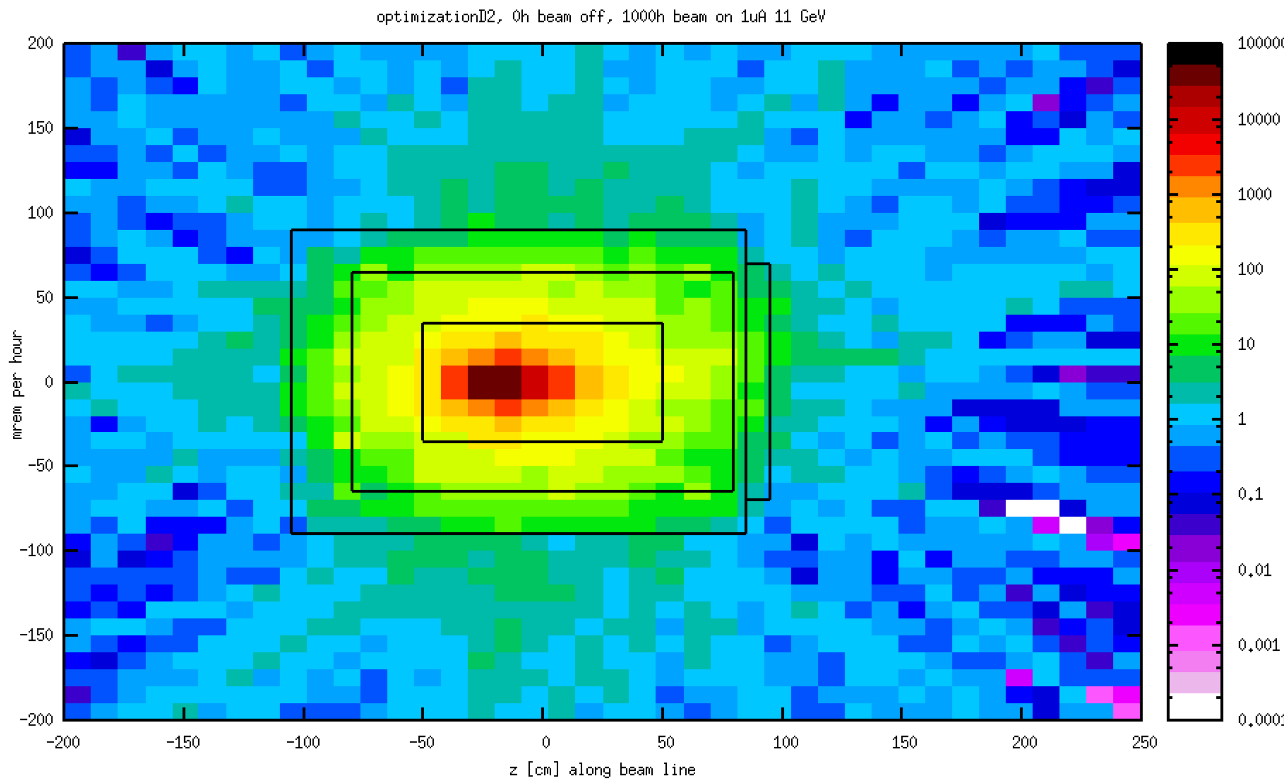
What factor is needed?

It looks that with 3x3x3 m^3 of iron the A_0 factor is too good

With A = 0.1 x A_0 , all-iron case -> 10% weight reduction

Structure optimization -> FLUKA => 30-40 tons

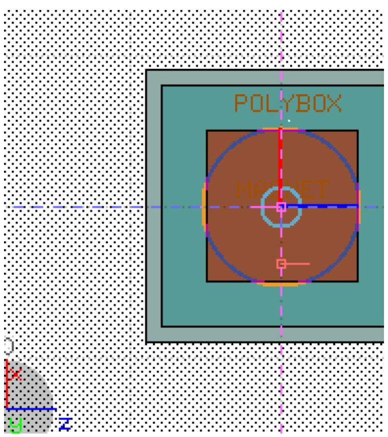


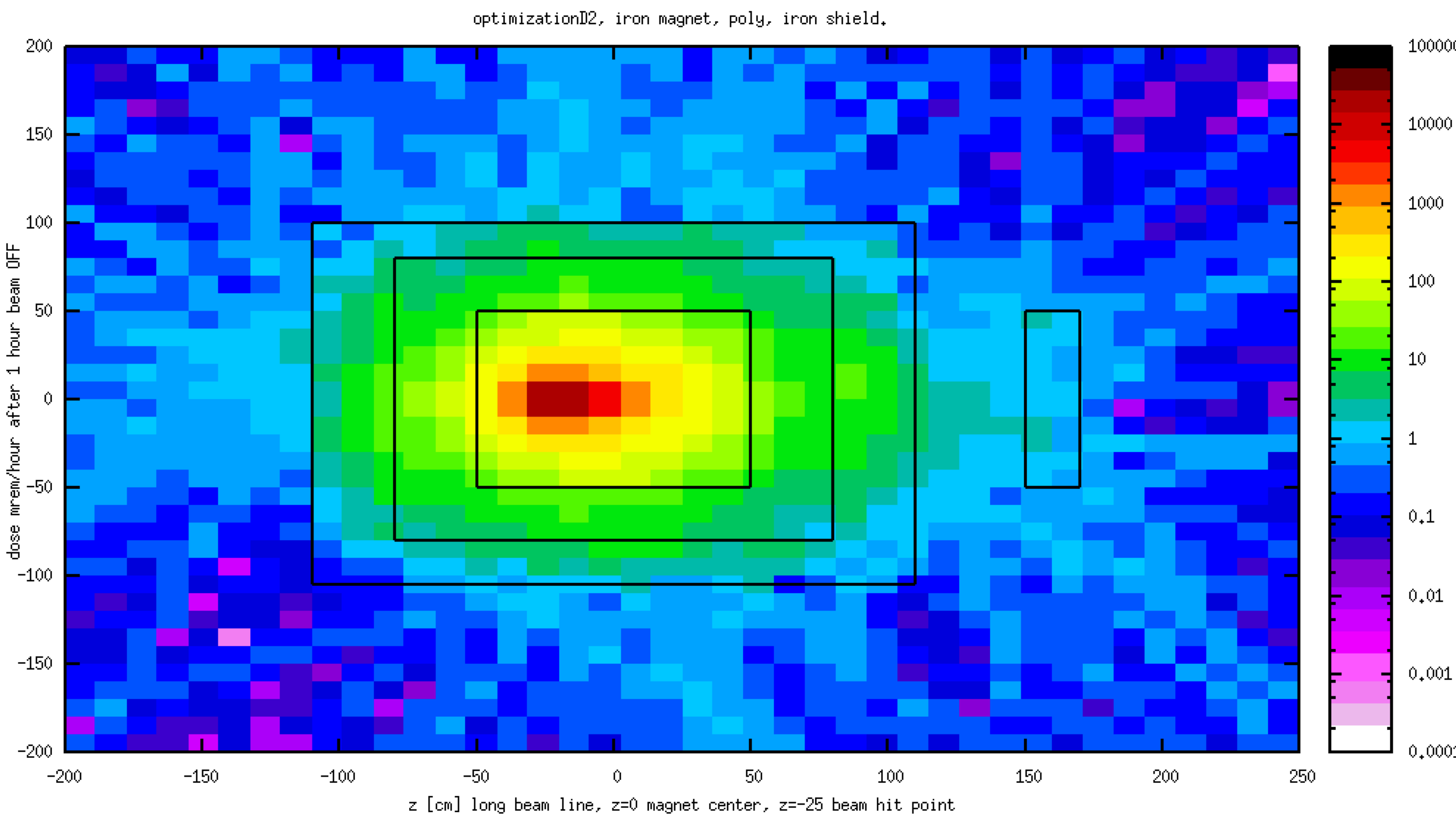


Optimization of shielding structure

Two regimes to calculate radiation at the target, DAQ, and both detectors:

a) At nominal current 1 μA with beam ON – Dose < 10 Rad/h (by Gabriel)
b) After 1000 hours 1 μA beam, beam OFF for 24 hours ~ 1 mrem/h



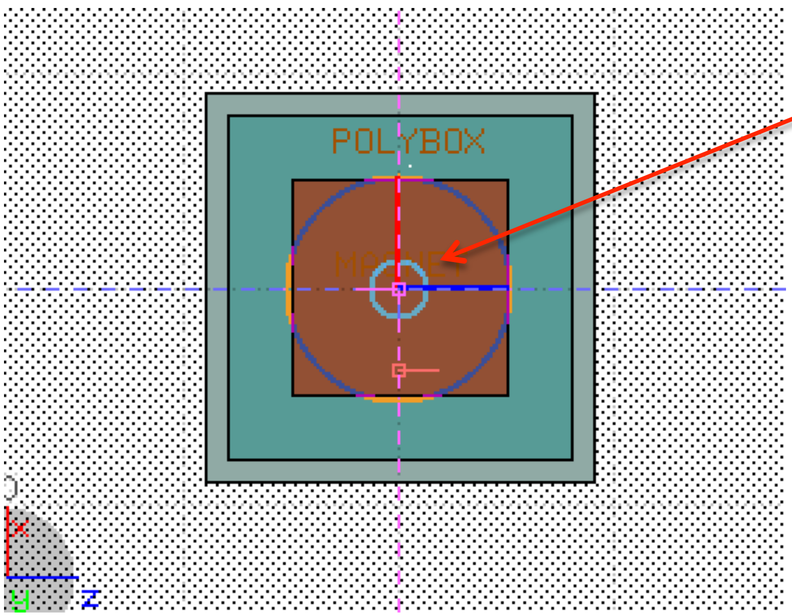


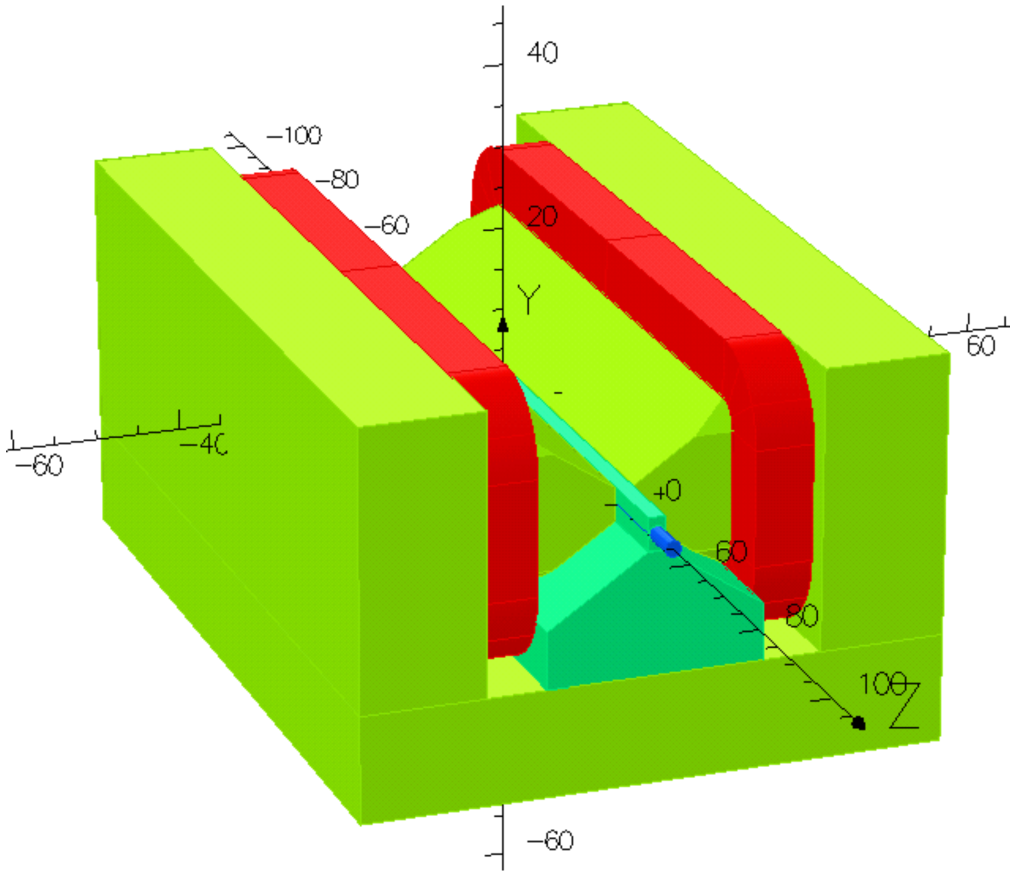
B. Wojtsekhowski

Optimization of shielding structure

Weight components, for example:

1) Magnet 0.7 m x 0.7 m x 1 m + insert ~ 5 tons





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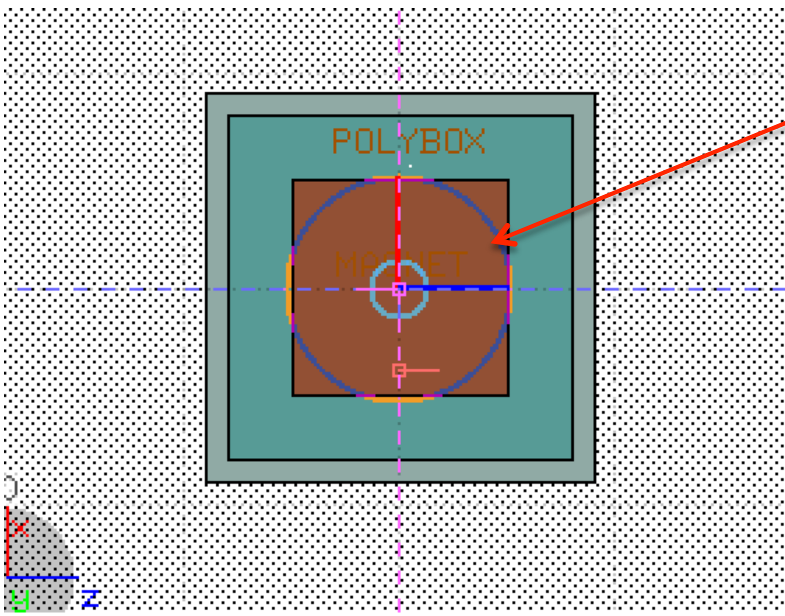
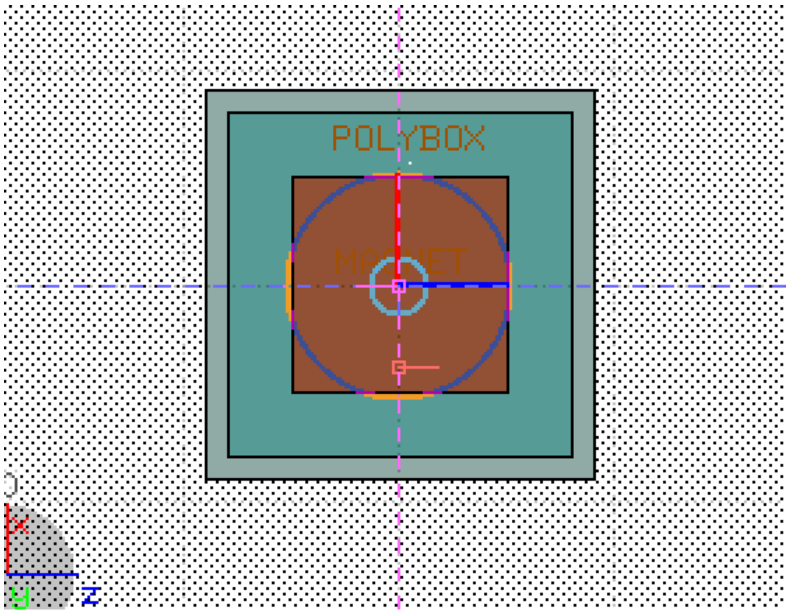


Weight components, for example:

1) Magnet 0.7 m x 0.7 m x 1 m + insert ~ 5 tons
2) Tungsten absorber 0.3 m thickness ~ 35 tons
3) Polypropylene shell 0.3 m thickness ~ 2.5 tons

Optimization of the shielding structure



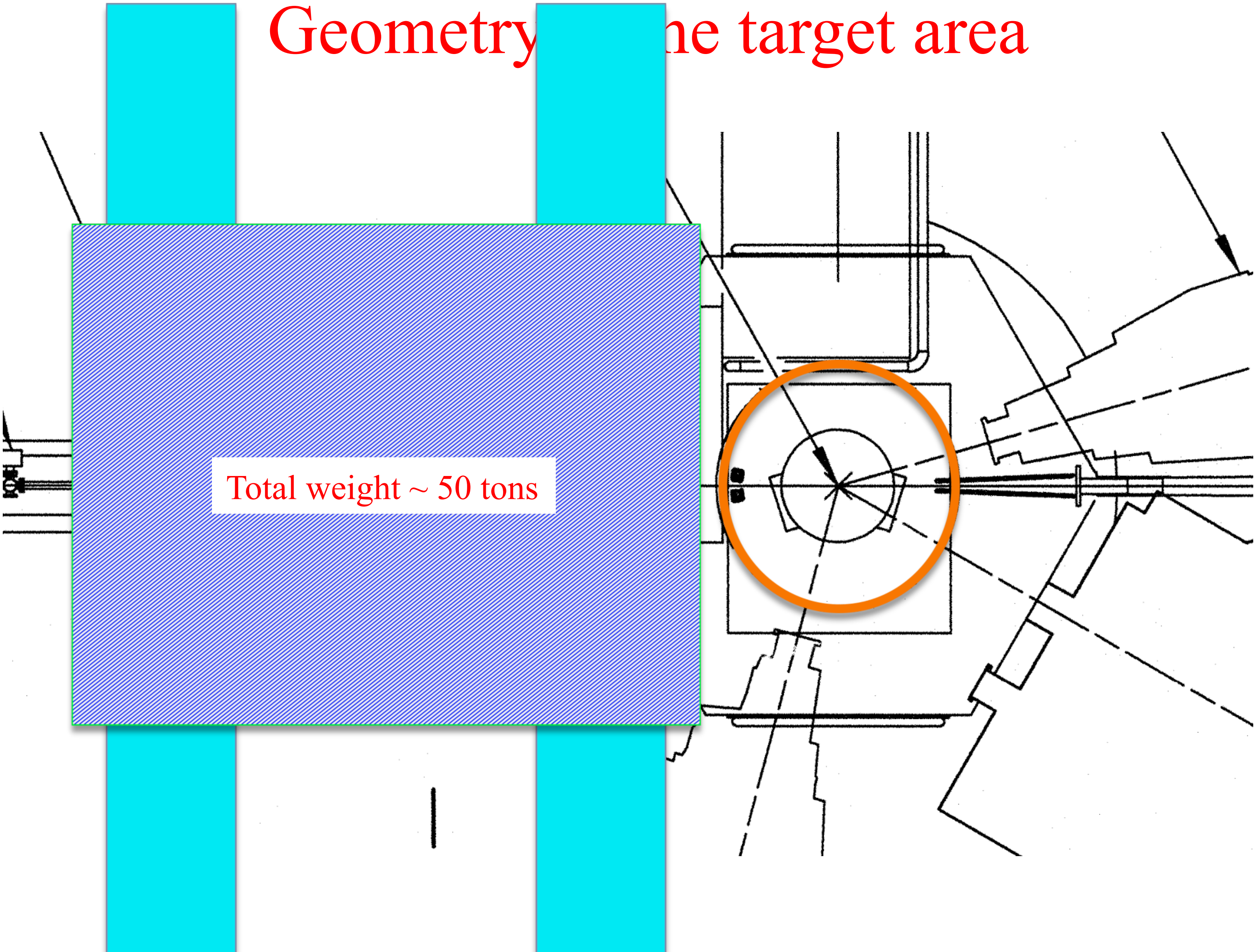
Weight components, for example:

1) Magnet 0.7 m x 0.7 m x 1 m + insert ~ 5 tons
2) Tungsten absorber 0.3 m thickness ~ 35 tons
3) Polypropylene shell 0.3 m thickness ~ 2.5 tons
4) External shell ~ 2 tons

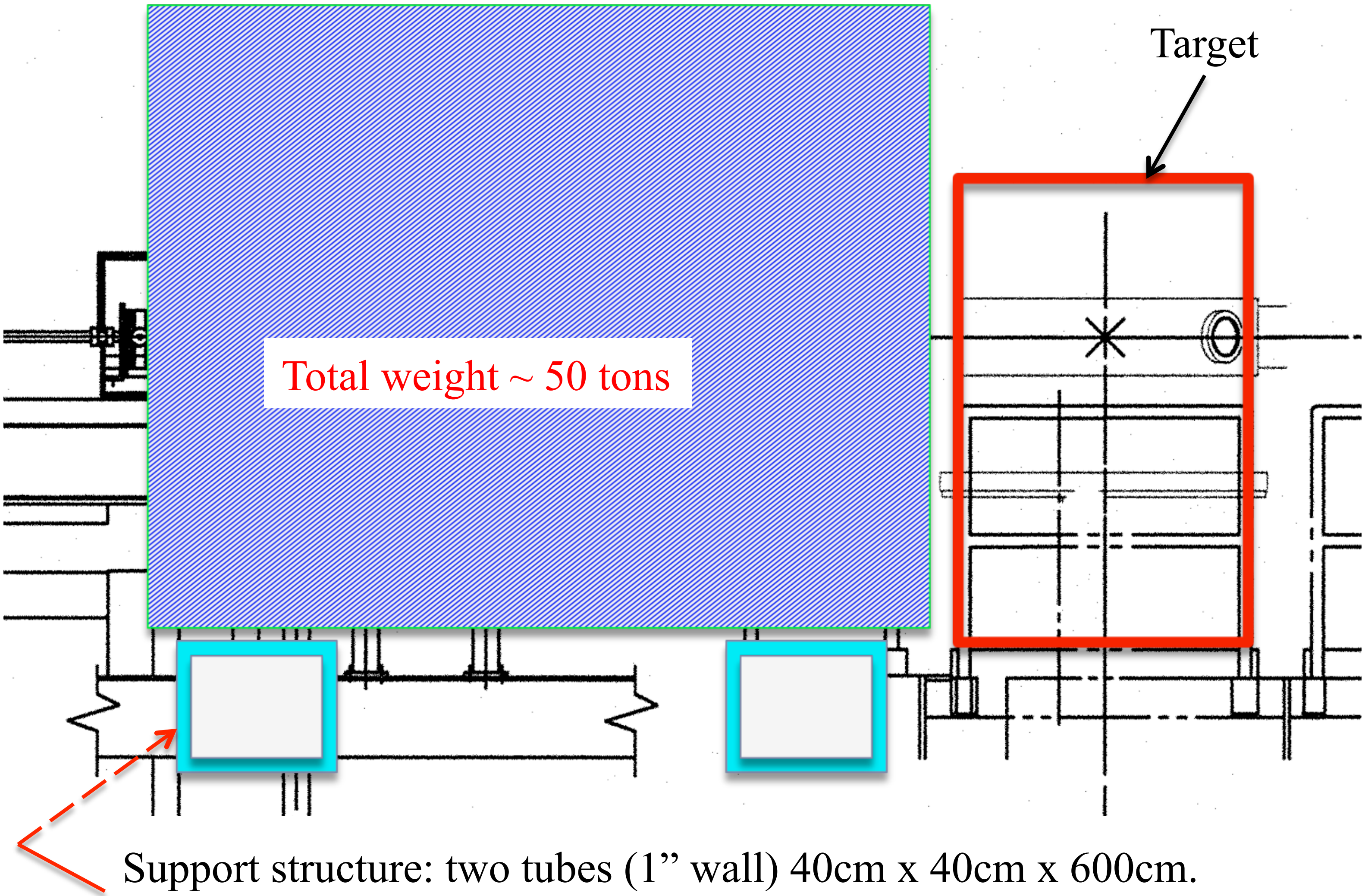
Total weight ~ 50 tons

Cost of material ~ $500k

Geometry ... he target area



Geometry in the target area

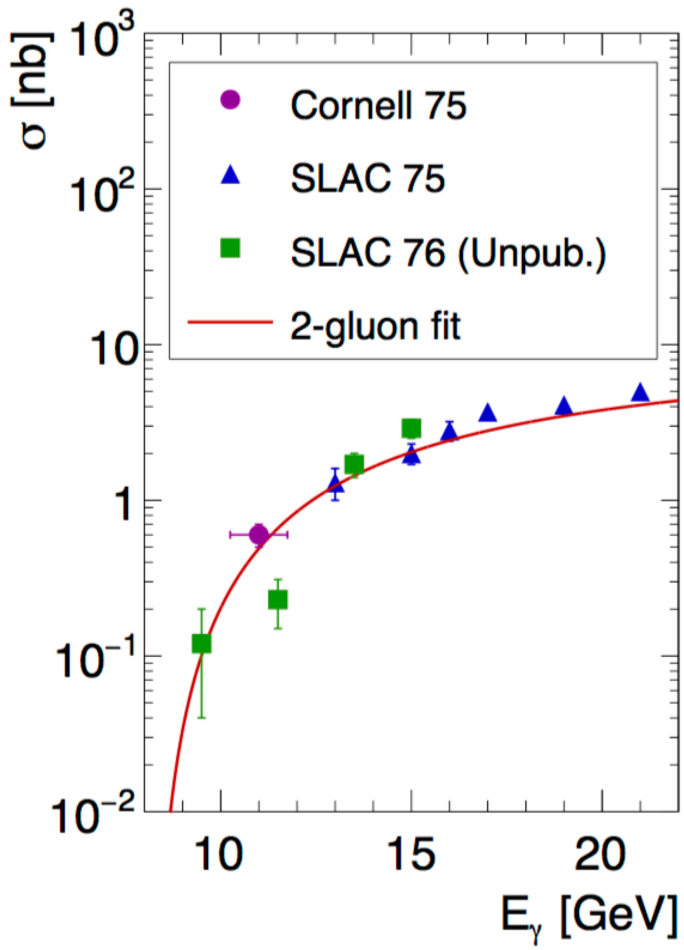


Support structure: two tubes (1” wall) 40cm x 40cm x 600cm.

Stress is of 2300 kG/cm^2 < acceptable for A36; Y= 36000 psi ; 36k/14.7

Hot physics to do with HCPS

From E12-16-006 proposal



Mechanism of J/Psi near threshold via ALL/ALS

Photon flux (2 micro Amp) ~ 10^{10} in a 100 MeV bin

J/Psi rate from the pol. Target (3 grams) is ~ 20 Hz

Acceptance ~ 50 msr/6 sr ~ 10^{-2} , e+e- ~ 6%

1000 counts per day => dA ~ 0.1 per day