

Mini-Workshop on ILC Infrastructure and CFS for Physics and Detectors

Update & Summary of Background & SiD Occupancy Studies

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DESY

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Pair background studies for the ILC250 schemes

ILC250 Beam Parameter Sets

The TDR beam parameters were changed in order to increase the luminosity of the ILC250 stage.

| Set | ϵ_x [μm] | β_x [mm] | β_y [mm] |
|------------|--------------------------------|----------------|----------------|
| TDR | 10 | 13.0 | 0.41 |
| (A) | 5 | 13.0 | 0.41 |
| (B) | 5 | 9.19 | 0.41 |
| (C) | 5 | 9.19 | 0.58 |

(The table only lists the parameters that are to be changed with respect to the original ILC250 parameters given in the Technical Design Report (TDR) [13, p. 11].)

Reduced emittance leads to stronger beam-beam interactions, and therefore to increased $e^+ e^-$ pair background.

1 Pair background studies for the new ILC250 schemes

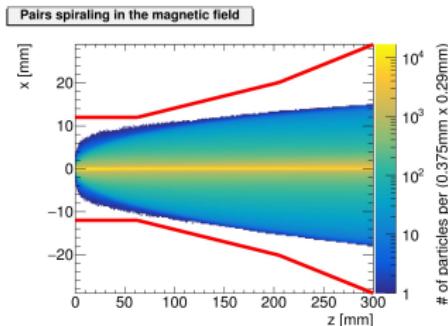
- Pair background envelopes
- SiD Occupancy
- Conclusion

2 Muons from the muon spoilers

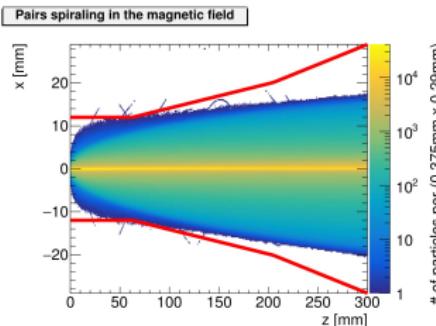
3 FLUKA simulation of the ILC Beam Dump

4 Backup

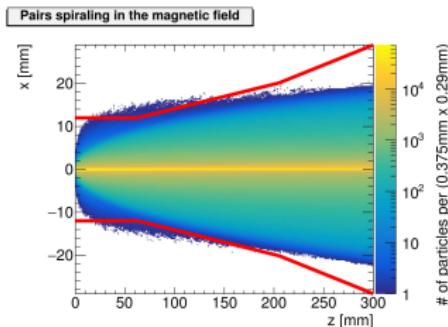
Pair background density in a 5 T solenoid field



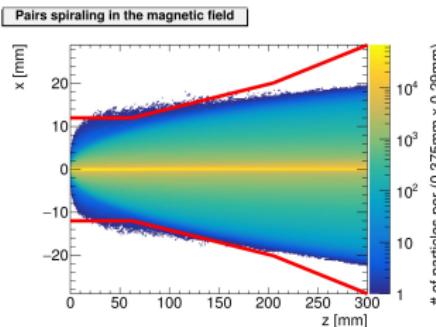
(a) ILC250 set (TDR)



(b) ILC250 set (A)

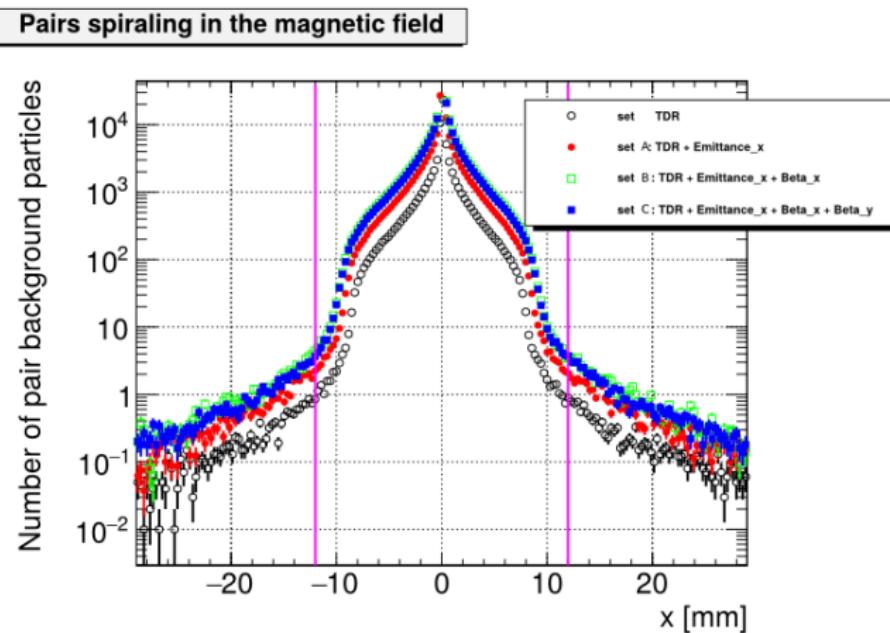


(c) ILC250 set (B)



(d) ILC250 set (C)

Projection of the pair background density along x



The envelopes are in all schemes well contained within the beam pipe. Less than 10 particles per bunch crossing are to be expected outside the beam pipe.

① Pair background studies for the new ILC250 schemes

- Pair background envelopes
- SiD Occupancy
- Conclusion

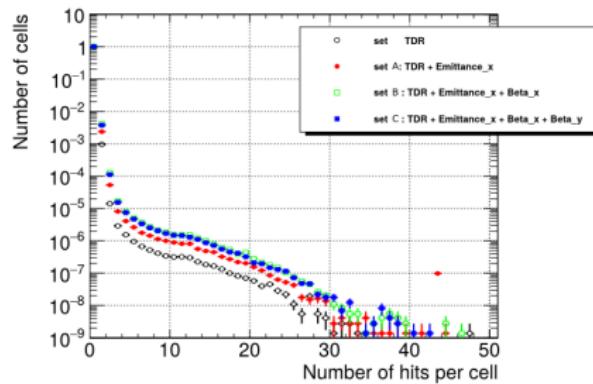
② Muons from the muon spoilers

③ FLUKA simulation of the ILC Beam Dump

④ Backup

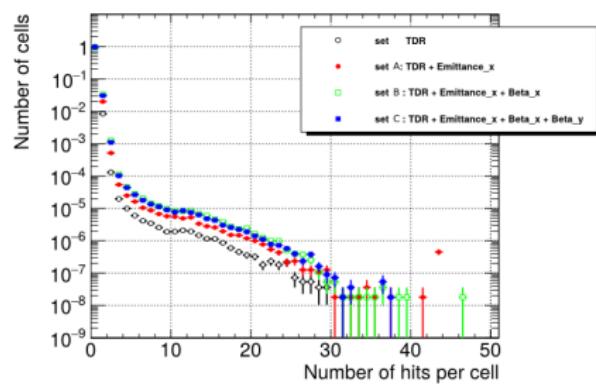
SiD Vertex Detector Occupancy

Occupancy for SiVertexBarrel wrt to tot # cells



(a) All layers

Occupancy for SiVertexBarrel wrt to tot # cells



(b) Innermost layer

Normalized Occupancy: Number of cells containing a certain amount of hits, normalized by the total number of cells of the vertex detector.
 The occupancy in layer 0 for the new sets is significantly increased with respect to the TDR scheme.

1 Pair background studies for the new ILC250 schemes

- Pair background envelopes
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2 Muons from the muon spoilers

3 FLUKA simulation of the ILC Beam Dump

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Conclusion

- The SiD vertex detector occupancies for the beam parameter sets (A, B, and C), which contain changes wrt the TDR parameters, are increased by a factor of $\sim 2\text{-}6$.
- For all schemes, the occupancy does not exceed $\sim 10^{-4}$ (limit of acceptance).
- Even in the innermost layer, for which the change in occupancy is the highest, the occupancy for the new parameter set A is below the critical limit.

Conclusion:

- SiD is confident that the rise in occupancy can be accommodated in the design of the pixel detector, and has welcomed CR-0016.

① *Pair background studies for the new ILC250 schemes*

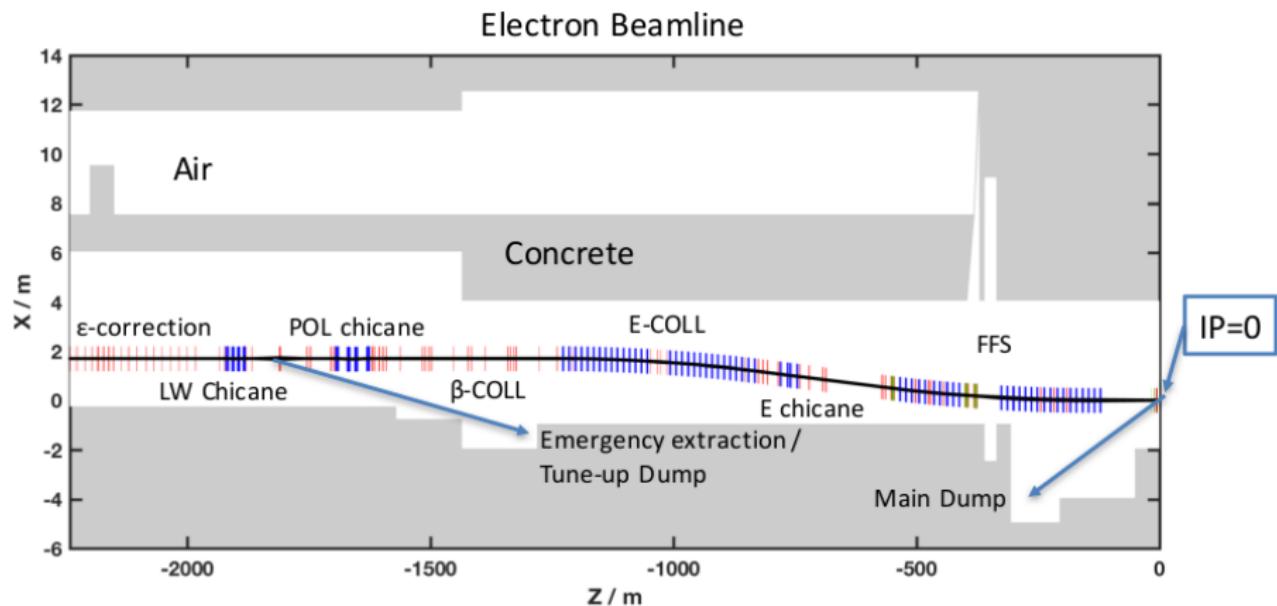
② *Muons from the muon spoilers*

- MUCARLO simulation
- Results of the Geant4 simulation
- Conclusion

③ *FLUKA simulation of the ILC Beam Dump*

④ *Backup*

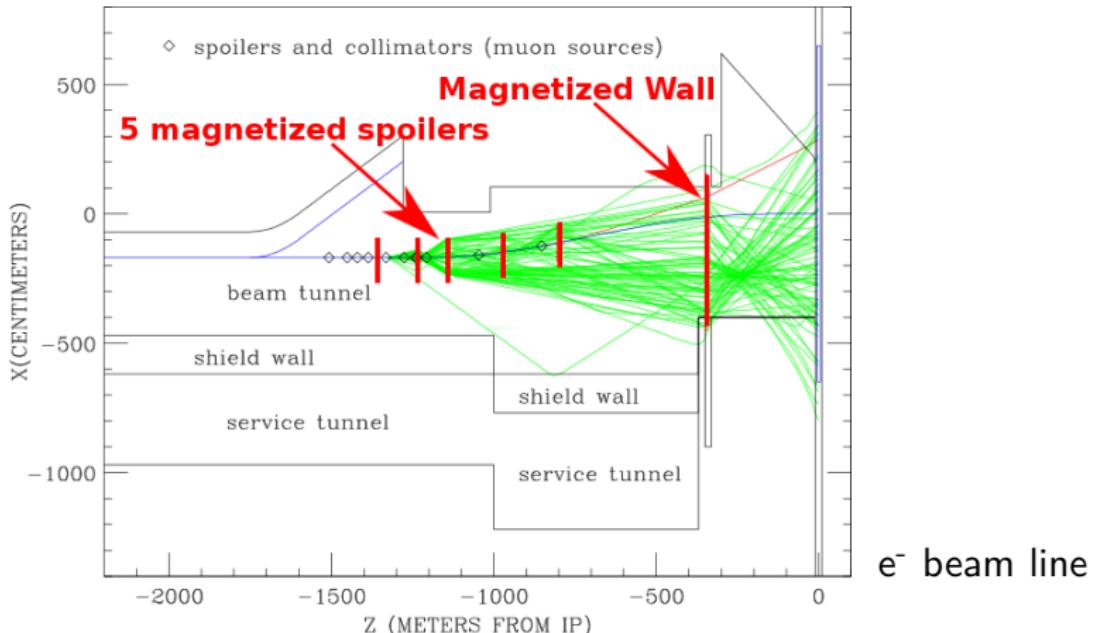
BDS tunnel layout



Muon spoiler scenarios

There are two spoiler scenarios under discussion:

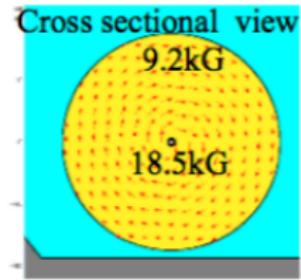
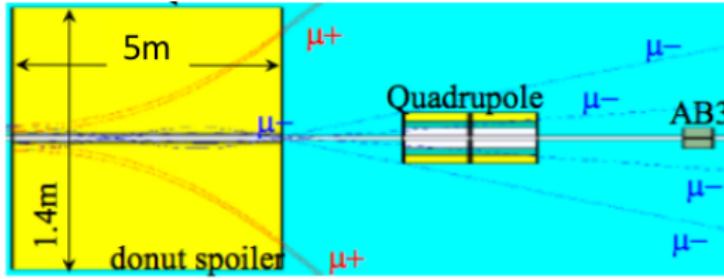
- **5 Spoilers**
- **5 Spoilers + Wall**



5 donut spoilers

The **donut spoilers** are designed as follows:

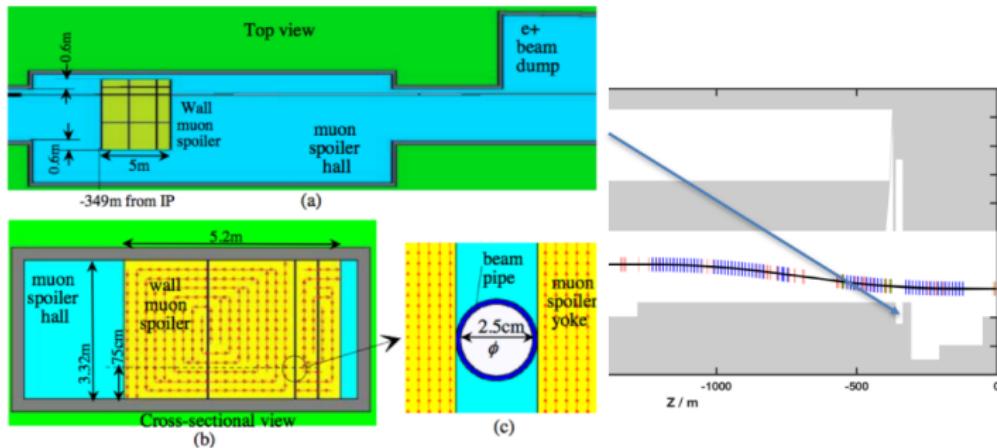
- 70 cm radius
- 5 m long
- Magnetized iron with a field of $\sim 10\text{-}19\text{ kG}$
- 5 locations (before IP):
 - 802.5m
 - 975.5m
 - 1145.5m
 - 1234.5m
 - 1358.5m



5 donut spoilers + wall

The **iron wall** would completely fill up the tunnel:

- 5 m x 5 m, 5 m long
- Magnetized with a field of ~ 16 kG
- Located ~ 400 m away from the IP
- Would cost $\sim \$3$ million



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

1 Pair background studies for the new ILC250 schemes

2 Muons from the muon spoilers

- MUCARLO simulation

- Muon 4-vectors
- Motivation

- Results of the Geant4 simulation
- Conclusion

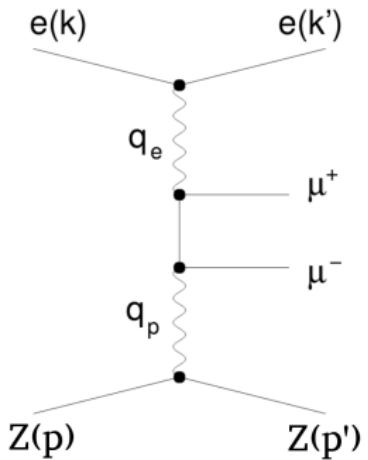
3 FLUKA simulation of the ILC Beam Dump

4 Backup

MUCARLO simulation overview



- BDS backgrounds with muon collimation system modelled with MUCARLO [Lewis Keller, SLAC] and Geant4 [Glen White, SLAC]
- Using TDR baseline machine parameters for the ILC500 & new beam parameters for the ILC250 stage
- Muon production processes:
 - Predominantly: Bethe-Heitler process:
 $\gamma + Z \rightarrow Z' + \mu^+ \mu^-$
 - Few % level: direct annihilation of positrons with atomic electrons: $e^+ e^- \rightarrow \mu^+ \mu^-$
- Halo particle tracking:
 - Turtle with MUCARLO
 - Lucretia with a built-in Geant4 model interface



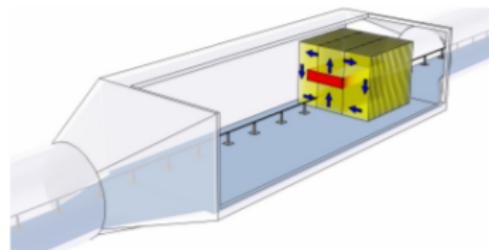


Muons in the detector

| Scenario | Muons per bunch crossing in a detector with 6.5m radius | |
|-------------------|---|--------|
| | ILC500 | ILC250 |
| 5 Spoilers | 4.3 | 1.3 |
| 5 Spoilers + Wall | 0.6 | 0.03 |

Do we need the muon wall at all?! It would be easier without it, because of safety issues, and the costs for such a iron wall.

Muon Wall Required?



- If flux with toroid spoilers acceptable running condition from detector groups:
 - **Can we remove 5m magnetized iron muon wall?**

On the other hand:

It serves as a tertiary containment device!

Removing the wall would mean NO access to IR when the beam is on!
And expecting considerably higher rates when going to 1 TeV → maybe wall then necessary anyway!

1 Pair background studies for the new ILC250 schemes

2 Muons from the muon spoilers

- MUCARLO simulation

- Results of the Geant4 simulation

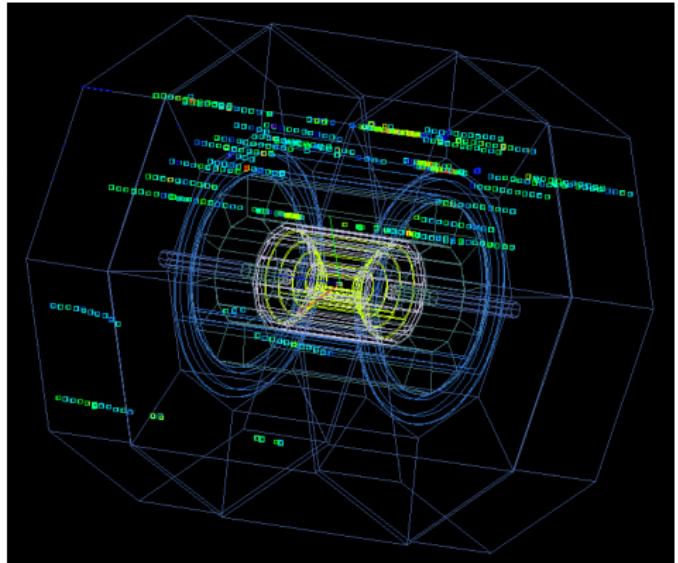
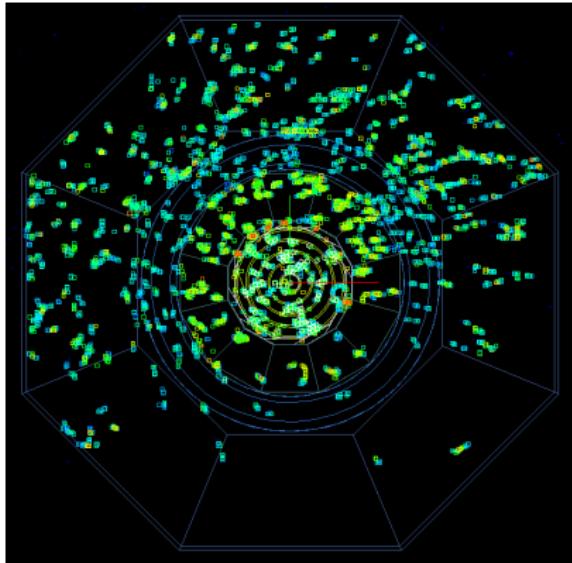
- Event displays of muons in the SiD detector
- Analysis - Total number of hits
- Analysis - Occupancies
- Analysis - Dead cells

- Conclusion

3 FLUKA simulation of the ILC Beam Dump

4 Backup

WIRED4 event display

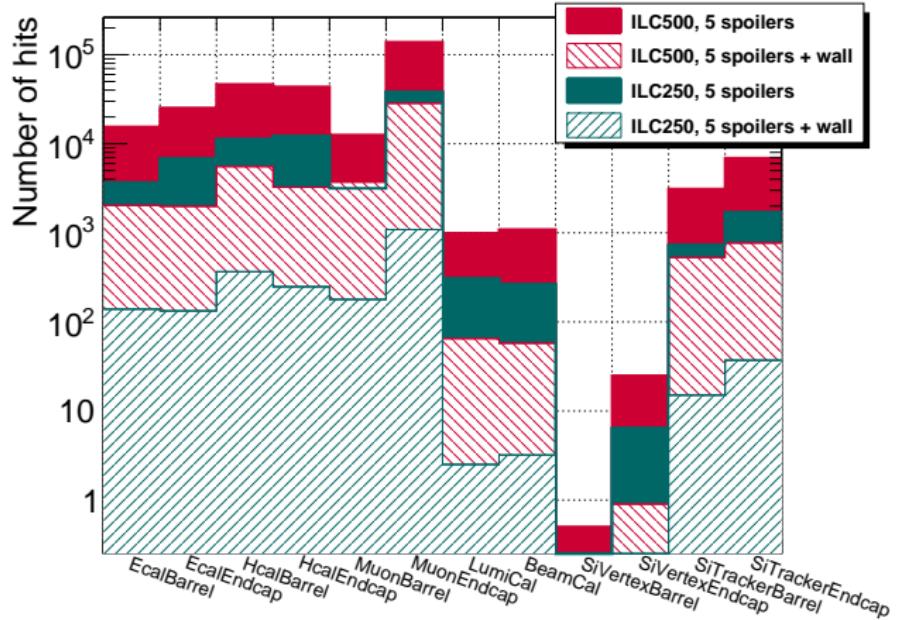


The muons exit the BDS tunnel, and penetrate the whole detector.

Total number of hits



Number of hits in SiD per train - 5 spoilers vs. 5 spoilers+wall



Comparison of the total number of hits in the different SiD subdetectors:

Vertex detectors

< ECAL, HCAL <

MuonEndcaps

Smallest effective detector area

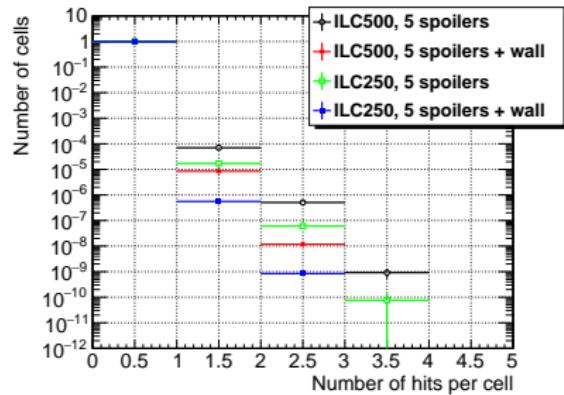
Particle showers

Biggest effective detector area

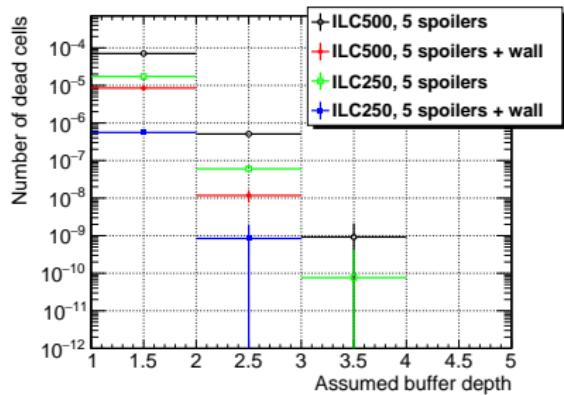
Occupancy plots - HcalBarrel

The following occupancy plots are normalized by the total number of cells.

Occupancy for HcalBarrel wrt to tot # cells



Number of dead cells for a given buffer depth for HcalBarrel



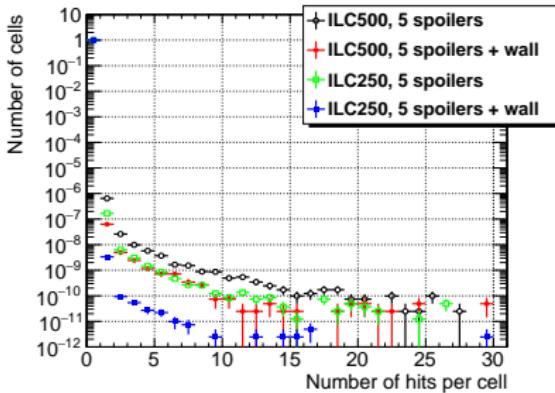
Only up to three hits per cell → Low occupancy

'5 Spoilers + Wall' for 250 and 500 GeV does better by up to an order of magnitude.

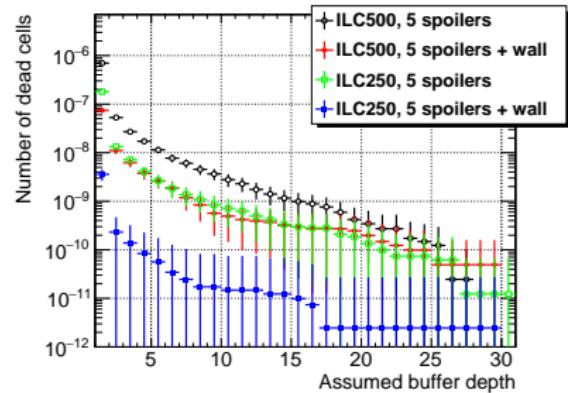


Occupancy plots - SiTrackerEndcap

Occupancy for SiTrackerEndcap wrt to tot # cells



Number of dead cells for a given buffer depth for SiTrackerEndcap



Number of hits per cell up to 30 → low energy muons spiral, and hit cells several times!

For all assumed buffer depth values, the total number of dead cells stays way below 10^{-4} (critical limit).

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Updated analysis framework and new numbers for ILC250 have shown:

- Muons penetrate the whole detector horizontally.
- At 500 GeV, the 5 spoilers can reduce the number of muons to $\sim 4/\text{bunch crossing}$, which results in occupancies of around $\sim 10^{-4}$ (limit of acceptance).
- The 5 spoilers + wall scenario reduces this significantly.
- In the ILC250 stage, the number of muons/bunch crossing is reduced by about a factor of 2.
- The occupancies are for both shielding scenarios well below $\sim 10^{-4}$.

Conclusion:

- High energy muons could be used for tracker alignment.
- Spatial distributions quite different in scenarios w/ & w/o the wall.
- With the shown evaluation of the muons from the current MUCARLO simulations, the magnetized wall is not required for limiting the detector occupancy in the ILC250 stage. However, the wall serves as a tertiary containment device, and might be mandatory anyway.

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Neutron Background and Beam Dump Irradiation



The 17 MW¹ beam is dumped into a water tank after collision.

- The activation of the dump surrounding will permit access to the dump area. Neutrons ($\lesssim 10^{10} \text{ cm}^{-2} \text{ yr}^{-1}$) are emitted that irradiate the surroundings, and travel back towards the detectors. [9]

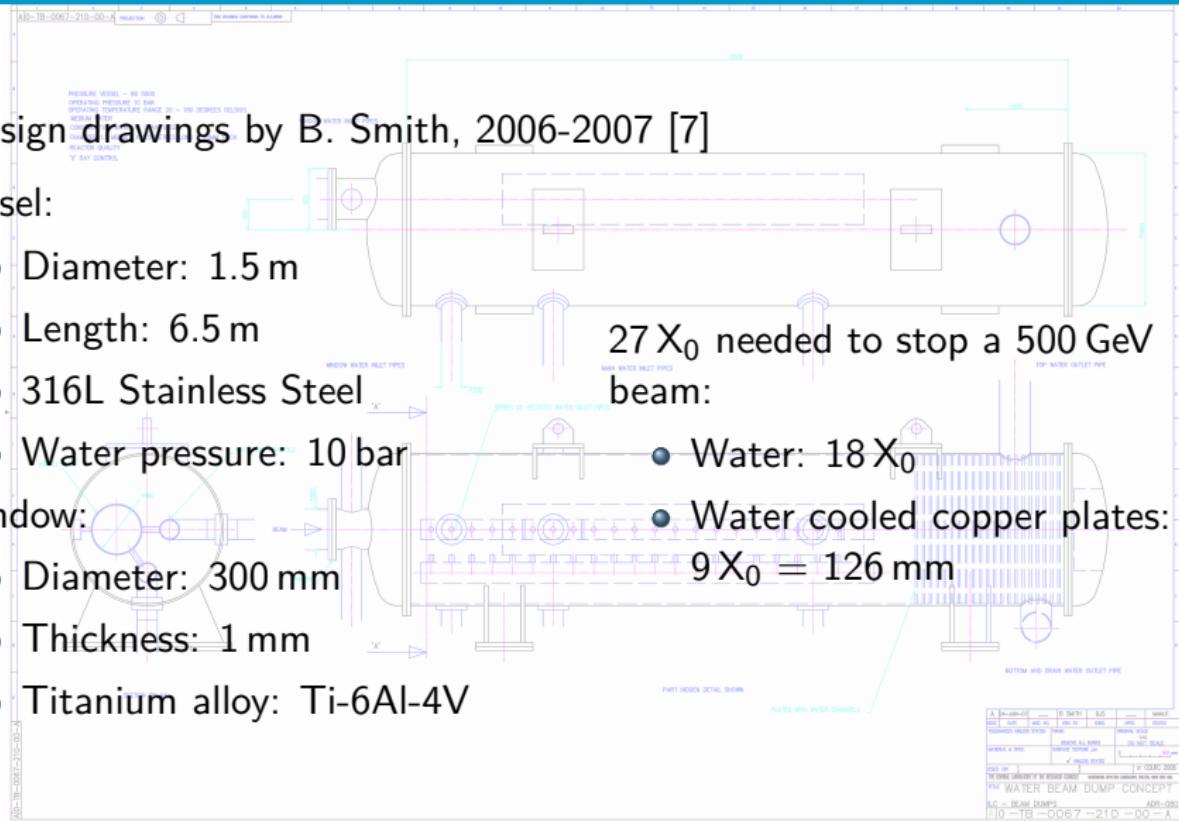
Goal: Simulating the energy deposition, irradiation, and background particles:

→Simulating the activation, and the neutrons from the beam dump with FLUKA, using the design drawings by B. Smith [7] to model the dump and the surrounding.

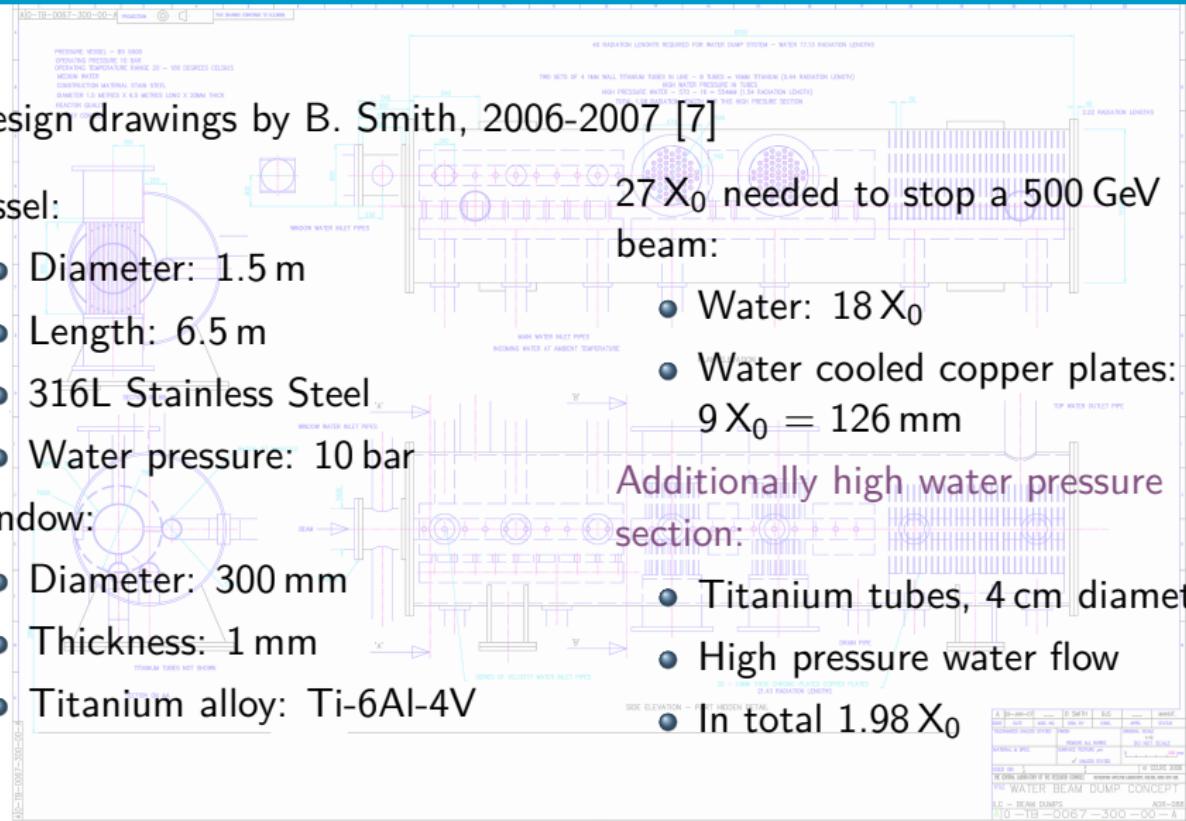
¹13.7 MW average beam power + 20% margin

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Design 1: 0-TB-0067-210-00-A



Design 2: 0-TB-0067-210-00-A



1 Pair background studies for the new ILC250 schemes

2 Muons from the muon spoilers

3 FLUKA simulation of the ILC Beam Dump

- The Beam Dump Designs
- The FLUKA simulation
 - Deposited Energy and Dose
- Summary and Outlook

4 Backup

For the simulation, the ILC1000B was chosen as the scenario with the largest beam power.

ILC1000B:

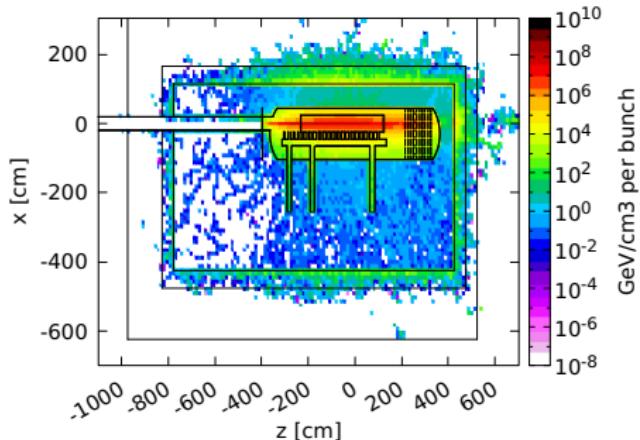
- Beam energy: 500 GeV
- Bunch population: 1.74×10^{10}
- Bunch size: $\sigma_x = 2.4 \text{ mm}$, $\sigma_y = 0.22 \text{ mm}$
- Bunches per train: 2450
- Bunch train duration: $896.7 \mu\text{s}$

Beams are considered un-collided and un-disrupted.

Deposited Energy per bunch

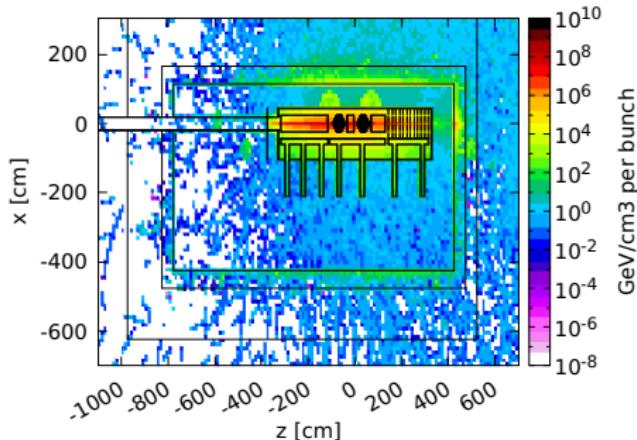
Design 1

Energy deposition density in the ILC main beam dump



Design 2

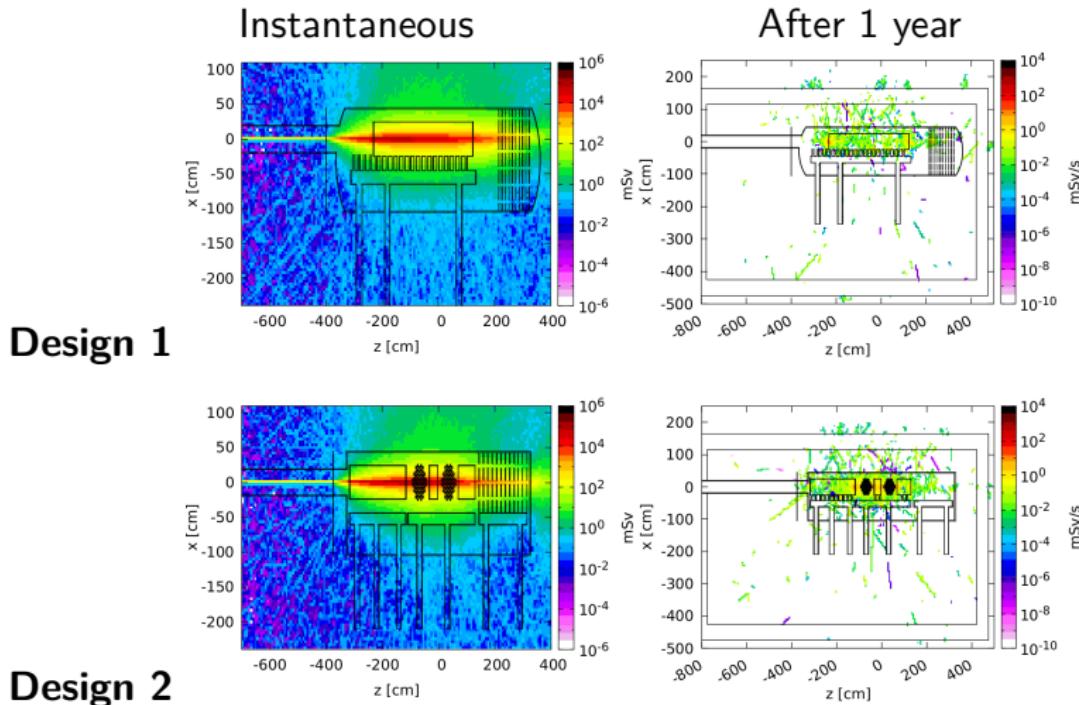
Energy deposition density in the ILC main beam dump



Shielding walls seem to stop particles fluxes well, but large scattering in Design 2 at high water pressure sections leads to energy deposition outside the walls.

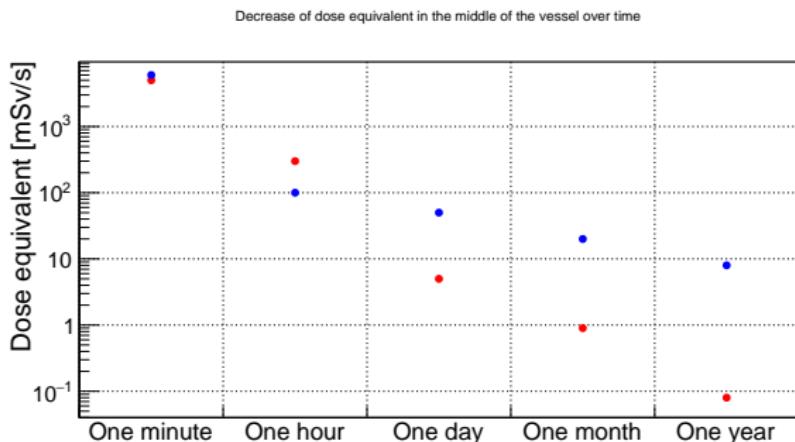
Dose equivalent after cooling times

After one month of beam operation, the beam is turned off.



Dose Rate over Time

The dose rate measured at the longitudinal shower maximum inside the vessel over time:



After one year, the dose rate drops to
~ **0.1 mSv/s** for **Design 1** and to ~ **10 mSv/s** for **Design 2**.

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Conclusion

Water beam dump designs:

- The simulations of the two water beam dump designs by B. Smith show **comparable results**.
- The dose rate of the beam dump surrounding is still after one year in the order of **0.1-1 mSv/s**.
- **Design 2** seems to be **more elaborated regarding the water cooling flow system**. This leads to **larger spreads in the energy deposition** due to the high water pressure sections.



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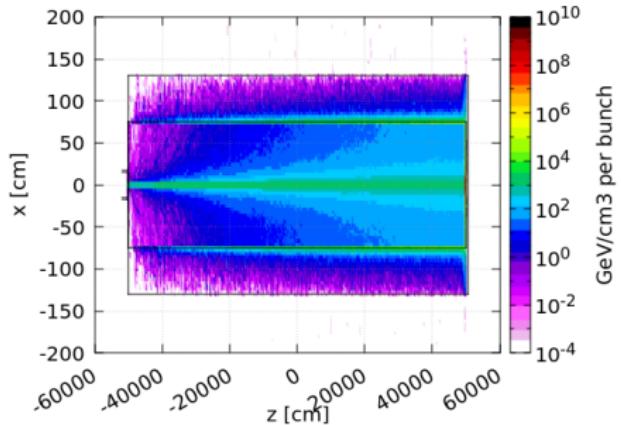
FOR FUN:

- Gas dump filled with Nitrogen
- Beam dump Design 1 filled with liquid Nitrogen

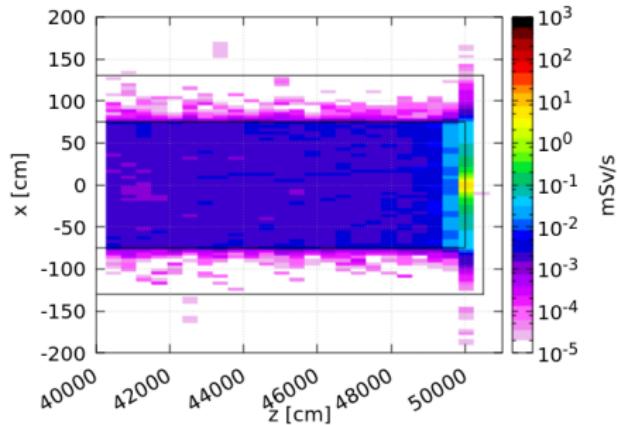
For Fun: Nitrogen Gas Dump

- Gas dump (~ 1 km long) filled with Nitrogen
- Adopting ideas from dump design studies for TESLA done at DESY.
- Copper walls with a thickness of ~ 60 cm

Energy deposition in the Nitrogen gas dump per bunch



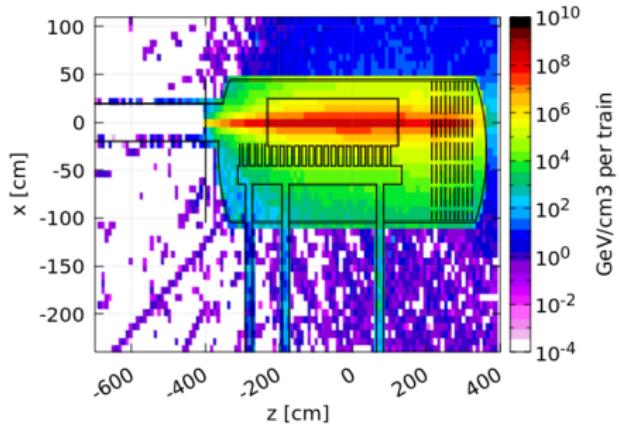
Dose rate for a Nitrogen Gas Dump - after 1 year



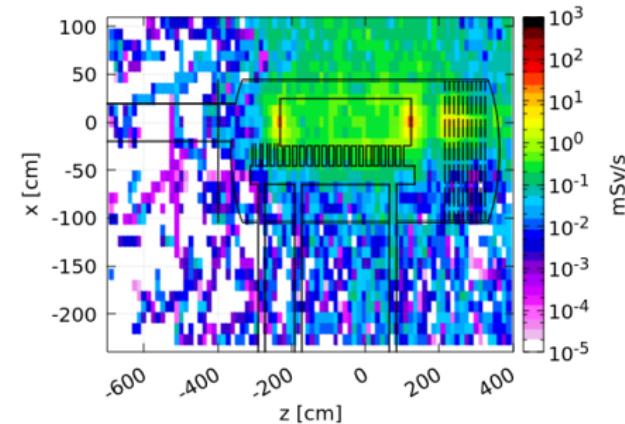
For Fun: Design 1 with liquid Nitrogen

- Design 1 (as shown above) filled with liquid Nitrogen
- Everything else as before

Energy deposition density in the ILC main beam dump



Dose equivalent in the ILC main beam dump - after 1 year



Thanks!

I am close to handing in my Ph.D. thesis.

Detailed explanations of all my studies will be given in my thesis, as well as in SiD confluence pages.

Simulation files are already or will be made available to everyone on the grid ([/ilc/user/a/aschuetz](http://ilc/user/a/aschuetz)).

References for the BDS muon study

ECFA 2016: Talk by Glen White about the MUCARLO simulation of the muons from the muon spoilers.

https://agenda.linearcollider.org/event/7014/contributions/34689/attachments/30076/44961/ILC_muons.pptx

DESY summer student program: Talk by Jonas Glomitza (RWTH Aachen) about "The Impacts of the Muon Spoiler Background on the ILC Detector Performance", 08. September 2016.

<https://indico.desy.de/getFile.py/access?contribId=9&resId=0&materialId=slides&confId=15972>

FERMILAB-CONF-07-276-AD: "Suppression of Muon Backgrounds generated in the ILC Beam Delivery System", Drozhdin et.al, 2007. <https://inspirehep.net/record/771808/files/fermilab-conf-07-276.pdf>

"Calculation of Muon Background in Electron Accelerators using the Monte Carlo Computer Program MUCARLO", Rokni et.al. <http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-7054.pdf>

*SLAC-PUB-6385: "Muon Background in a 1.0-TeV Linear Collider", L.P. Keller, 1993.
<http://www.slac.stanford.edu/pubs/slacpubs/6250/slac-pub-6385.pdf>*

*SLAC-PUB-5533: "Calculation of Muon Background in a 0.5 TeV Linear Collider", L.P. Keller, 1991.
<http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-pub-5533.pdf>*

References for the FLUKA study

- B. Smith (Rutherford Lab), *Design drawings 0-TB-0067-300-00-A, 0-TB-0067-210-00-A, 0-TB-0067-404-00-A*, Dec. 2006 - Jan. 2007
- B. Smith (CCLRC Technology Department), *18 MW Water Beam Dump Concept*, Report 088-D-006-01, Jan. 2007
- S. Darbha, *Simulation of Neutron Backgrounds from the ILC Extraction Line Beam Dump*, SLAC-TN-07-013, Aug. 2007
- P. Satyamurthy, et al., *Design of an 18 MW vortex flow water beam dump for 500 GeV electrons/positrons of an international linear collider*, NIM A 679 (2012) 67-81
- A. Mereghetti, et al., *FLUKA and Thermo-Mechanical Studies for the CLIC Main Dump*, CLIC-Note-876, Mach 2011
- K. Okuno, et al., *Application of neutron shield concrete to neutron scattering instrument TAIKAN in J-PARC*, Progress in Nuclear Science and Technology, Vol. 4, pp 619-622, 2014

References for the Pair background study

-]] T. Behnke, et al., *The International Linear Collider - Technical Design Report, Volume 1*, 2013.

- 1 Pair background studies for the new ILC250 schemes
- 2 Muons from the muon spoilers
- 3 FLUKA simulation of the ILC Beam Dump
- 4 Backup

Additional Material

5 ILC

- The ILC beam parameters

6 BDS muons

- Analysis - Spatial distributions
- Analysis - Energy distributions
- Analysis - SiD hit distribution
- Analysis - SiD Occupancy
- Analysis - Time distributions

7 FLUKA simulation

- Particle Fluxes

5 ILC

- The ILC beam parameters

6 BDS muons

7 FLUKA simulation

5 *ILC*

- The ILC beam parameters

6 *BDS muons***7** *FLUKA simulation*



ILC baseline parameters

| Centre-of-mass energy | E_{CM} | GeV | 200 | 230 | 250 | 350 | 500 |
|---|---------------------|---|-------|-------|-------|------|------|
| Luminosity pulse repetition rate | | Hz | 5 | 5 | 5 | 5 | 5 |
| Positron production mode | | | 10 Hz | 10 Hz | 10 Hz | nom. | nom. |
| Estimated AC power | P_{AC} | MW | 114 | 119 | 122 | 121 | 163 |
| Bunch population | N | $\times 10^{10}$ | 2 | 2 | 2 | 2 | 2 |
| Number of bunches | n_b | | 1312 | 1312 | 1312 | 1312 | 1312 |
| Linac bunch interval | Δt_b | ns | 554 | 554 | 554 | 554 | 554 |
| RMS bunch length | σ_z | μm | 300 | 300 | 300 | 300 | 300 |
| Normalized horizontal emittance at IP | $\gamma \epsilon_x$ | μm | 10 | 10 | 10 | 10 | 10 |
| Normalized vertical emittance at IP | $\gamma \epsilon_y$ | nm | 35 | 35 | 35 | 35 | 35 |
| Horizontal beta function at IP | β_x^* | mm | 16 | 14 | 13 | 16 | 11 |
| Vertical beta function at IP | β_y^* | mm | 0.34 | 0.38 | 0.41 | 0.34 | 0.48 |
| RMS horizontal beam size at IP | σ_x^* | nm | 904 | 789 | 729 | 684 | 474 |
| RMS vertical beam size at IP | σ_y^* | nm | 7.8 | 7.7 | 7.7 | 5.9 | 5.9 |
| Vertical disruption parameter | D_y | | 24.3 | 24.5 | 24.5 | 24.3 | 24.6 |
| Fractional RMS energy loss to beamstrahlung | δ_{BS} | % | 0.65 | 0.83 | 0.97 | 1.9 | 4.5 |
| Luminosity | L | $\times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ | 0.56 | 0.67 | 0.75 | 1.0 | 1.8 |
| Fraction of L in top 1% E_{CM} | $L_{0.01}$ | % | 91 | 89 | 87 | 77 | 58 |
| Electron polarisation | P_- | % | 80 | 80 | 80 | 80 | 80 |
| Positron polarisation | P_+ | % | 30 | 30 | 30 | 30 | 30 |
| Electron relative energy spread at IP | $\Delta p/p$ | % | 0.20 | 0.19 | 0.19 | 0.16 | 0.13 |
| Positron relative energy spread at IP | $\Delta p/p$ | % | 0.19 | 0.17 | 0.15 | 0.10 | 0.07 |

ILC parameters for the different upgrade stages

| Centre-of-mass energy | E_{CM} | GeV | Baseline | 1st Stage | L Upgrade | TeV Upgrade | |
|--------------------------------------|---------------------|---|----------|-----------|-----------|-------------|-----------|
| | | | 500 | 250 | 500 | A 1000 | B 1000 |
| Collision rate | f_{rep} | Hz | 5 | 5 | 5 | 4 | 4 |
| Electron linac rate | f_{linac} | Hz | 5 | 10 | 5 | 4 | 4 |
| Number of bunches | n_b | | 1312 | 1312 | 2625 | 2450 | 2450 |
| Bunch population | N | $\times 10^{10}$ | 2.0 | 2.0 | 2.0 | 1.74 | 1.74 |
| Bunch separation | Δt_b | ns | 554 | 554 | 366 | 366 | 366 |
| Pulse current | I_{beam} | mA | 5.79 | 5.8 | 8.75 | 7.6 | 7.6 |
| Average total beam power | P_{beam} | MW | 10.5 | 5.9 | 21.0 | 27.2 | 27.2 |
| Estimated AC power | P_{AC} | MW | 163 | 129 | 204 | 300 | 300 |
| RMS bunch length | σ_z | mm | 0.3 | 0.3 | 0.3 | 0.250 | 0.225 |
| Electron RMS energy spread | $\Delta p/p$ | % | 0.124 | 0.190 | 0.124 | 0.083 | 0.085 |
| Positron RMS energy spread | $\Delta p/p$ | % | 0.070 | 0.152 | 0.070 | 0.043 | 0.047 |
| Electron polarisation | P_- | % | 80 | 80 | 80 | 80 | 80 |
| Positron polarisation | P_+ | % | 30 | 30 | 30 | 20 | 20 |
| Horizontal emittance | $\gamma \epsilon_x$ | μm | 10 | 10 | 10 | 10 | 10 |
| Vertical emittance | $\gamma \epsilon_y$ | nm | 35 | 35 | 35 | 30 | 30 |
| IP horizontal beta function | β_x^* | mm | 11.0 | 13.0 | 11.0 | 22.6 | 11.0 |
| IP vertical beta function (no TF) | β_y^* | mm | 0.48 | 0.41 | 0.48 | 0.25 | 0.23 |
| IP RMS horizontal beam size | σ_x^* | nm | 474 | 729 | 474 | 481 | 335 |
| IP RMS vertical beam size (no TF) | σ_y^* | nm | 5.9 | 7.7 | 5.9 | 2.8 | 2.7 |
| Luminosity (inc. waist shift) | L | $\times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ | 1.8 | 0.75 | 3.6 | 3.6 | 4.9 |
| Fraction of luminosity in top 1% | $L_{0.01}/L$ | | 58.3% | 87.1% | 58.3% | 59.2% | 44.5% |
| Average energy loss | δ_{BS} | | 4.5% | 0.97% | 4.5% | 5.6% | 10.5% |
| Number of pairs per bunch crossing | N_{pairs} | $\times 10^3$ | 139.0 | 62.4 | 139.0 | 200.5 | 382.6 |
| Total pair energy per bunch crossing | E_{pairs} | TeV | 344.1 | 46.5 | 344.1 | 1338.0 | 3441.0 |

5 ILC

6 BDS muons

- Analysis - Spatial distributions
- Analysis - Energy distributions
- Analysis - SiD hit distribution
- Analysis - SiD Occupancy
- Analysis - Time distributions

7 FLUKA simulation

5 ILC

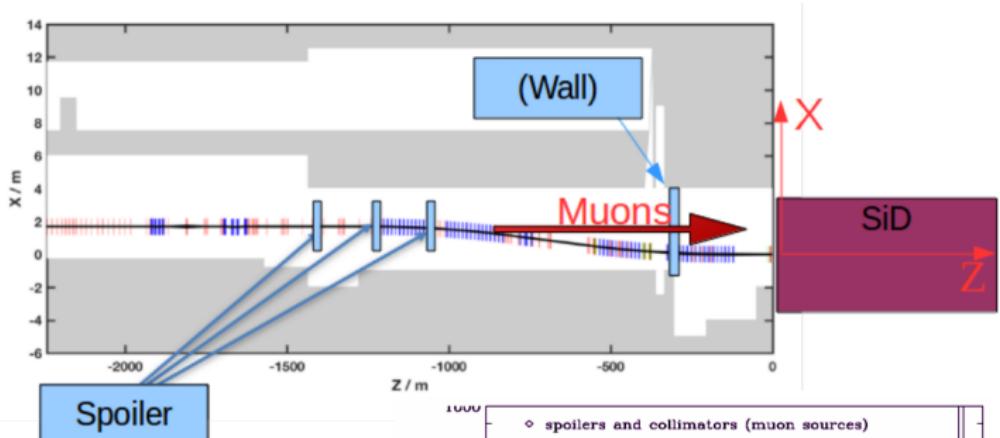
6 BDS muons

- Analysis - Spatial distributions
- Analysis - Energy distributions
- Analysis - SiD hit distribution
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- Analysis - Time distributions

7 FLUKA simulation

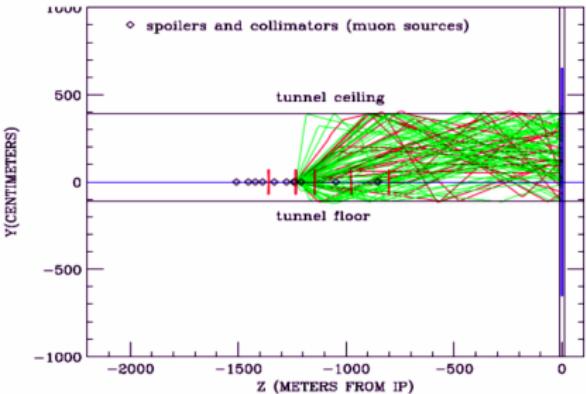
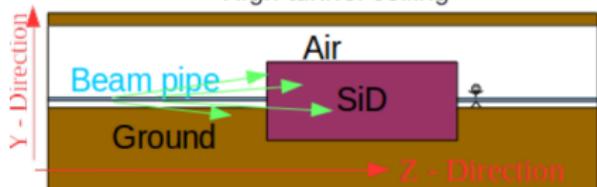


Explanation of spatial distributions



- > Beam pipe is curved
- > Beam pipe close to floor

= High tunnel ceiling



5 ILC

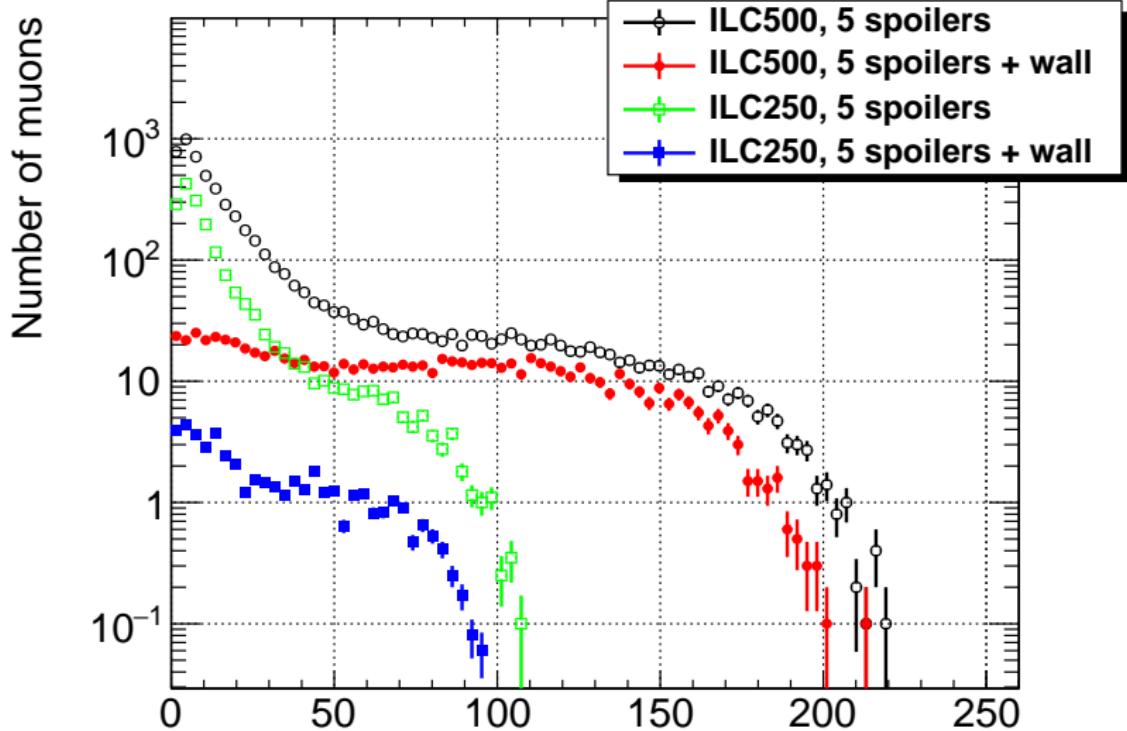
6 BDS muons

- Analysis - Spatial distributions
- **Analysis - Energy distributions**
- Analysis - SiD hit distribution
- Analysis - SiD Occupancy
- Analysis - Time distributions

7 FLUKA simulation

Energy distribution of muons

Muon Energy



5 ILC

6 BDS muons

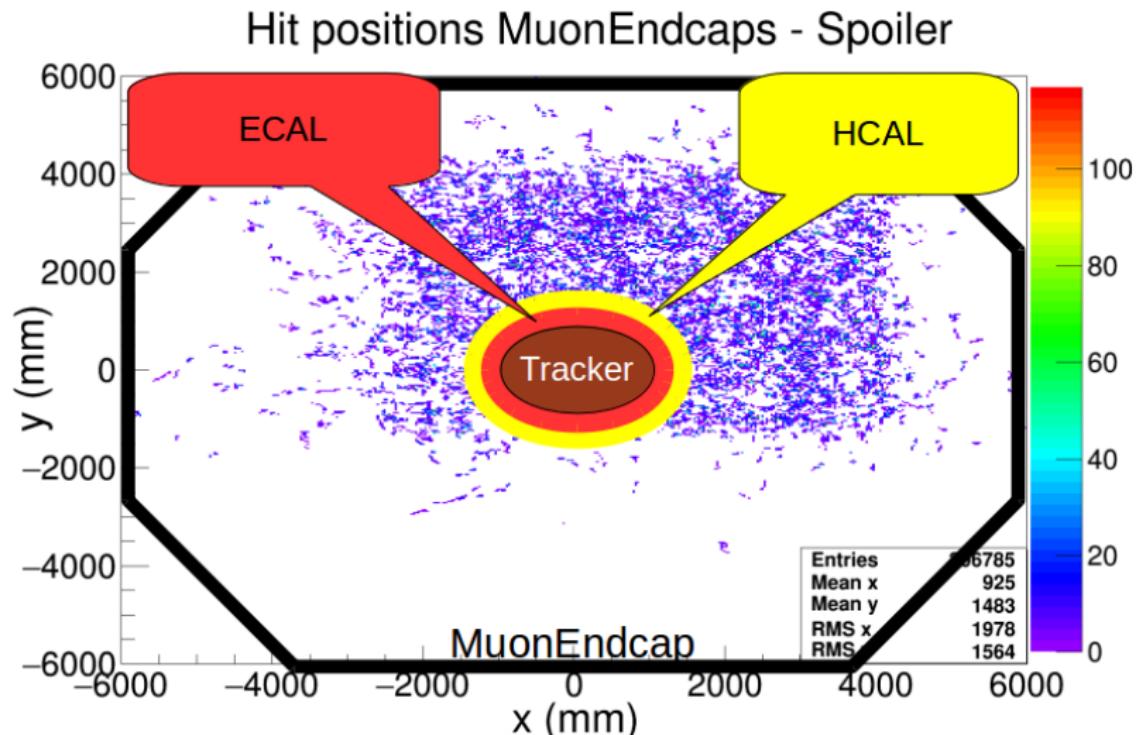
- Analysis - Spatial distributions
- Analysis - Energy distributions
- **Analysis - SiD hit distribution**
- Analysis - SiD Occupancy
- Analysis - Time distributions

7 FLUKA simulation



Explanation of hit number distribution -

Spatial distribution in the MuonEndcaps



5 ILC

6 BDS muons

- Analysis - Spatial distributions
- Analysis - Energy distributions
- Analysis - SiD hit distribution
- **Analysis - SiD Occupancy**
- Analysis - Time distributions

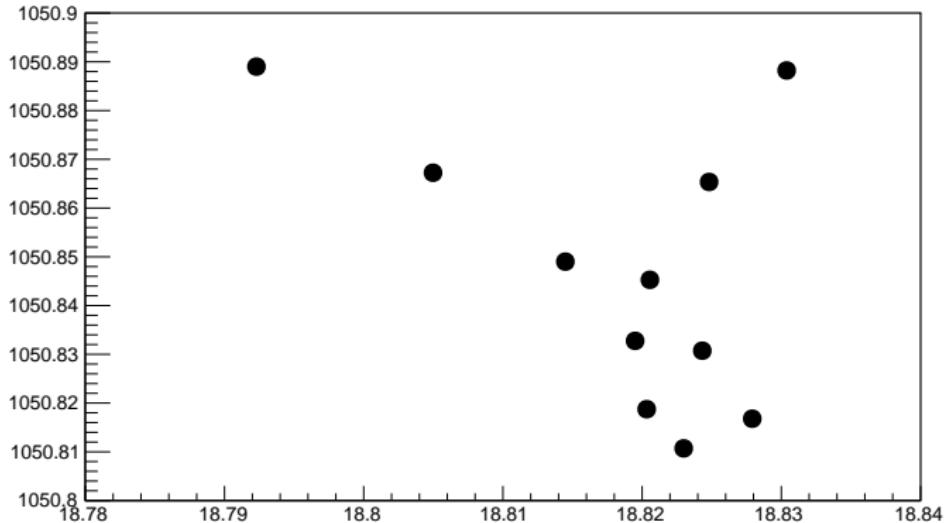
7 FLUKA simulation



Occupancy plots - SiTrackerEndcap

Low energy muon (order of MeV) is deflected in the magnetic solenoid field, and hits the active layer several times.

Pos_y:Pos_x {Layer == 4}

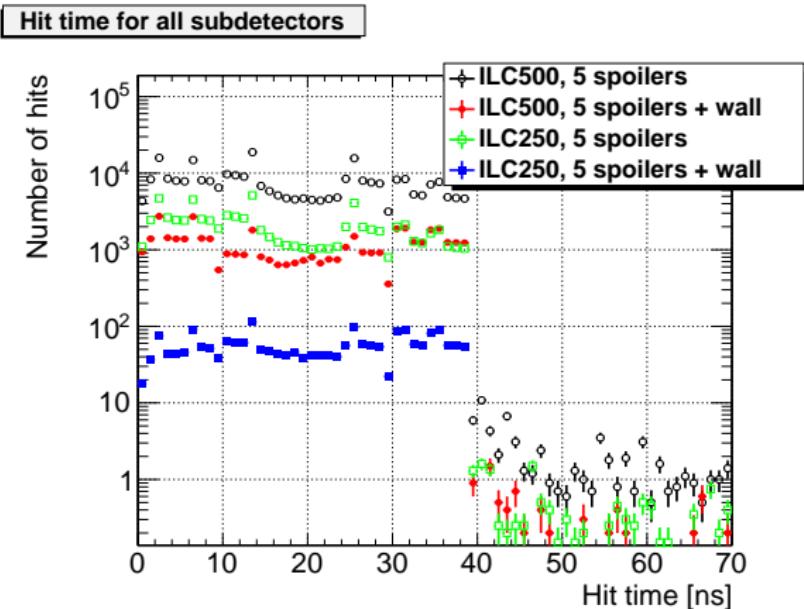


5 ILC**6** BDS muons

- Analysis - Spatial distributions
- Analysis - Energy distributions
- Analysis - SiD hit distribution
- Analysis - SiD Occupancy
- Analysis - Time distributions

7 FLUKA simulation

Hit Time distribution



Muons are first hitting the MuonEndcaps as the most outer subdetector.

5 ILC

6 BDS muons

7 FLUKA simulation

- Particle Fluxes

5 ILC

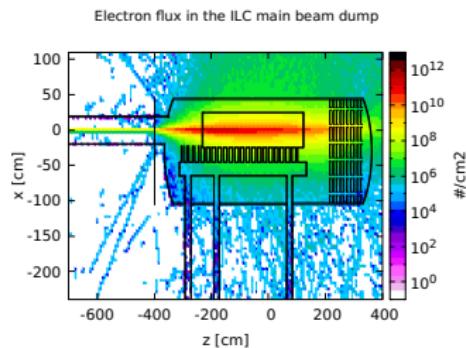
6 BDS muons

7 FLUKA simulation
• Particle Fluxes

Electron and Photon fluxes from one bunch

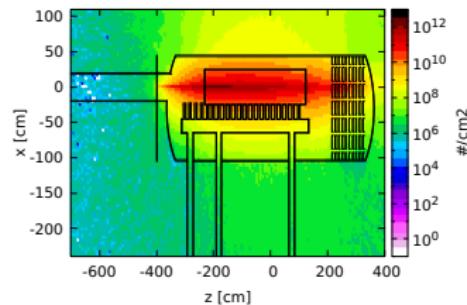
Design 1

Electrons



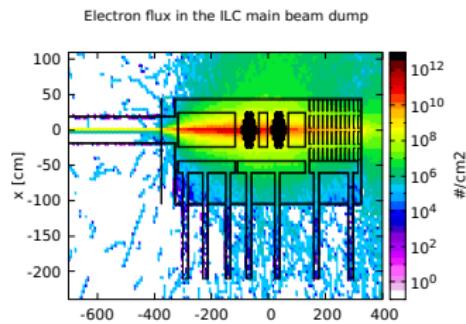
Photons

Photon flux in the ILC main beam dump



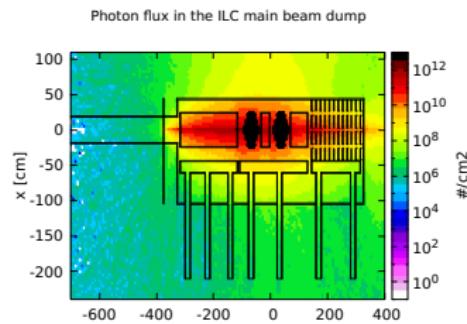
Design 2

Electrons



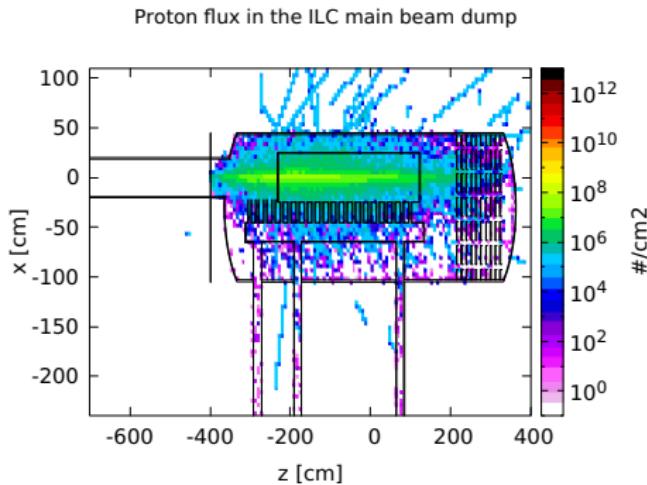
Photons

Photon flux in the ILC main beam dump

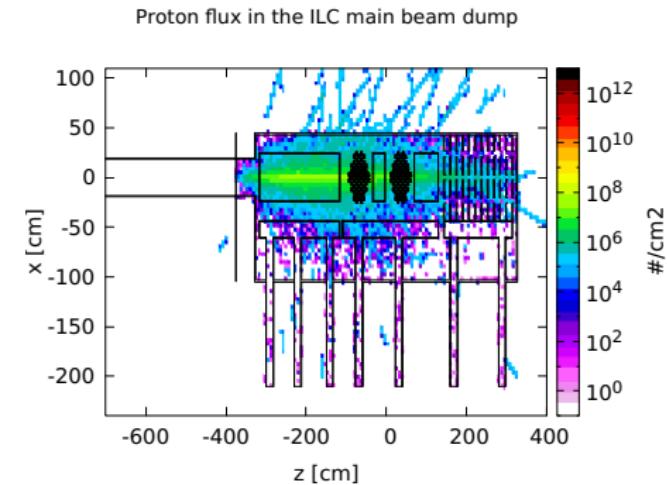


Proton fluxes

Design 1

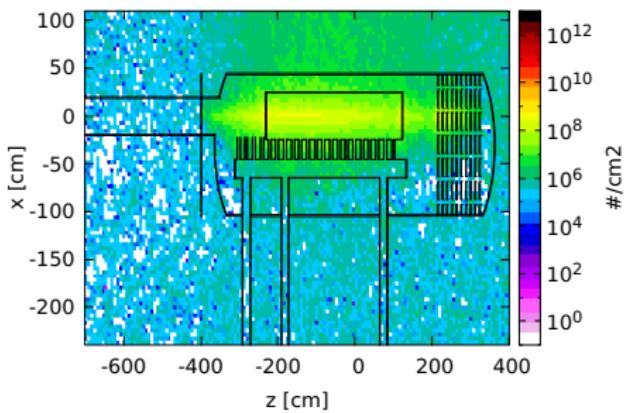


Design 2

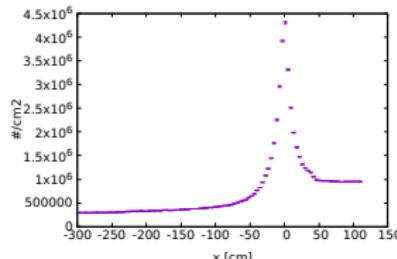


Neutron fluxes from one bunch: Design 1

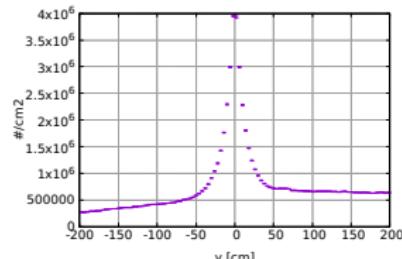
Neutron flux in the ILC main beam dump

 **x -direction**

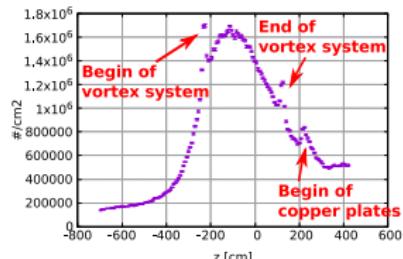
Neutron flux in the ILC main beam dump

 **y -direction**

Neutron flux in the ILC main beam dump

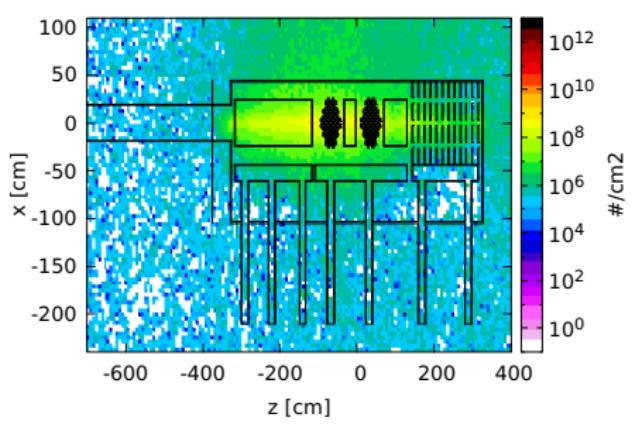
 **z -direction**

Neutron flux in the ILC main beam dump

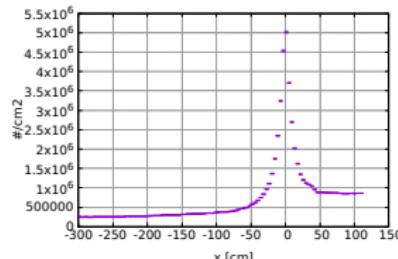


Neutron fluxes from one bunch: Design 2

Neutron flux in the ILC main beam dump

**x-direction**

Neutron flux in the ILC main beam dump

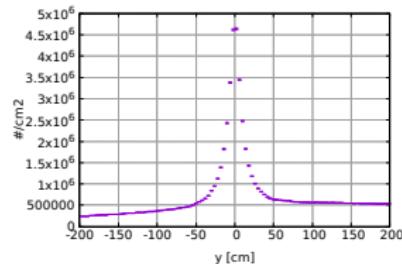


Anne Schütz (DESY)

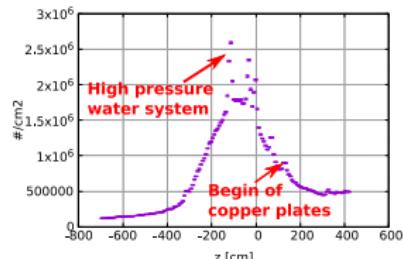
The neutrons again spread more in the positive x and y-direction. Within the tank, the point of highest neutron production is the high pressure water system. The production rate again decreases with the beam being stopped by the copper plates.

y-direction

Neutron flux in the ILC main beam dump

**z-direction**

Neutron flux in the ILC main beam dump



ILC backgrounds & SiD Occupancy