# ILC Collimator Backgrounds

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U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

# Overview

**Muon production from halo in collimator absorbers**

- Predominantly coherent production from high-energy photon - nuclei interactions (Bethe-Heitler process): $\gamma + A \rightarrow A' + \mu^+\mu^-$
- Also direct annihilation of positrons on atomic electrons contributes at few-% level: $e^+ + e^-$ -> $\mu^+\mu^-$
- Consider flux @ detector with "donut" and/or muon wall shielding solutions
- Potentially important background for detectors

**Turtle halo particle tracking with MUCARLO**

- $E_{cm}$=500 (TDR) & 250 GeV

**Lucretia halo particle tracing with built-in GEANT4 model interface**

- $E_{cm}$=500 GeV (TDR)

**Other radiation considerations**

- Photons, neutron flux @ detector
- Shielding requirements local to absorbers

# Halo Collimation Systems

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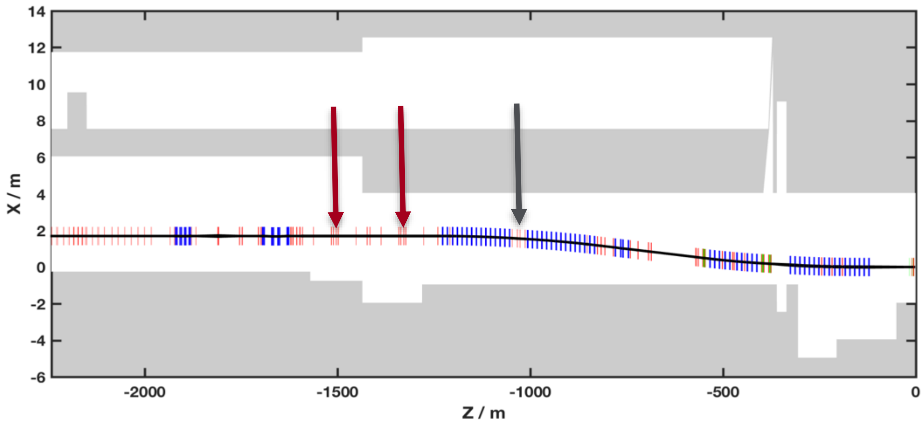
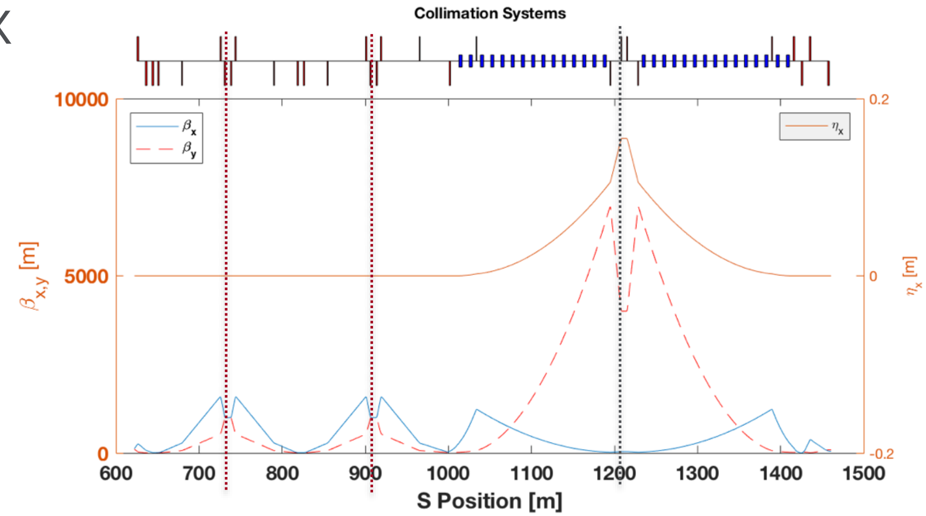
## Betatron COLL SP2 & SP4

Energy COLL SPEX



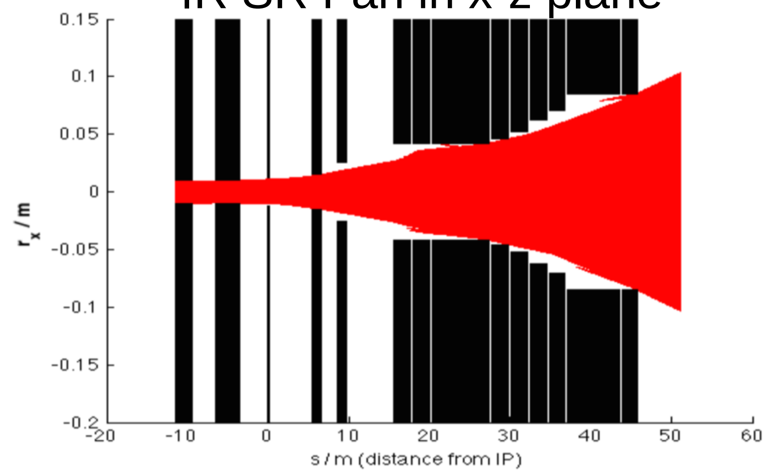




Primary spoilers & absorbers source of backgrounds in BDS

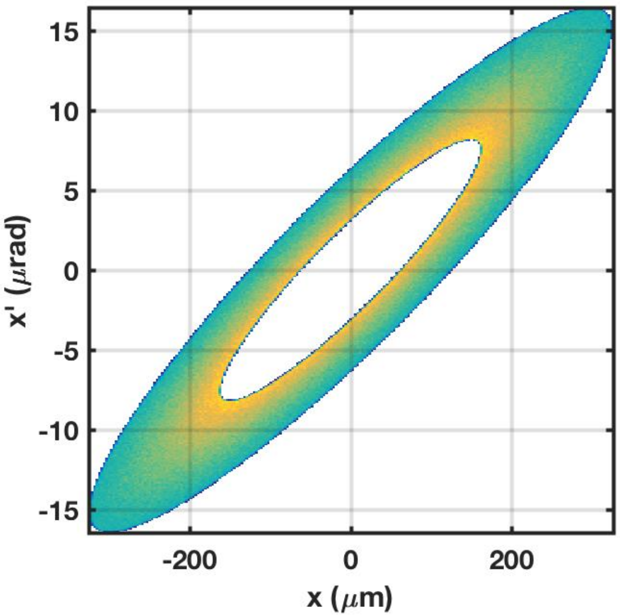
Collimation apertures set to protect IR region from SR

- Calculated from 6d particle tracking
- Collimation types and settings recorded in BDS decks

IR SR Fan in x-z plane



# Halo Distribution @ SP1




- 5-13 $\sigma_x$
- 36-93 $\sigma_y$

“1/r” distribution

Normalized to **0.1%** of nominal beam power incident on collimation system

- Pessimistic: HTGEN calculation with 10 nTorr in main Linac = $10^{-5}$

Energy normally distributed with nominal 0.1% rms width

# Muon Shielding – Toroid Spoilers

5 muon spoilers at z locations from IP:

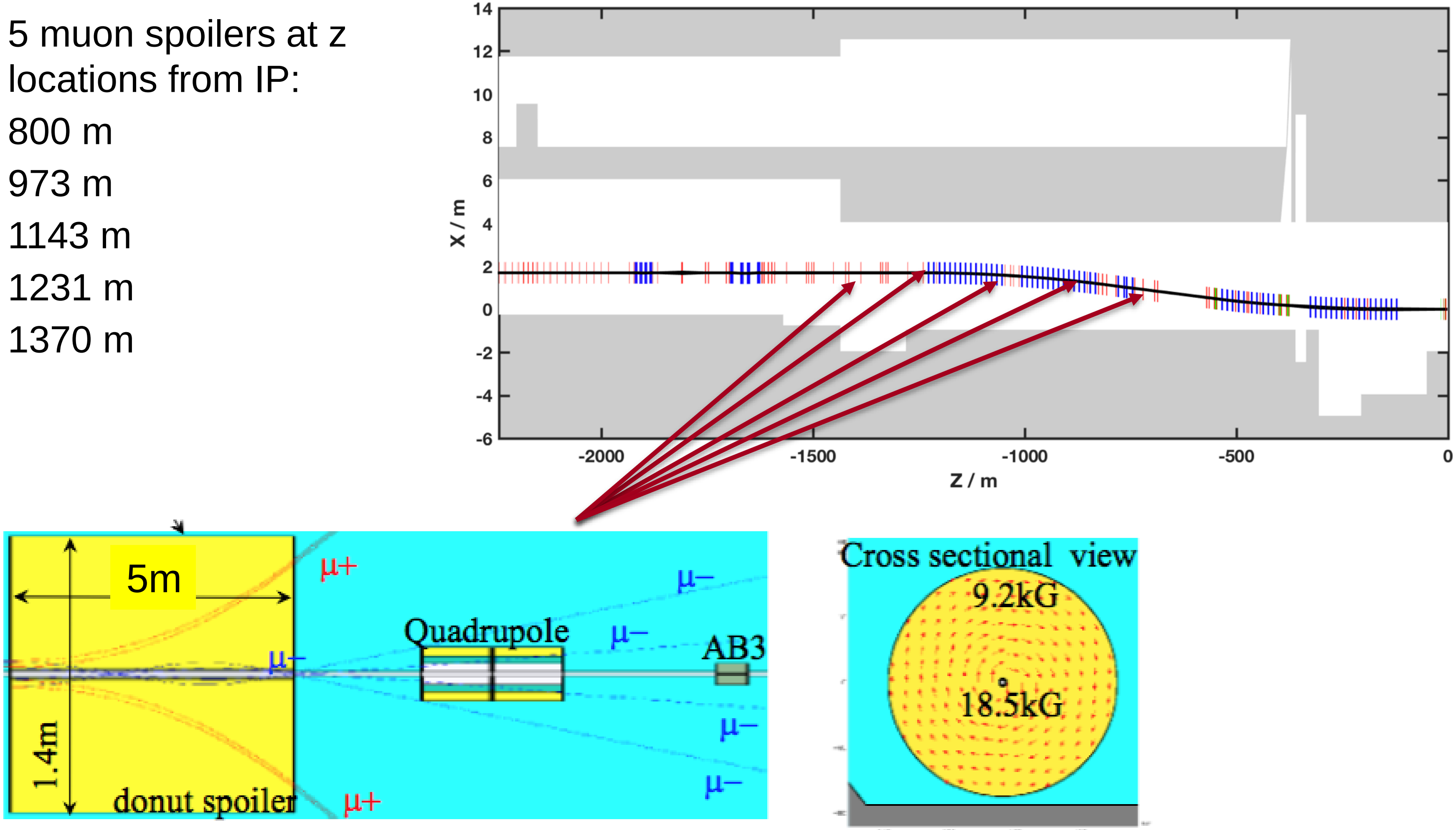
800 m

973 m

1143 m

1231 m

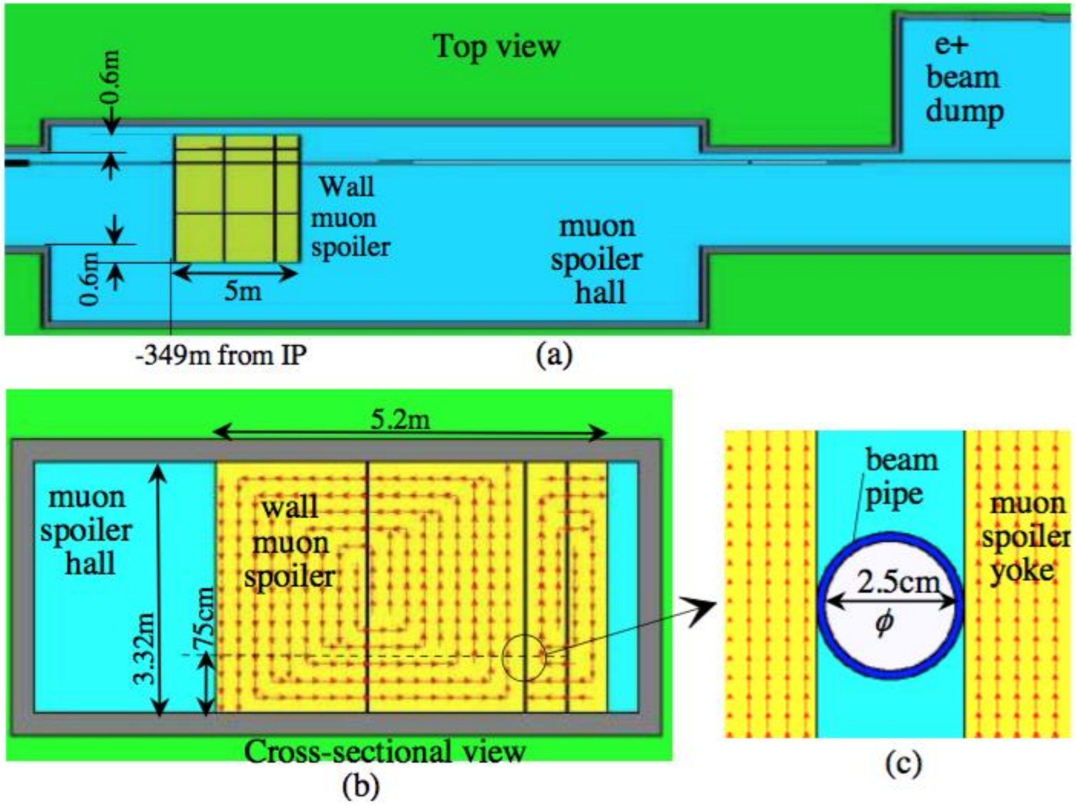
1370 m

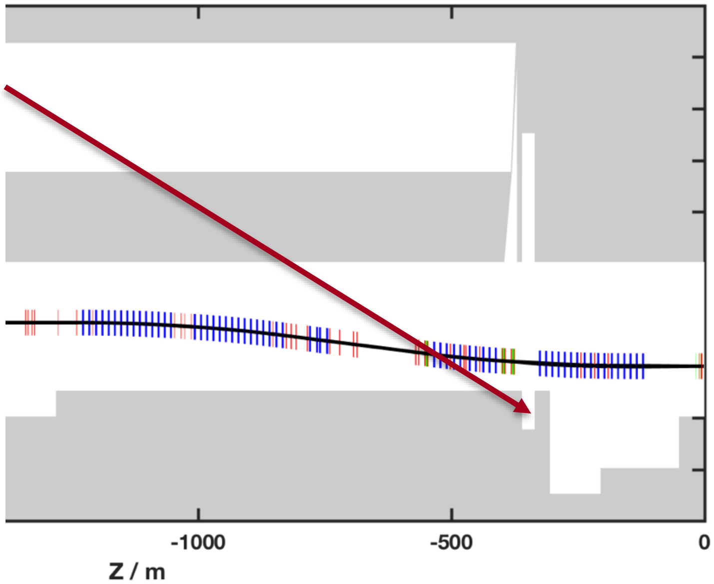



(c)

(d)

# Muon Shielding - Wall




FERMILAB-CONF-07-276-AD

**SUPPRESSION OF MUON BACKGROUNDS GENERATED**
**IN THE ILC BEAM DELIVERY SYSTEM** *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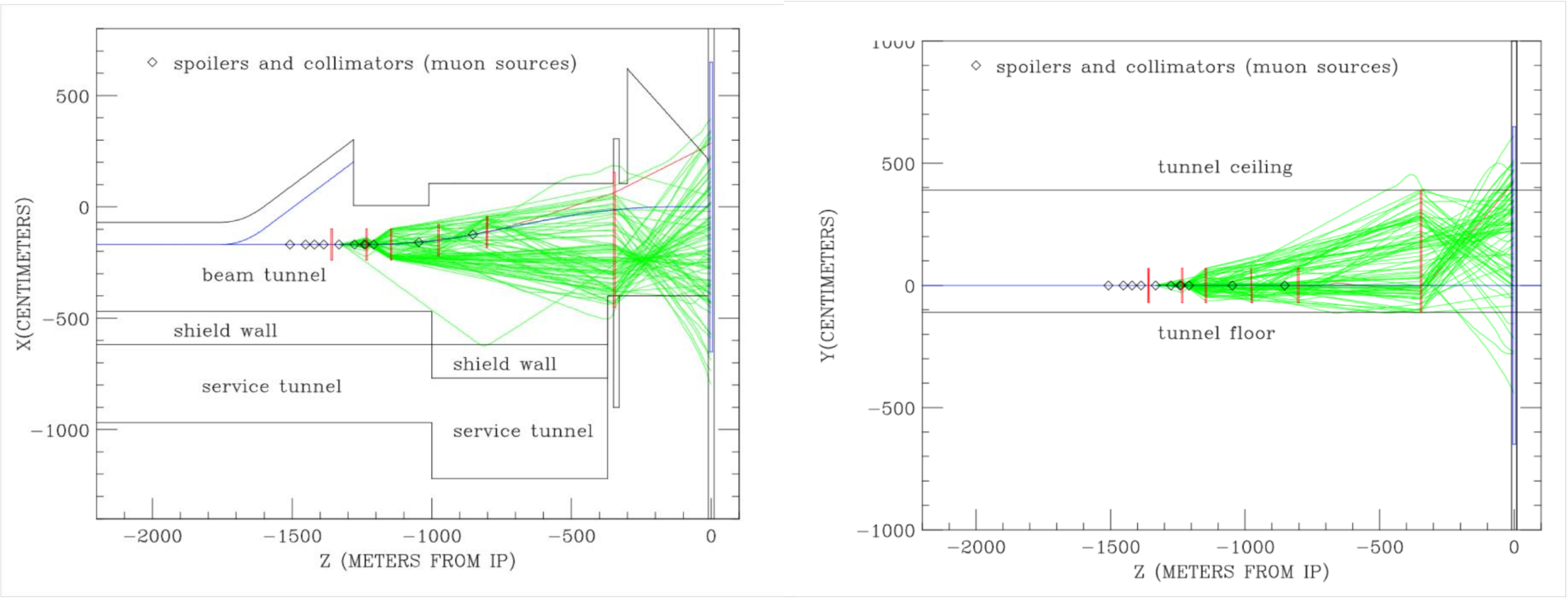
# Muon Tracking




- Spoilers scatter one charge sign of muon preferentially.

# Muon Rates @ Detector

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| Tunnel Condition | R < 6.5 m (rate/bunch crossing) | | | R < 2.5 m (rate/bunch crossing) | |
|---|---|---|---|---|---|
| | *GEANT4* | *MUCARLO* | | *GEANT4* | *MUCARLO* |
| $E_{cm}$ (GeV) | ***500*** | ***500*** | ***250*** | ***500*** | ***500*** |
| No Spoilers | 39.4 | 130 | 38 | 20.5 | 40 |
| 5 μ Spoilers | 2.8 | 4.3 | 1.3 | 1.4 | 2.0 |
| 5 μ Spoilers + 5m Wall | -- | 0.6 | 0.03 | -- | 0.1 |

- Total muon rates (from e- and e+ BDS sides) per bunch crossing
- Halo interception rate used = 0.1 % of main beam charge
- MUCARLO predicts more muons than GEANT4, mainly from d/s SPEX source. MUCARLO uses more generic magnet model, but uses much higher statistics and semi-analytic model for muon production.
  - 60k MUCARLO IP hitting mu tracks for 5 spoiler case compared with ~150 (from 500k generated) for GEANT4
  - Increased stats for GEANT4 model requires more work on process biasing and parallelization of muon tracking code

# Neutron and photon flux estimates from SHIELD11

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@ Detector

$E_{cm}$ = 500GeV

| Photons | | | | Neutron Total | |
|---|---|---|---|---|---|
| Rem/KWH | Rem/hr | #/cm**2.sec | | Rem/hr | #/cm**2.sec |
| 7.20E-17 | 3.74E-16 | 8.24E-10 | | 5.82E-15 | 4.24E-10 |
| 3.80E-05 | 1.98E-04 | 4.35E+02 | | 1.82E-05 | 9.26E-01 |
| 2.7 | 1.40E+01 | 3.09E+07 | | 6.40E-03 | 4.87E+02 |

| Wall Condition | Photons | Neutrons |
|---|---|---|
| • 5m iron | <<0.2 μSv/h | <<0.2 μSv/h |
| • 2m concrete | 2 μSv/h | 0.02 μSv/h |
| • No wall | 0.14Sv/h | 64 μSv/h |

which is smaller than that expected from the beamstrahlung bakground, $\sim 5.4 \times 10^{12}\mathrm{hit/cm^2}$ for 3 years at the innermost vertex detector (NIMA568(2006)233)

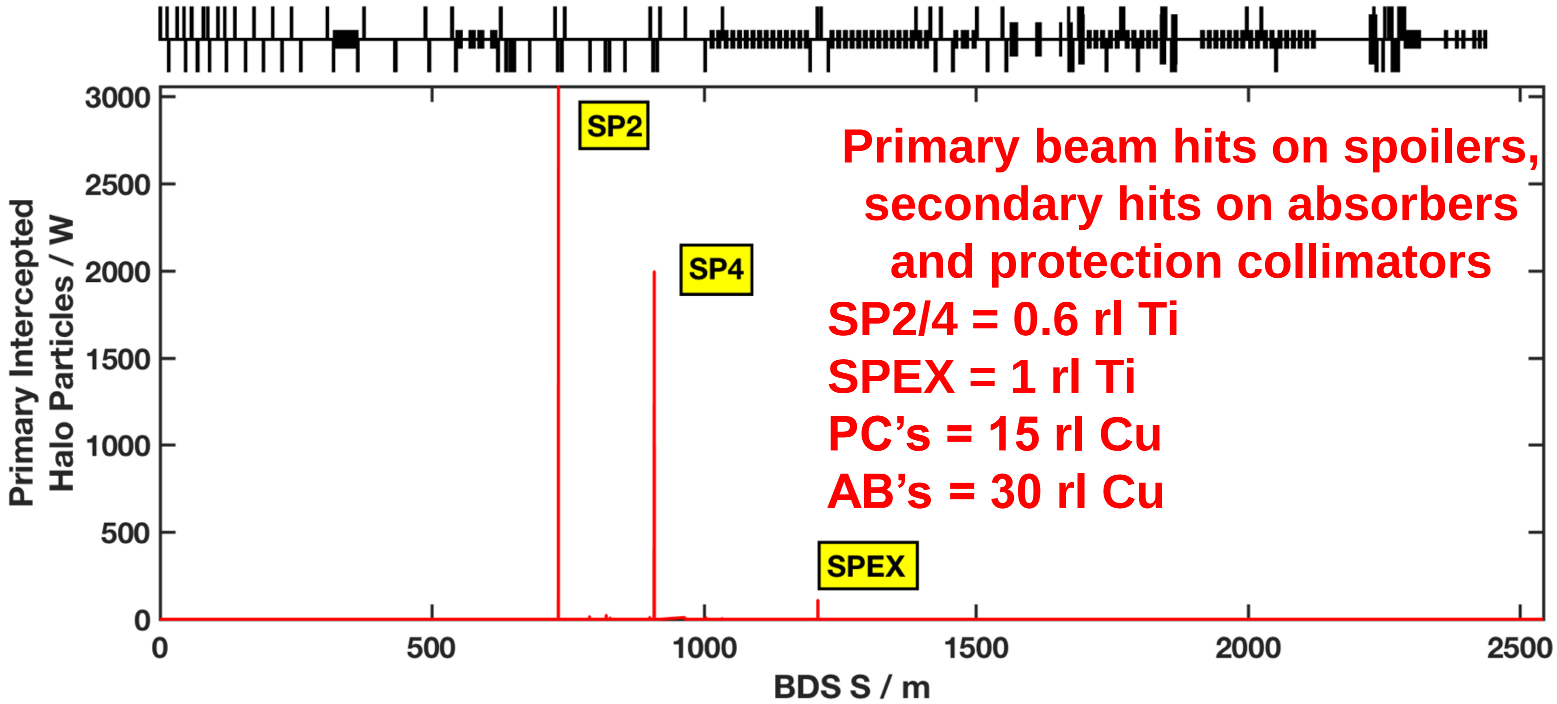
- Analytical estimate from SLAC SHIELD11 program for photon and neutron flux order-of-magnitude estimate.
- NOT ACCURATE (especially for photons) -> need detailed (e.g. FLUKA or GEANT) simulation including material interactions
- Need some shielding for neutrons. Maybe pacman enough for this?

KEK radiation rules (1 Sv = 100 Rem)
0.2 μSv/h for Non-designated area (K1)
1.5 μSv/h for Supervised area (K2) , e.g. experimental hall

*(T. Tauchi, ALCWS18)*

# Beam Power Incident on Collimation Absorbers

TDR ($E_{cm}$=500GeV)




- For $E_{cm}$ = 250 GeV, $10^{-3}$ halo rate:
  - ~1.5 kW @ SP2 absorber
  - ~1 kW @ SP4 absorber
  - ~75 W @ SPEX absorber

Shielding requirements for absorbers?

# LCLS-II Collimator Shielding Designs

SLAC

LCLS-II has collimator systems with similar requirements ~1kW

Shielding designs exist considering SLAC requirements

- Residual radiation low enough to enter tunnel after 1 hour
- Airborne radiation & ozone levels
- Soil & groundwater activation

Some local shielding required when intercepted power > 20W

**Table 2: Iron (or concrete) shielding required around the LCLS-II halo collimators**

| Collimator name | Energy [GeV] | Z [m] | Intercepted [W] | Iron local shielding thickness [cm] *North* | South | *Below* | Above | Alternative concrete [cm] *North* | *Below* |
|---|---|---|---|---|---|---|---|---|---|
| HXR | | | | | | | | | |
| CEHTR | 0.098 | 6.681 | 10 | shielding required | 5 | | 5 | No shielding required | |
| CY01 | | 24.102 | 2 | | | | | | |
| CX01 | 0.098 | 36.132 | 2 | No shielding required | | | | | |
| CY02 | | 48.162 | 2 | | | | | | |
| CX02 | | 60.192 | 2 | | | | | | |
| CEBC1* | 0.25 | 121.42 | 182 | 8 | 17 | 4 | 17 | 17 | 7 |
| CY11 | 0.25 | 142.59 | 5 | | 4 | | 4 | | |
| CX11 | | 150.66 | 4 | | 3 | | 3 | | |
| CY12 | | 158.72 | 4 | | 3 | | 3 | | |
| CX12 | | 166.78 | 3 | | 3 | | 3 | | |
| CEBC2* | 1.6 | 353.26 | 287 | **Fill all** | 34 | Fill all | 34 | Not enough Space!! | |
| CY21* | | 395.34 | 29 | 8 | 11 | 8 | 11 | 21 | 20 |
| CX21 | 1.6 | 407.33 | 26 | 6 | 10 | 6 | 10 | 15 | 15 |
| CY22 | | 419.32 | 23 | 4 | 10 | 4 | 10 | 10 | 10 |
| CX22 | | 431.31 | 21 | 3 | 9 | 3 | 9 | 5 | 5 |
| CEDOG | 4 | 967.38 | 1036 | See dedicated PRD | | | | See dedicated PRD | |
| CX13* | | 1249.7 | 104 | 22 | 27 | 14 | 38 | 50 | 31 |
| CY14 | 4 | 1351.3 | 93 | 20 | 25 | 12 | 36 | 45 | 26 |
| CX17 | | 1656.1 | 84 | 18 | 23 | 10 | 34 | 41 | 22 |
| CY18 | | 1757.7 | 76 | 16 | 23 | 10 | 32 | 37 | 17 |
| CXQ6 | 4 | 3177.8 | 306 | | 39 | 4 | 39 | | 7 |
| CEDL1 | | 3264.8 | 187 | | 30 | 32 | 30 | | 72 |
| CYBX32 | | 3275.6 | 19 | | 9 | | 9 | | |
| CXQT22 | 4 | 3317.8 | 17 | | 9 | | 9 | | |
| CEDL3** | | 3336.4 | 15 | 8 | 8 | | | | |
| CYBX36** | | 3345.3 | 14 | 8 | 8 | | | | |
| SXR | | | | | | | | | |
| CXBP30 | | 2972.3 | 68 | 6 | 17 | | 17 | 5 | |
| CXBP34 | | 3198.8 | 61 | | 15 | | 15 | | |
| CYBDL | 4 | 3218.1 | 275 | 40 | 45 | 31 | 55 | 82 | 63 |
| CEDL14 | | 3269.4 | 138 | | 27 | 25 | 27 | | 38 |
| CYDL16 | | 3295.2 | 14 | | 8 | | 8 | | |
| CEDL18* | | 3320.4 | 62 | 15 | 15 | 15 | 15 | | 11 |

*(LCLS-II Final Design Report)*

# LCLS-II CEDOG Collimator Shielding Design

*(SLAC-RP-14-18)*

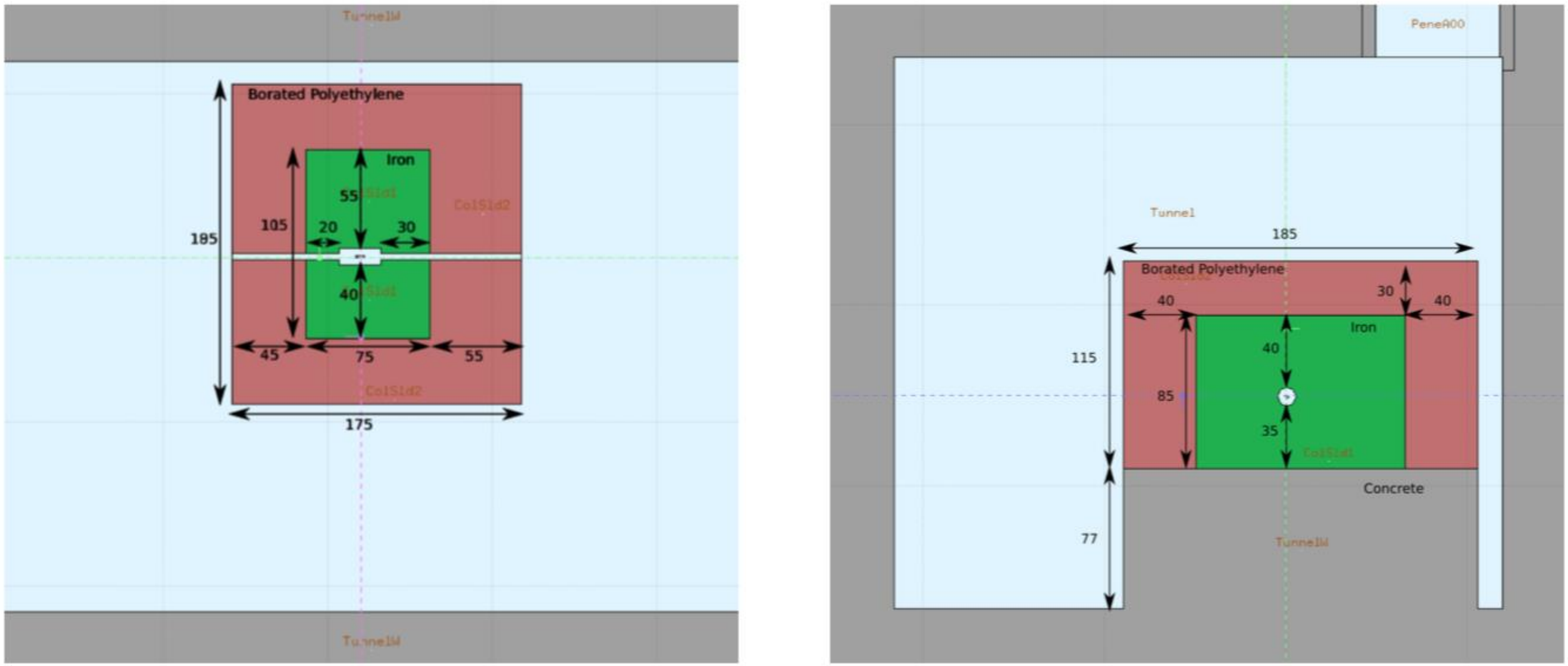
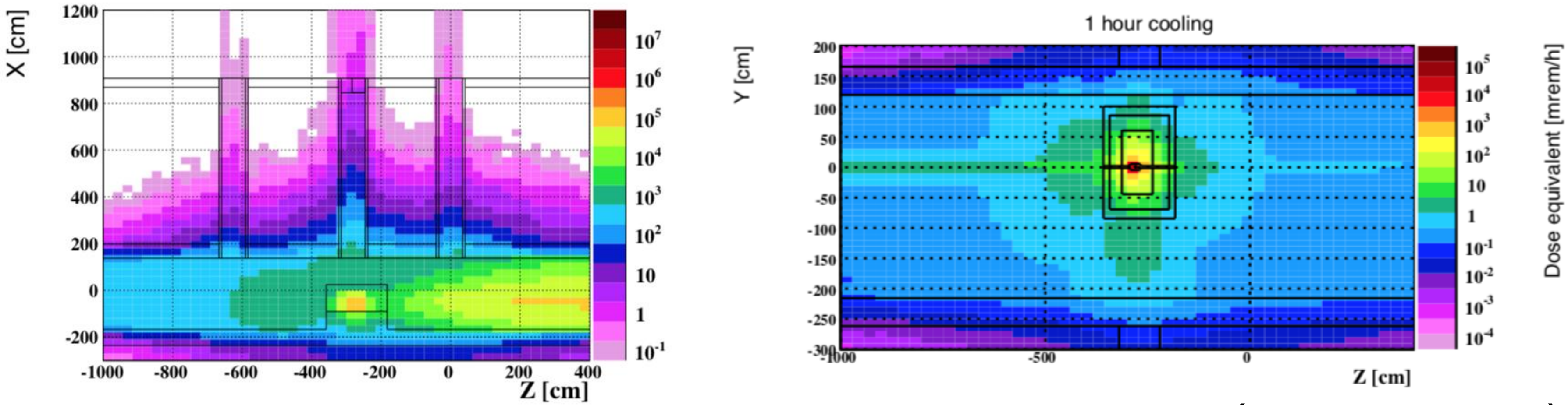



Figure 4: Top (left) and front view (right) of the W collimator and its shielding. All dimensions are given in cm.

# LCLS-II CEDOG Collimator Shielding Design




*(SLAC-RP-14-18)*

- Dose rates <0.5 mrem/hr above tunnel penetrations
- < required 5 mrem/hr 30cm from shielding 1 hour after beam shut off
- Soil & groundwater activation (mainly H-3) below EPA detection limits (~2000 pCi/L) [EPA limit 20,000]

# Summary

Tight collimation in BDS required to protect IR from SR hits

Rates @ detector for $10^{-3}$ intercepted halo @ $E_{beam}$ = 125 GeV :

- 38/bunch R<6.5m (no shielding)
  - 1.3 with spoilers
  - 0.03 spoilers + wall

Detector community: wall not needed for muons

- Neutron/photon shielding?

Local shielding needed near collimator absorbers

- Example shown for LCLS-II with similar intercepted power requirements
- Need some shielding for all sources >20W
  - Need further look at all AB & PC sources for new reference design