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

Summary of Background & SiD Occupancy Studies

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DESY

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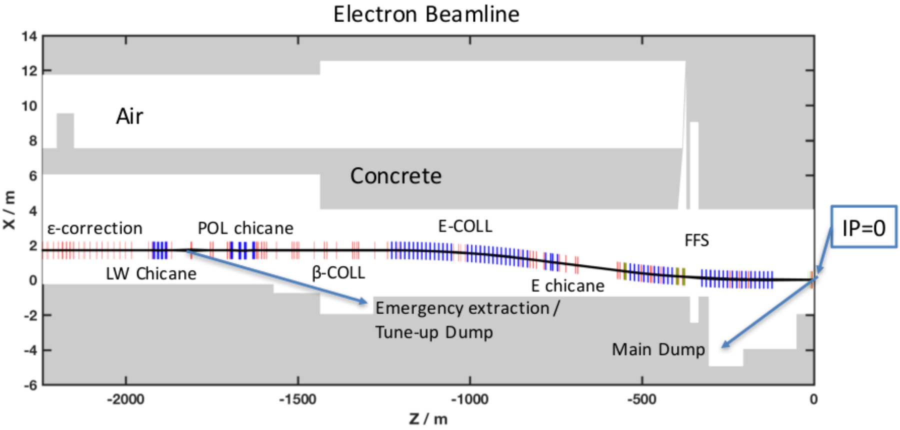
For more information, see the more detailed talks:

- BDS muon study:
  https://agenda.linearcollider.org/event/7371/contributions/38190/attachments/30975/46399/MuonSpoilerStudy_ASchuetz.pdf
- Beam dump study:
  https://agenda.linearcollider.org/event/7507/contributions/39283/attachments/31735/47826/BeamDump_ASchuetz.pdf
- Pair background study for ILC250 schemes:
  See LCWS2017 in Strasbourg in October

Muons from the BDS system

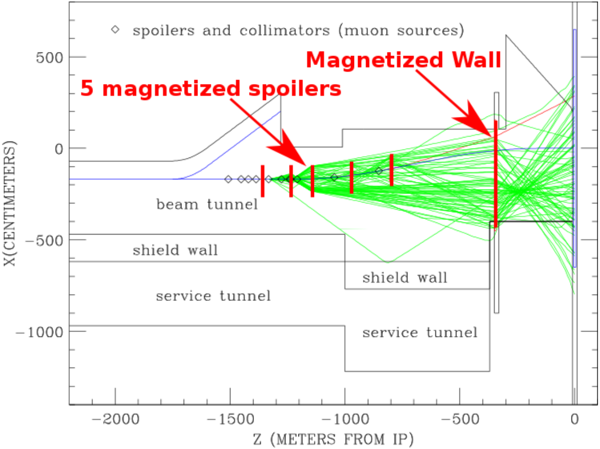
BDS tunnel layout



Muon spoiler scenarios

There are TWO SPOILER SCENARIOS under discussion:

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

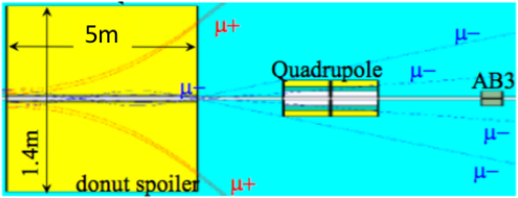


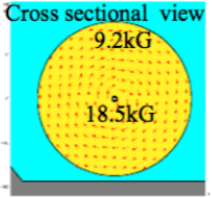
e⁻ beam line

5 donut spoilers

The donut spoilers are designed as follows:

- 70 cm radius
- 5 m long
- Magnetized iron with a field of ∼10-19 kG
- 5 locations (before IP):
  - 802.5m
  - 975.5m
  - 1145.5m
  - 1234.5m
  - 1358.5m

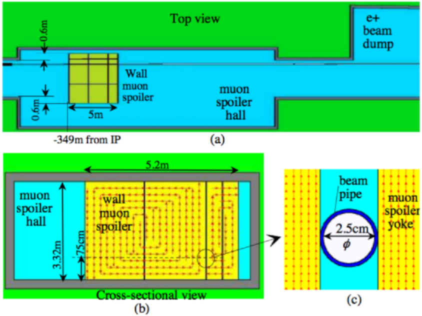


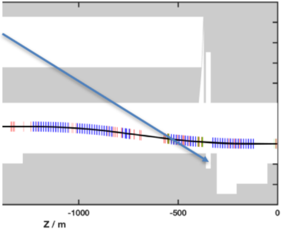


5 donut spoilers + wall

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 ∼ $3 million





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

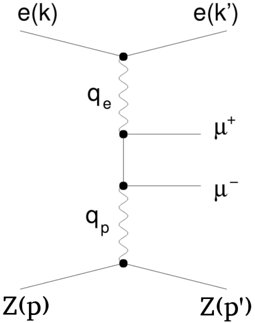
1. *Muons from the muon spoilers*
   - Muon spoiler scenarios
   - MUCARLO simulation
     - Muon 4-vectors
     - Motivation
   - Results of the Geant4 simulation
   - Conclusion

2. *FLUKA simulation of the ILC Beam Dump*

3. *Pair background studies for the new ILC250 schemes*

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
- 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



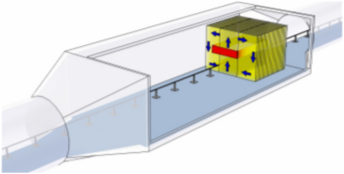
Muons in the detector

4-vectors of the muons are given to SiD and ILD for studying the effect of the muons on the detector performance.

Scenario	Number of muons in a detector with 6.5m radius
No Spoilers	130 muons/bunch crossing
5 Spoilers	4.3 muons/bunch crossing
5 Spoilers + Wall	0.6 muons/bunch crossing

Question to SiD and ILD: Do we need the muon wall at all?! MID people would be happy to get rid of it because of safety issues, and the costs for such a iron wall.

Muon Wall Required?



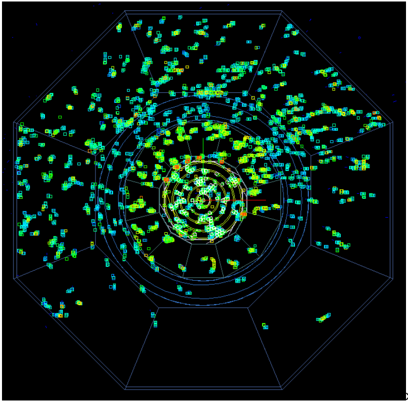
- If flux with toroid spoilers acceptable running condition from detector groups:
  - **Can we remove 5m magnetized iron muon wall?**

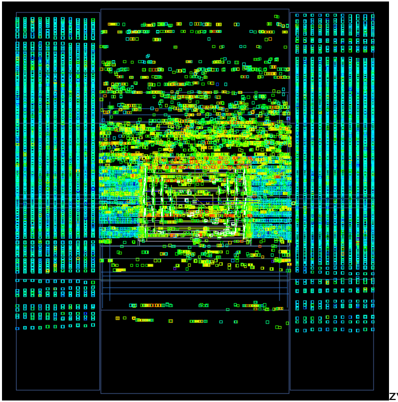
On the other hand:

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

WIRED4 event display - 5 Spoilers + Wall

1 train's worth of muons ($\sim$ 515 muons) **from the positron line only**:

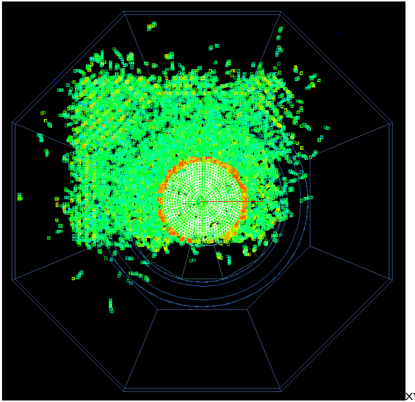

xy-view


zy-view

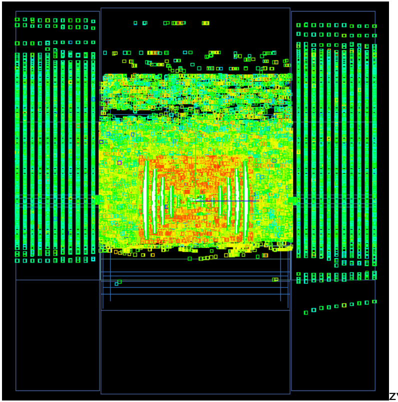
Together with the muons from the e$^-$ line, there will be $\sim$ **900 muons per train in the '5 Spoilers + Wall' scenario**.

WIRED4 event display - 5 Spoilers

1 train's worth of muons (∼ 2961 muons) **from the positron line only**:



xy-view



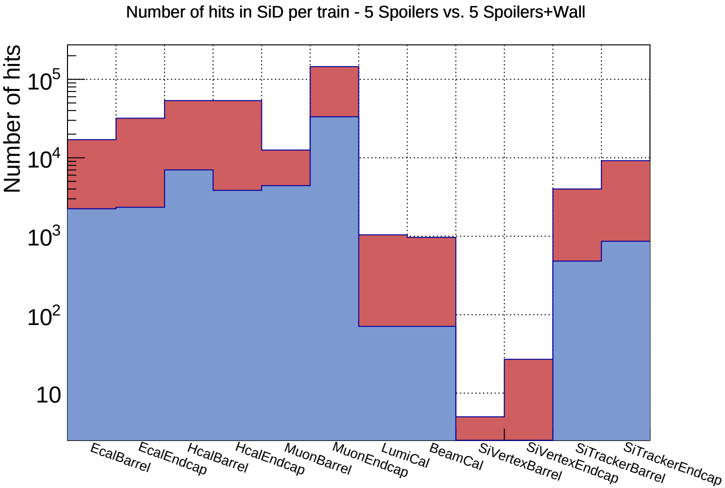
zy-view

Together with the muons from the e^- line, there will be ∼ **5600 muons per train in the '5 Spoilers' scenario**.

The spatial distribution is due to the tunnel shape and its shielding effects.

Total number of hits

Comparison of the total number of hits in the different SiD subdetectors in the '5 Spoilers' and the '5 Spoilers + Wall' case:

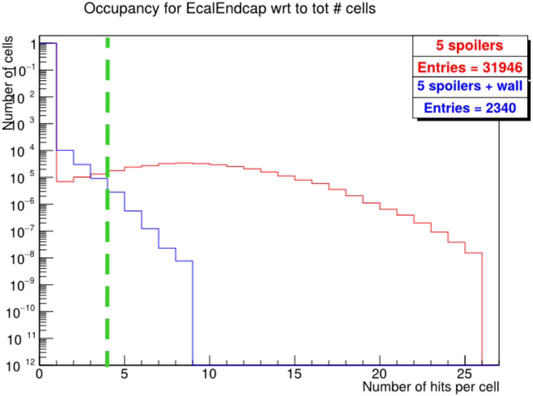


Vertex detectors	$<$	ECAL, HCAL	$<$	MuonEndcaps
Smallest effective detector area		Particle showers		Biggest effective detector area

Occupancy plots - EcalEndcap

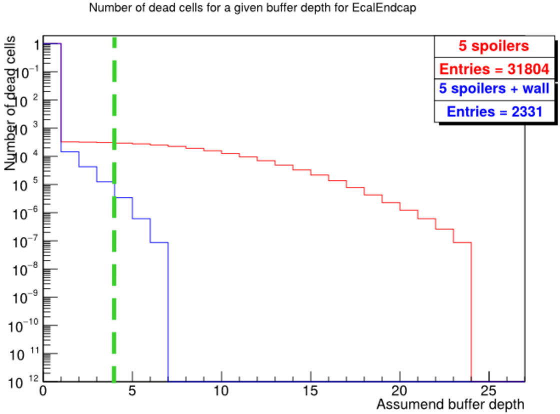
Comparison of the muon occupancy in the '5 Spoilers and the '5 Spoilers + Wall' case.
The buffer depth of the current sensor design is 4.

The following occupancy plots are normalized by the first bin.



'5 Spoilers + Wall' seems to do better by an order of magnitude, when looking at a buffer depth of 4. The occupancy is still at a level of only $\sim 10^{-6}$.
The '5 Spoiler' case shows up to 27 hits per cell.$\rightarrow$ Constant occupancy for all buffer depths.

Dead cells - EcalEndcap



For an assumed buffer depth of 4, the total number of dead cells is different by about two orders of magnitude. → In the '5 Spoiler' case, 10^{-3} cells would have reached the buffer limit.

1. *Muons from the muon spoilers*
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3. *Pair background studies for the new ILC250 schemes*

Conclusion:

- Low energy muons are stopped/deflected by the magnetized wall.
- High energy muons could be used for tracker alignment.
- Spatial distributions quite different in the '5 Spoiler' and '5 Spoiler+Wall' scenarios.
- Number of hits in subdetectors are explained by different geometries.
- With the shown evaluation of the muons from the current MUCARLO simulations, SiD would prefer to **keep the wall**. Additional studies with a comparison to other background sources will be done.

Neutron Background and Beam Dump Irradiation

The 17 MW[1] beam is dumped into a water tank after collision.
The activation of the dump surrounding will permit access to the dump area. Neutrons ($\lesssim 10^{10}\,\mathrm{cm}^{-2}\,\mathrm{yr}^{-1}$) are emitted that irradiate the surroundings, and travel back towards the detectors. [9]

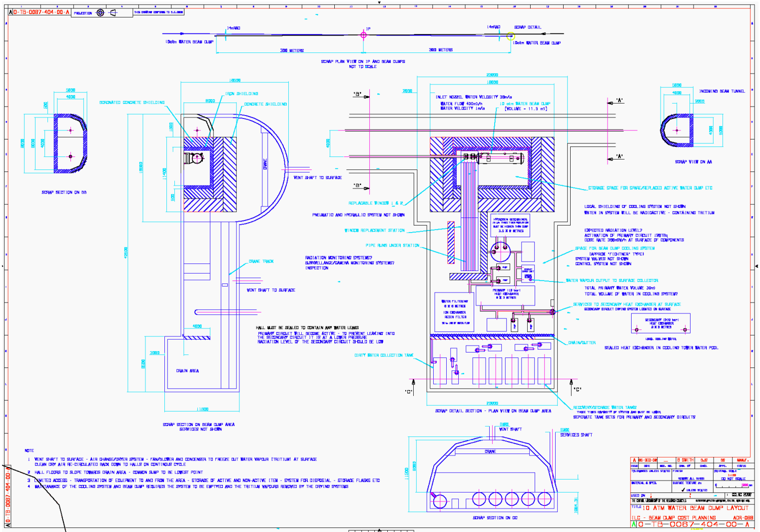
Goal: Simulating the energy deposition, irradiation, and background particles:

1. 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.
2. Neutrons through the EXT line: With Benno List (DESY): Python program to plug the real extraction line lattice into FLUKA. Realistic simulation of the interaction between the neutrons and the lattice.
3. Simulating the neutrons reaching the interaction point in a full detector simulation.

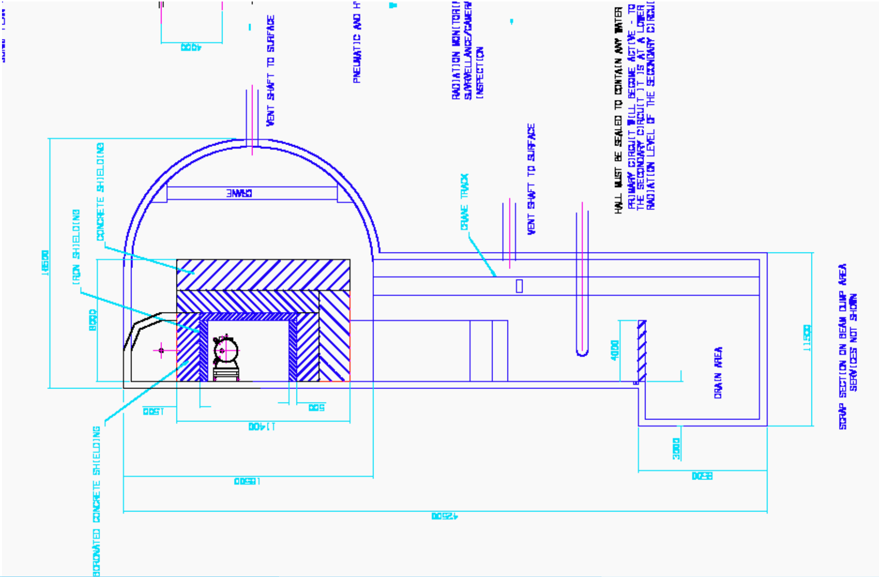
[1] 13.7 MW average beam power + 20% margin

Shielding walls: 0-TB-0067-404-00-A

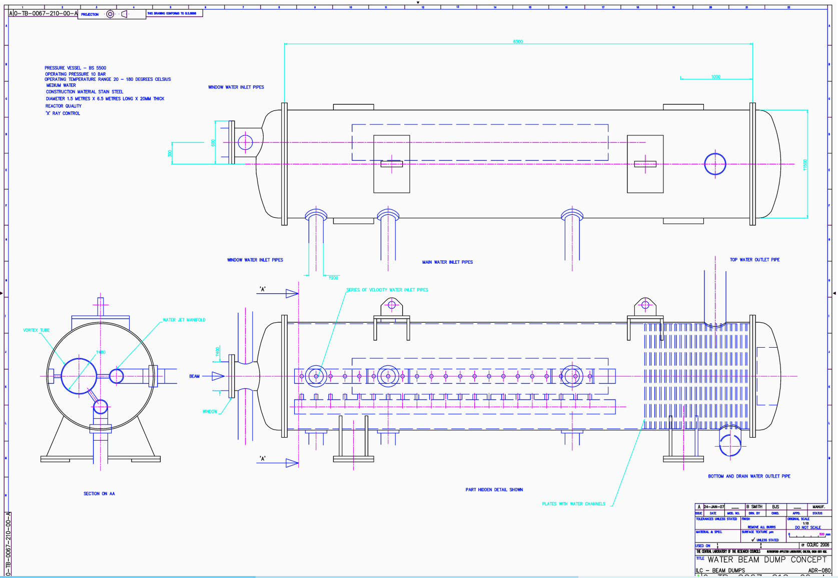
Design drawings by B. Smith, 2006-2007 [7]



Shielding walls: 0-TB-0067-404-00-A



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



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

Vessel:

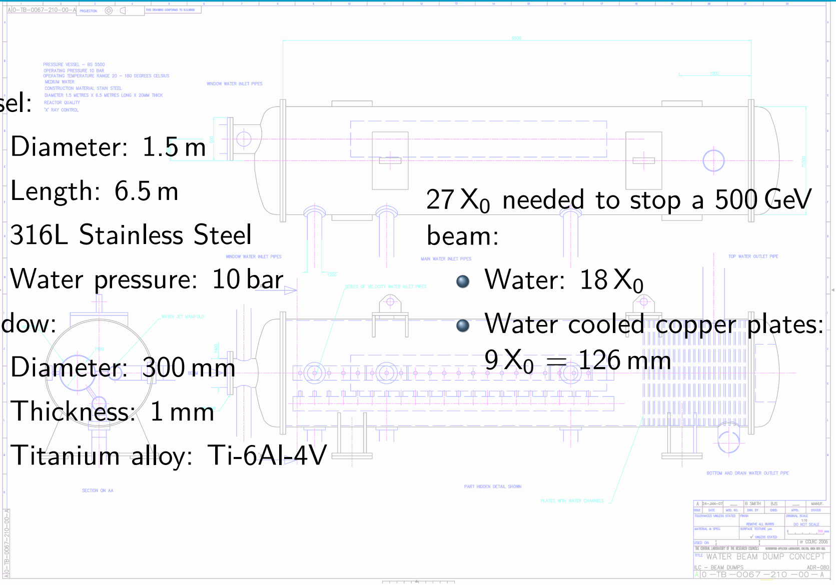
- Diameter: 1.5 m
- Length: 6.5 m
- 316L Stainless Steel
- Water pressure: 10 bar

Window:

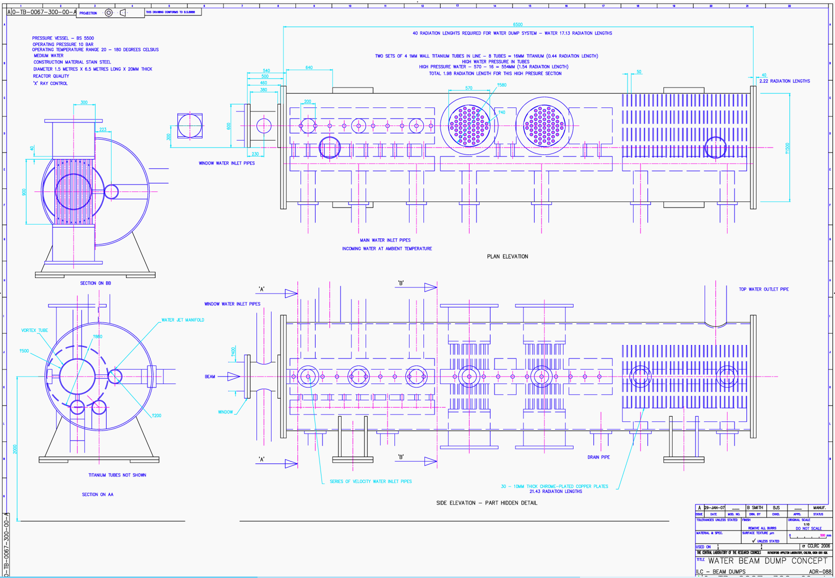
- Diameter: 300 mm
- Thickness: 1 mm
- Titanium alloy: Ti-6Al-4V

$27\,X_0$ needed to stop a 500 GeV beam:

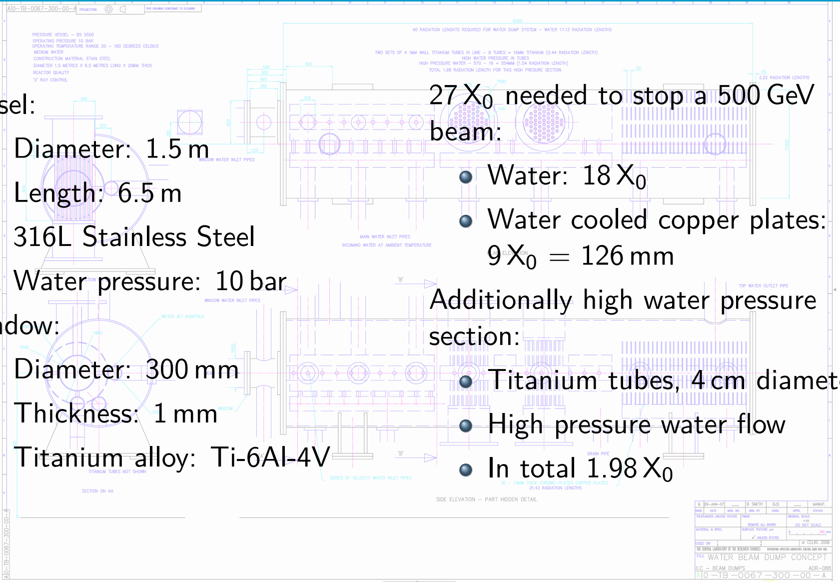
- Water: $18\,X_0$
- Water cooled copper plates: $9\,X_0 = 126\,\mathrm{mm}$



Design 2: 0-TB-0067-300-00-A



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



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$27\,X_0$ needed to stop a 500 GeV beam:

- Water: $18\,X_0$
- Water cooled copper plates: $9\,X_0 = 126$ mm

Additionally high water pressure section:

- Titanium tubes, 4 cm diameter
- High pressure water flow
- In total $1.98\,X_0$

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

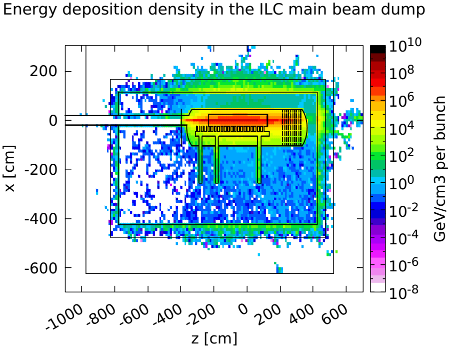
ILC1000B:

- Beam energy: 500 GeV
- Bunch population: 1.74e10
- Bunch size: $\sigma_x = 2.4\,\mathrm{mm}$, $\sigma_y = 0.22\,\mathrm{mm}$
- Bunches per train: 2450
- Bunch train duration: 896.7 µs

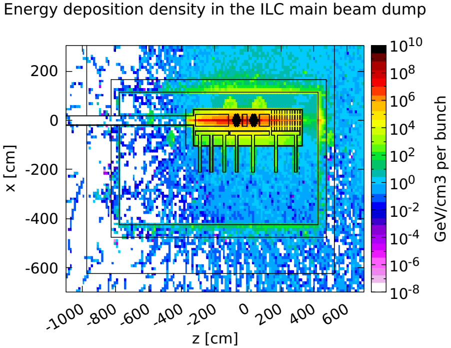
Beams are considered un-collided and un-disrupted.

Deposited Energy per bunch

Design 1



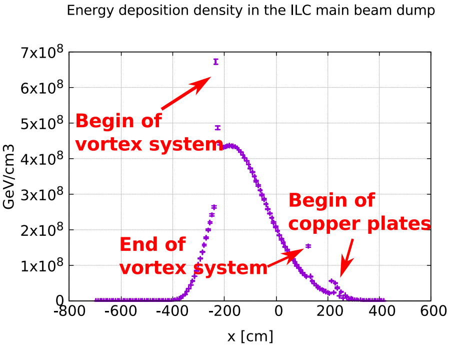
Design 2



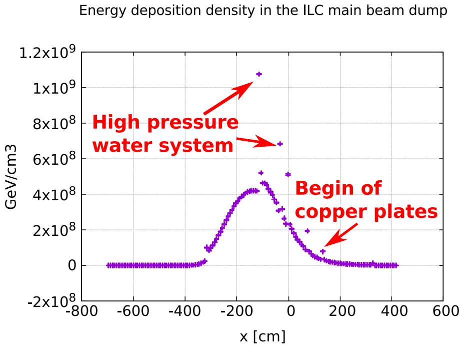
Shielding walls seem to stop particles fluxes well, but large scattering in Design 2 at high water pressure sections leads to energy deposition outside the walls.

Maximum Deposited Energy over Z per bunch

Design 1



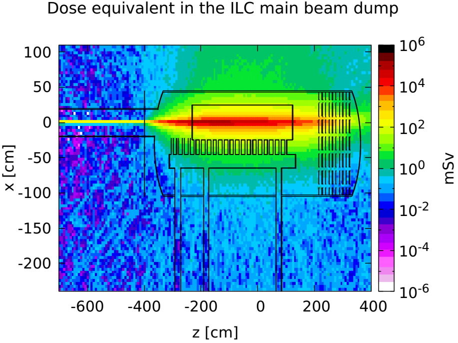
Design 2



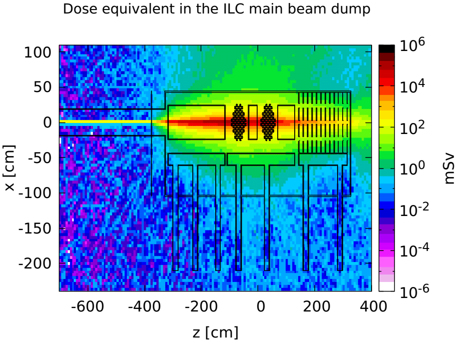
Maximum deposited energy within the water tank up to **10^8-10^9 GeV/cm^3 (= 0.016 - 0.16 J/cm^3) per bunch**.

Instantaneous Dose Equivalent per bunch

Design 1



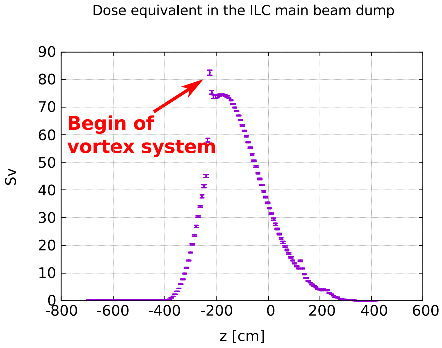
Design 2



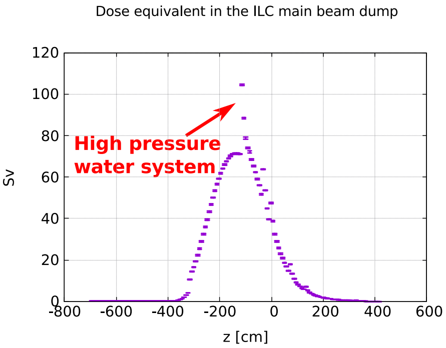
The two designs show comparable distributions of the dose equivalent.

Maximum Instantaneous Dose Equivalent over Z

Design 1



Design 2

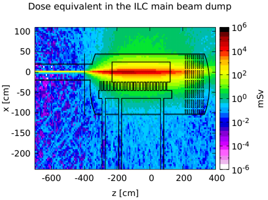


Maximum dose equivalent within the water tank up to **100 Sv per bunch**. Peaks in distributions at locations with lots of material.

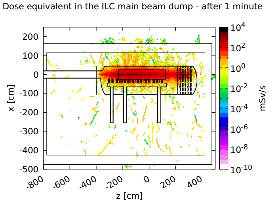
*Dose equivalent after cooling times - **Design 1***

After one month of beam operation, the beam is turned off.
Different **cooling times** are considered:
1 minute, 1 hour, 1 day, 1 month, and 1 year

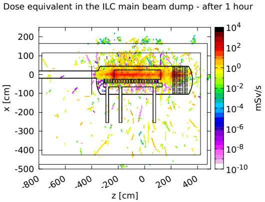
Instantaneous



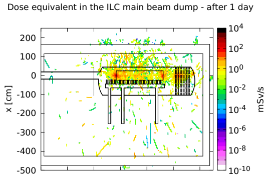
After 1 minute



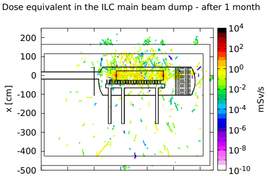
After 1 hour



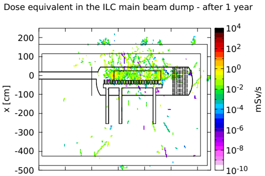
After 1 day



After 1 month

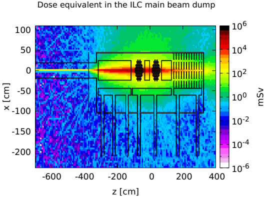


After 1 year

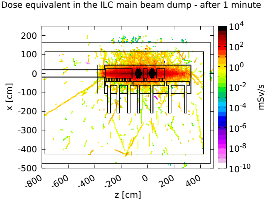


Dose equivalent after cooling times - ***Design 2***

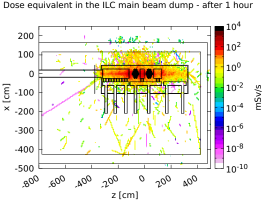
Instantaneous



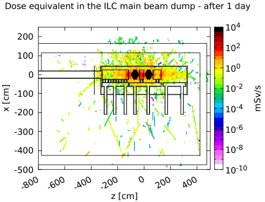
After 1 minute



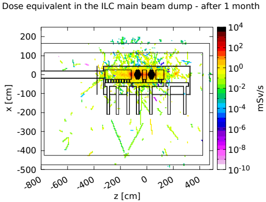
After 1 hour



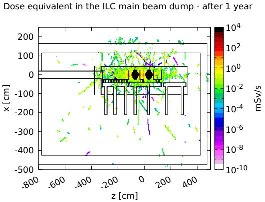
After 1 day



After 1 month

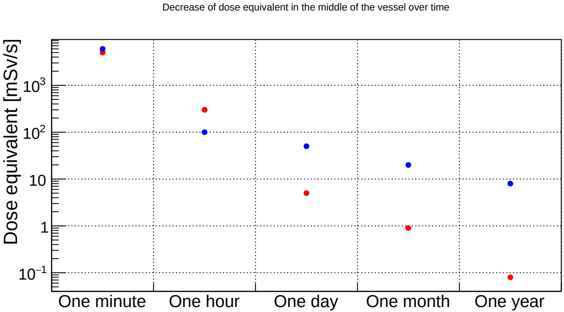


After 1 year



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
$\sim$ **0.1 mSv/s** for Design 1 and to $\sim$ **10 mSv/s** for Design 2.

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 $\mathbf{10^{-1}}$ **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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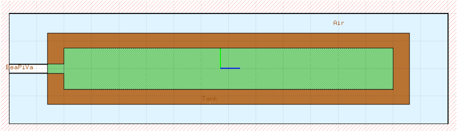
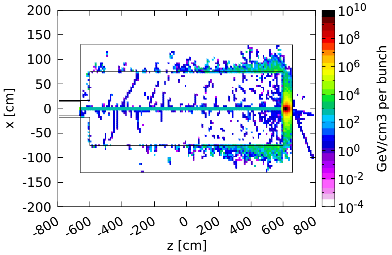
FOR FUN:

- Simulated simplified gas dump filled with Nitrogen
- Adopting ideas from dump design studies for TESLA done at DESY.
- Copper walls with a thickness of $\sim 60\,\text{cm}$

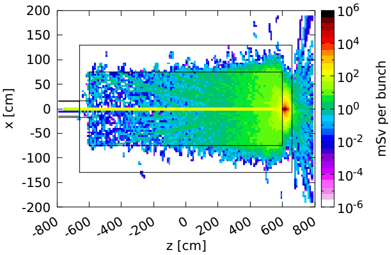


For Fun: Nitrogen Gas Dump

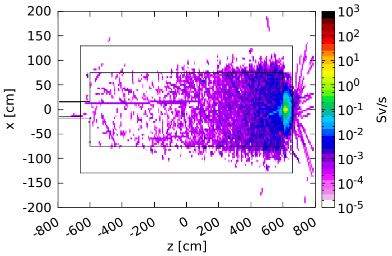
Energy deposition in the Nitrogen gas dump per bunch



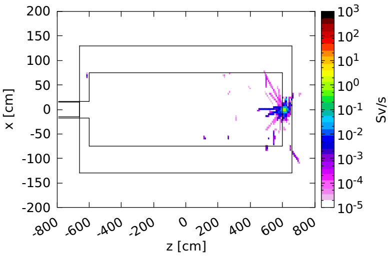
Dose equivalent - instantaneous



Dose rate for a Nitrogen Gas Dump - after 1 day



Dose rate for a Nitrogen Gas Dump - after 1 month



Summary and outlook

Goals for the next months:

- Studying the influence of the water composition (amount of deuterium),
- the influence of the composition of the steel vessel and the concrete shielding,
- simulating the neutron flux through the EXT line,
- the number of neutrons reaching the IP,
- the neutron occupancy in SiD.

1. *Muons from the muon spoilers*

2. *FLUKA simulation of the ILC Beam Dump*

3. *Pair background studies for the new ILC250 schemes*
   - Pair background envelopes
   - SiD Occupancy

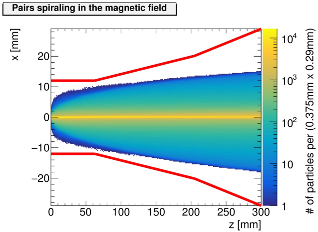
ILC250 Beam Parameter Sets

Table 1: Possible beam parameter sets for the ILC250 stage.
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].

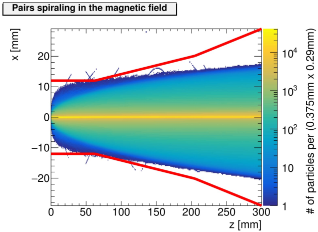
Set	ϵ_x **[µm]**	β_x **[mm]**	β_y **[mm]**
TDR	10	13.0	0.41
(A)	5	13.0	0.41
(B)	5	9.19	0.41
(C)	5	9.19	0.58

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

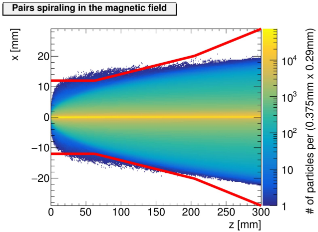
Pair background density in a 5 T solenoid field



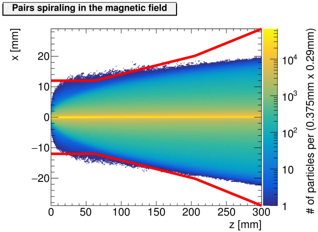
(a) ILC250 set (TDR)



(b) ILC250 set (A)

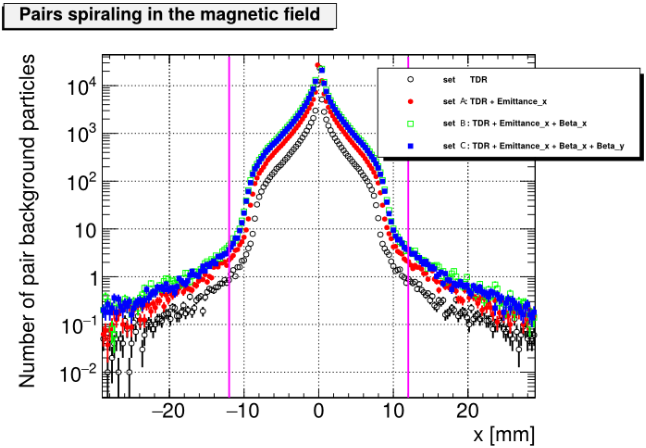


(c) ILC250 set (B)



(d) ILC250 set (C)

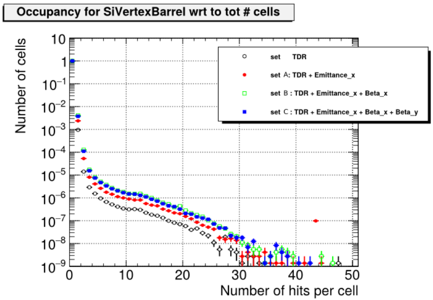
Projection of the pair background density along x



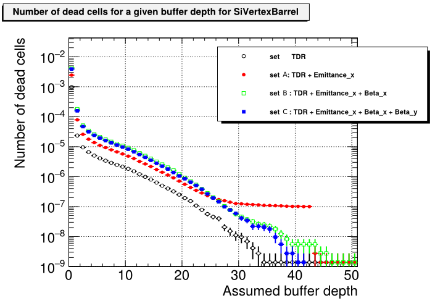
The envelopes are in all schemes well contained within the beam pipe. Less than 10 particles per bunch crossing are to be expected outside the beam pipe.

1. *Muons from the muon spoilers*
2. *FLUKA simulation of the ILC Beam Dump*
3. *Pair background studies for the new ILC250 schemes*
   - Pair background envelopes
   - SiD Occupancy

SiD Vertex Detector Occupancy: All layers

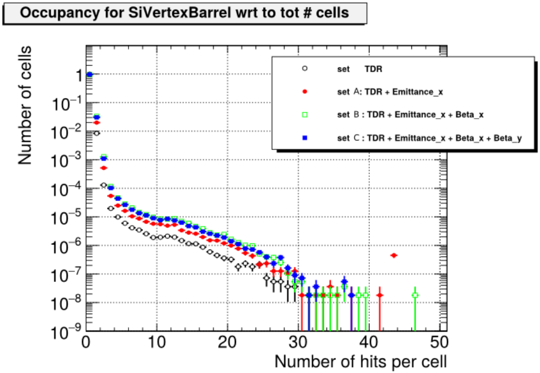


(a) Normalized Occupancy: Number of cells containing a certain amount of hits, normalized by the total number of cells of the vertex detector.



(b) Normalized number of dead cells: Number of cells with full buffer, normalized by the total number of cells of the vertex detector.

SiD Vertex Detector Occupancy: Layer 0



The occupancy in layer 0 for the new sets is significantly increased with respect to the TDR scheme.
SiD is confident that the occupancy can be accommodated in the design of the pixel detector.
Studies with smaller original L* of 3.5 m are ongoing. → Stay tuned!


山地の地下には
mにわたる
な岩盤があり
精密な実験に邪魔に
なる振動が少ないことが
決定の決め手となり
ました
ILC本体は
地下トンネルの中に
設置されます
粒子にエネルギーを与え
加速する超伝導
クライオモジュールを
直線状に連結

Thanks!

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.

Additional Material

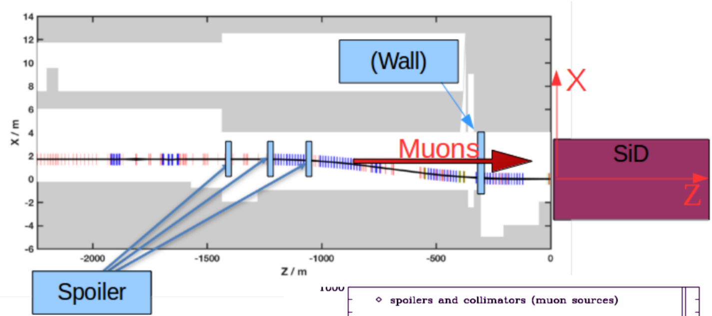
ILC baseline parameters

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	$\times 10^{34}$ cm^{-2} 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

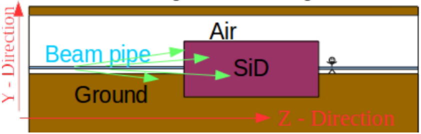
ILC parameters for the different upgrade stages

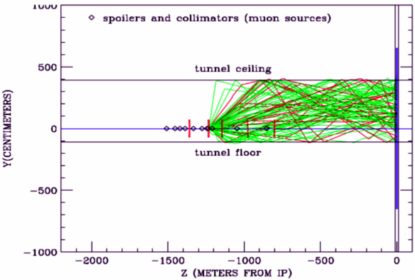
Centre-of-mass energy	E_{CM}	GeV	Baseline 500	1st Stage 250	L Upgrade 500	TeV Upgrade A 1000	TeV Upgrade B 1000
Collision rate	f_{rep}	Hz	5	5	5	4	4
Electron linac rate	f_{linac}	Hz	5	10	5	4	4
Number of bunches	n_b		1312	1312	2625	2450	2450
Bunch population	N	$\times 10^{10}$	2.0	2.0	2.0	1.74	1.74
Bunch 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 veritcal beam size (no TF)	σ_y^*	nm	5.9	7.7	5.9	2.8	2.7
Luminosity (inc. waist shift)	L	$\times 10^{34}$ cm^{-2}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

Explanation of spatial distributions



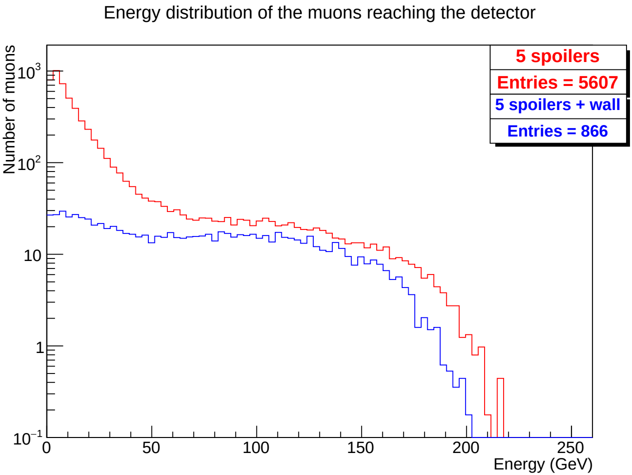
- Beam pipe is curved
- Beam pipe close to floor
  - High tunnel ceiling





Energy distribution of muons

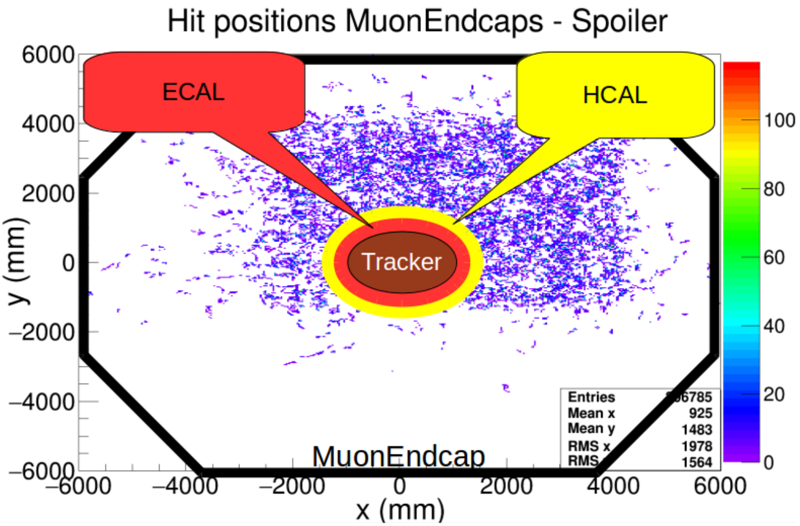
Comparison of the muon energies in the '5 Spoilers' and the '5 Spoilers + Wall' case:



In the 'Spoiler + Wall' case, the lower energy muons are either stopped or deflected by the magnetized wall.

Explanation of hit number distribution -

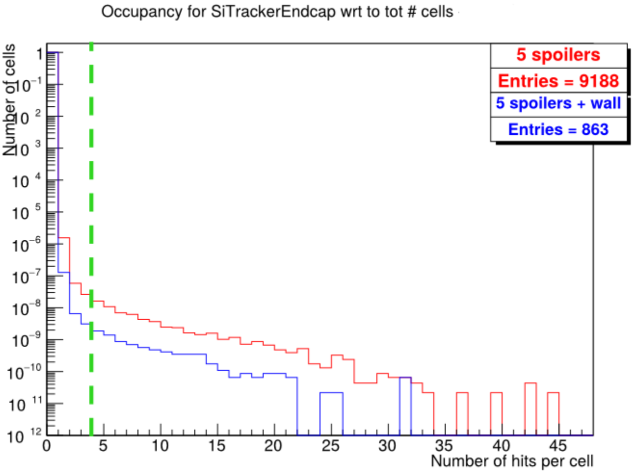
Spatial distribution in the MuonEndcaps



Occupancy plots - SiTrackerEndcap

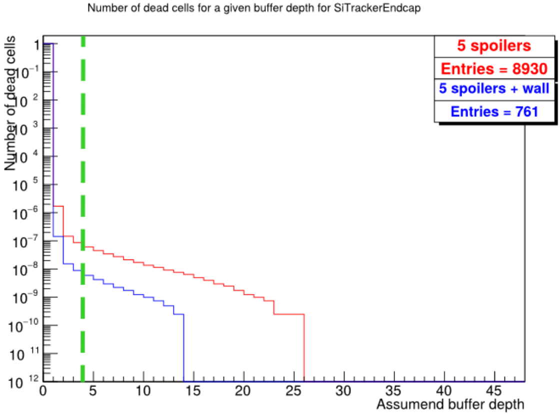
Comparison of the muon occupancy in the '5 Spoilers and the '5 Spoilers + Wall' case.
The buffer depth of the current sensor design is 4.

The following occupancy plots are normalized by the first bin.



For both scenarios, 5 Spoilers w/ and w/o Wall, 10^{-9} - 10^{-7} of all cells that get hit have 4 hits.

Dead cells - SiTrackerEndcap



For an assumed buffer depth of 4, the total number of dead cells is different by an order of magnitude. → In the '5 Spoiler' case, 10^{-7} cells would have reached the buffer limit.

4 *ILC*

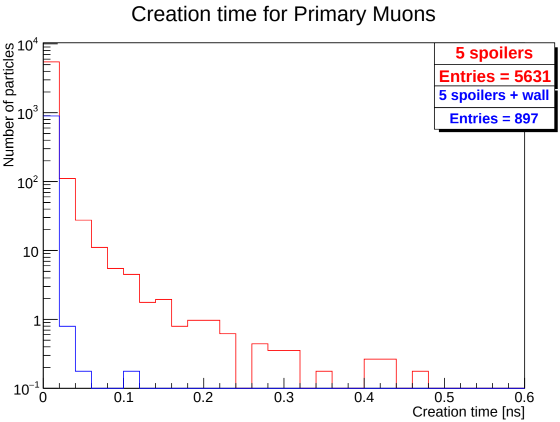
5 *BDS muons*

6 *FLUKA simulation*

7 *Zoom Plots*

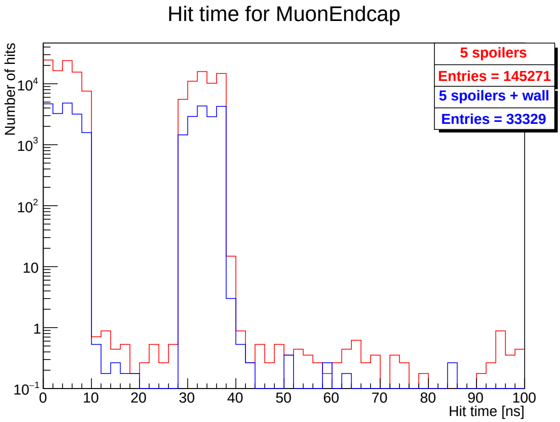
Creation time distribution

All of the primary muons are created up to 0.5 ns after the bunch passing the material.



The lower energy muons, which have a broader creation time, do not reach the detector in the '5 Spoilers + Wall' case.

Hit Time distribution - MuonEndcaps

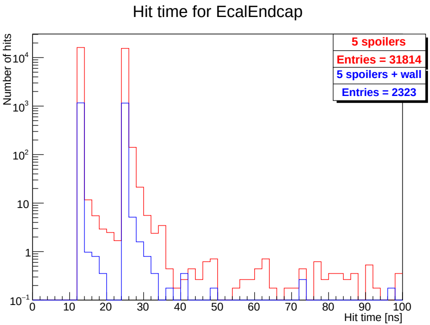


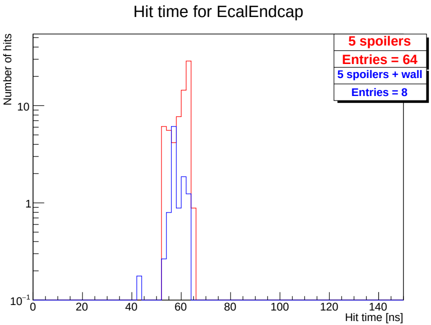
Muons are first hitting the MuonEndcaps as the most outer subdetector.

Hit Time distribution - EcalEndcaps

Hit time distributions for

the PRIMARY MUONS and the SHOWER PARTICLES:



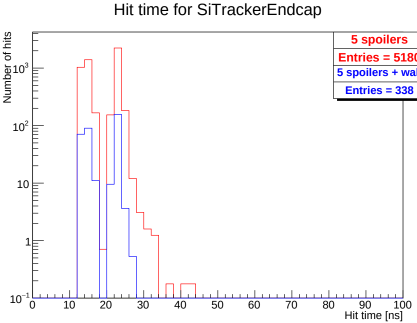


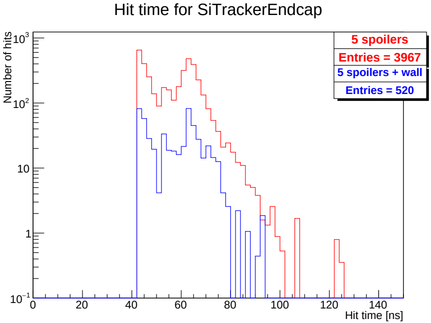
The primary muons leave hits between 12 and $\sim$ 50 ns after the bunch crossing, whereas the shower particles hit the EcalEndcaps about 60 ns after the crossing.

Hit Time distribution - SiTrackerEndcaps

Hit time distributions for

the PRIMARY MUONS and the SHOWER PARTICLES:





The primary muons leave hits between 12 and $\sim 40\,$ns after the bunch crossing, whereas the shower particles hit the Tracker endcaps about 40-100 ns after the crossing.

Total Deposited Energy per region per bunch

Dep. Energy [J]	**Water**	**Vessel**	**Window**
Design 1	233.24	5.14	0.0019
Design 2	240.67	4.36	0.0018

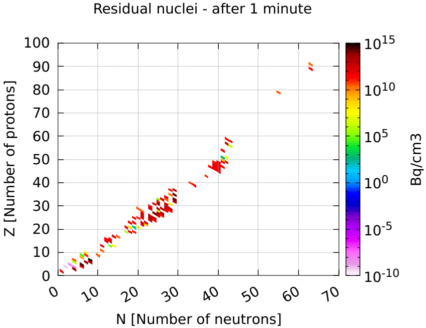
Dep. Energy [J]	**Cu plate 1**	**Last Cu plate**	**Iron shielding**
Design 1	4.44	1.46	5.09
Design 2	1.58	0.13	5.87

Numbers comparable to former FLUKA simulations of beam dump concepts for the ILC [10] and CLIC [11].

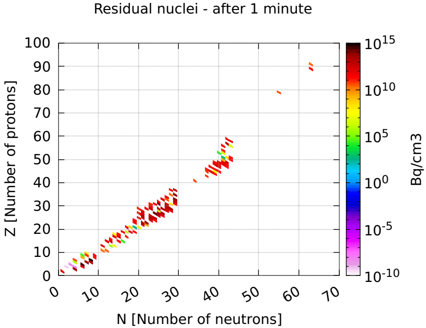
Residual nuclei after cooling times

After one month of beam operation, the beam is turned off.
Different **cooling times** are considered:
1 minute, 1 hour, 1 day, 1 month, and 1 year

Design 1

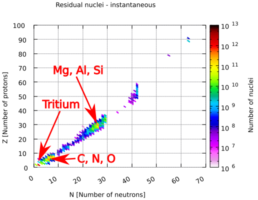


Design 2

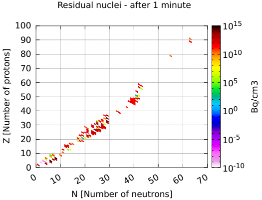


Residual nuclei after cooling times - ***Design 1***

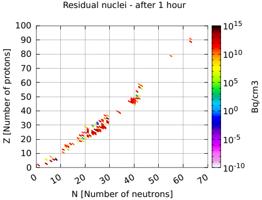
Instantaneous



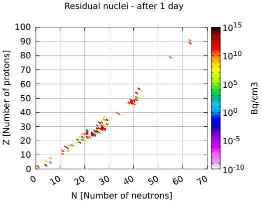
After 1 minute



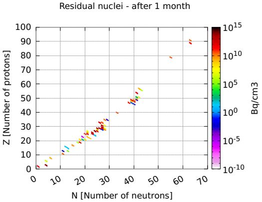
After 1 hour



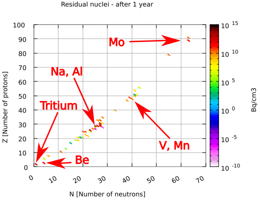
After 1 day



After 1 month

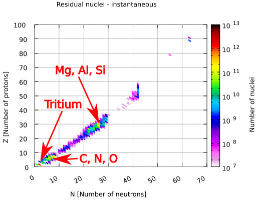


After 1 year

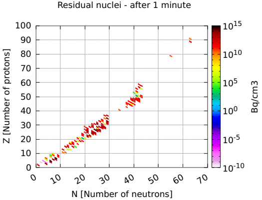


Residual nuclei after cooling times - Design 2

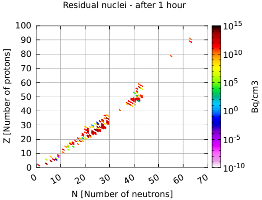
Instantaneous



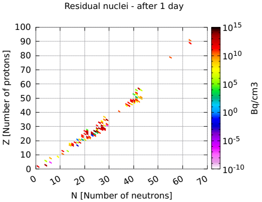
After 1 minute



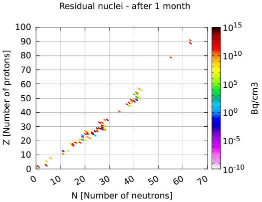
After 1 hour



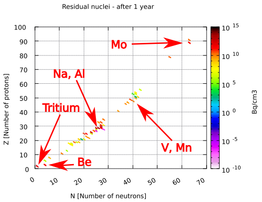
After 1 day



After 1 month



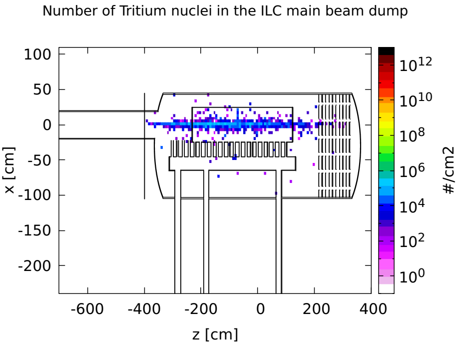
After 1 year



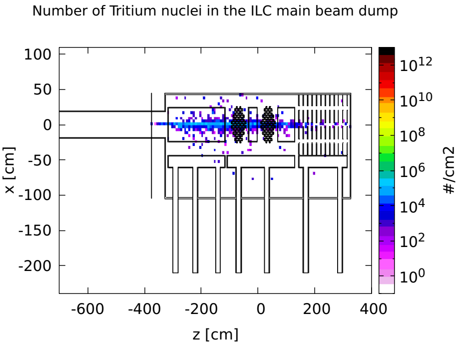
Number of radio-nuclides

The presence of certain nuclei is dependent on the choice of materials used for the dump vessel, the shielding[2] etc.

Tritium flux: Design 1



Tritium flux: Design 2

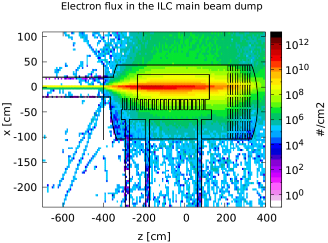


[2] Composition of concrete and neutron shielding concrete was taken from [12].

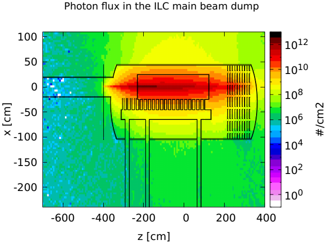
Electron and Photon fluxes from one bunch

Design 1

Electrons

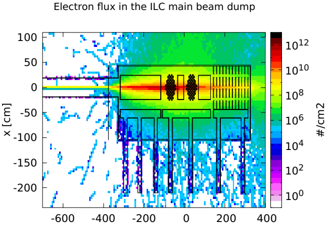


Photons

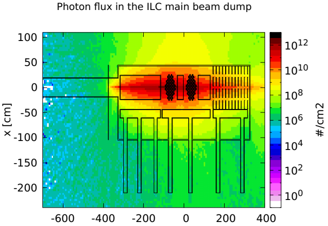


Design 2

Electrons

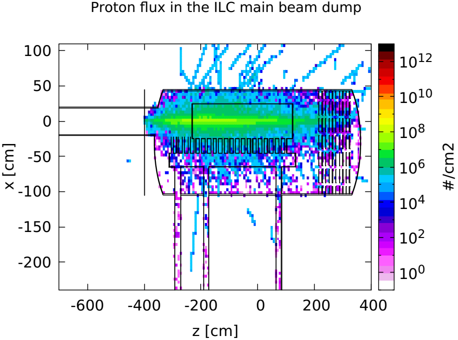


Photons

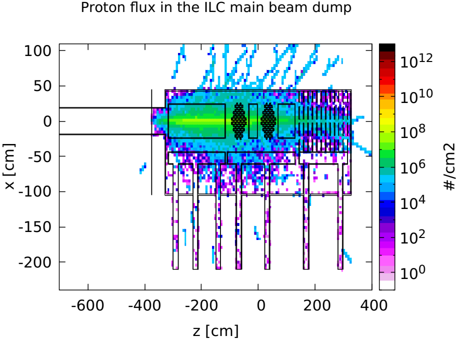


Proton fluxes

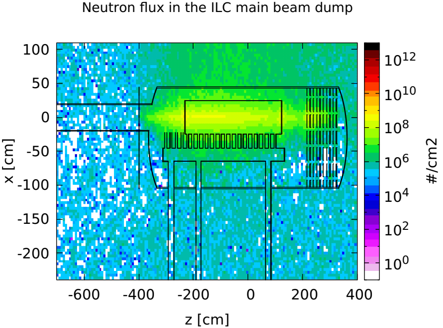
Design 1



Design 2

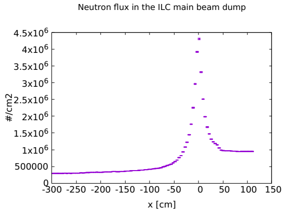


Neutron fluxes from one bunch: ***Design 1***

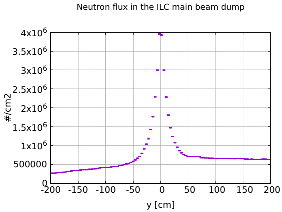


The neutrons spread more in the positive x and y-direction. Within the tank, the neutrons are mainly produced in the water vortex system. When the beam is stopped by the copper plates, the neutron production rate decreases.

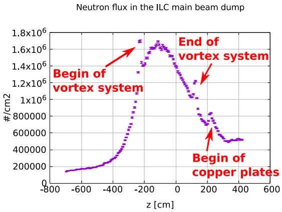
x-direction



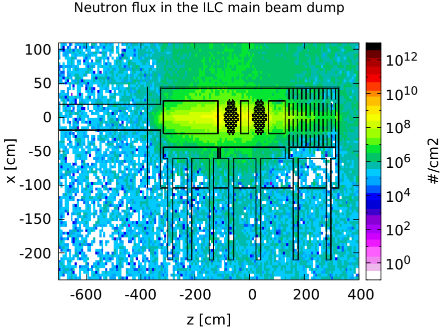
y-direction



z-direction

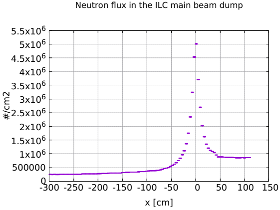


*Neutron fluxes from one bunch: **Design 2***

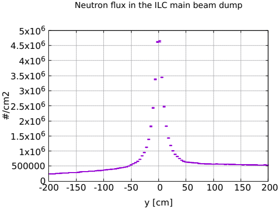


The neutrons again spread more in the positive x and y-direction. Within the tank, the point of highest neutron production is the high pressure water system. The production rate again decreases with the beam being stopped by the copper plates.

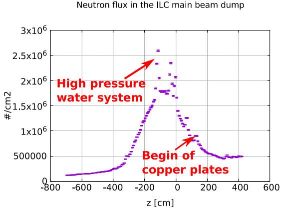
x-direction



y-direction

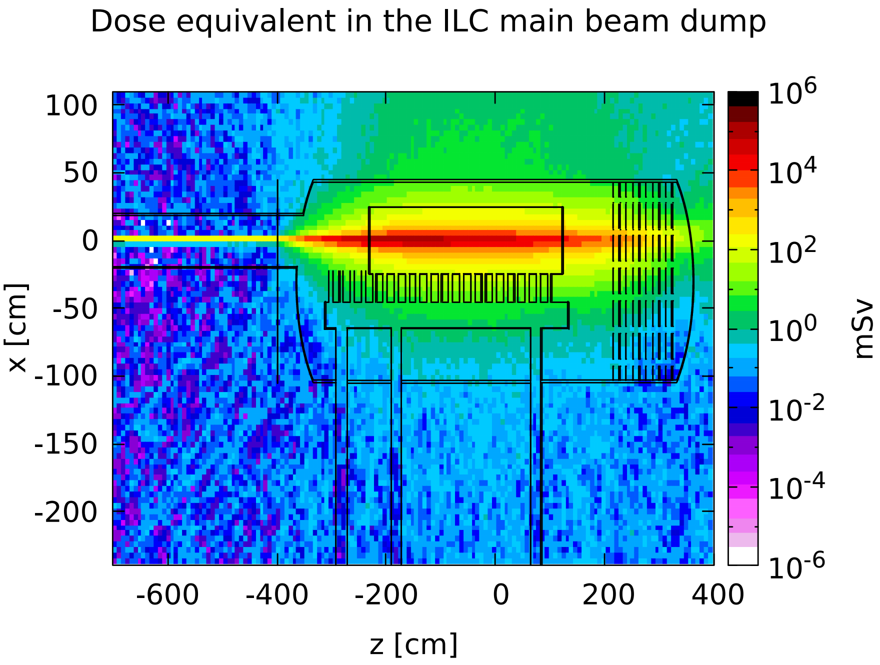


z-direction

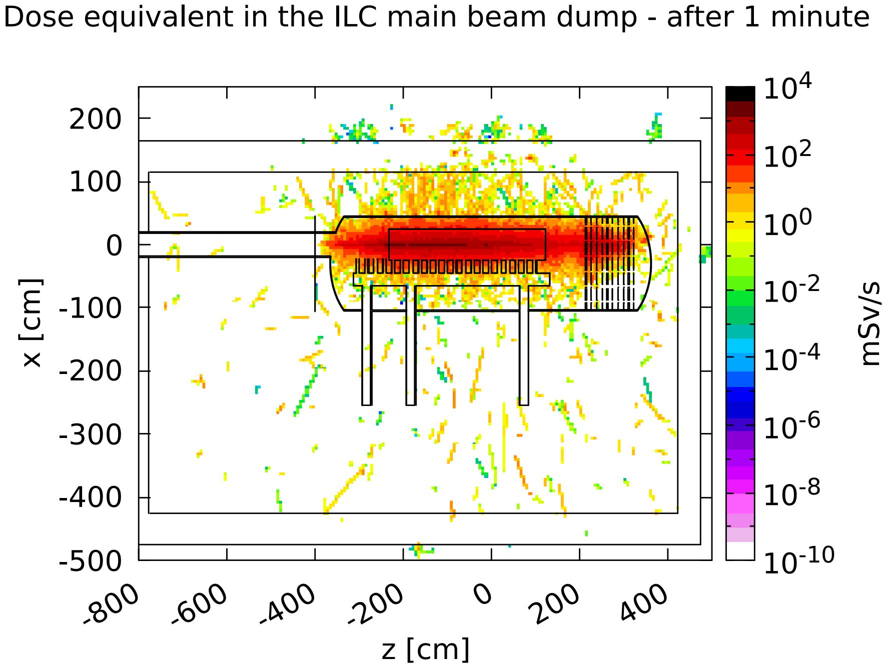


ZOOM PLOTS

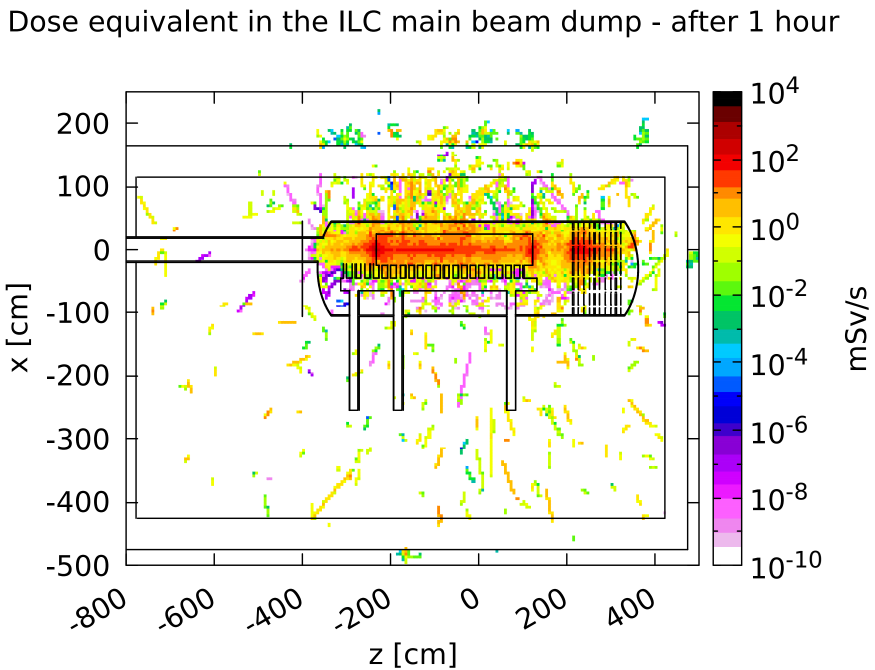
Here be dragons

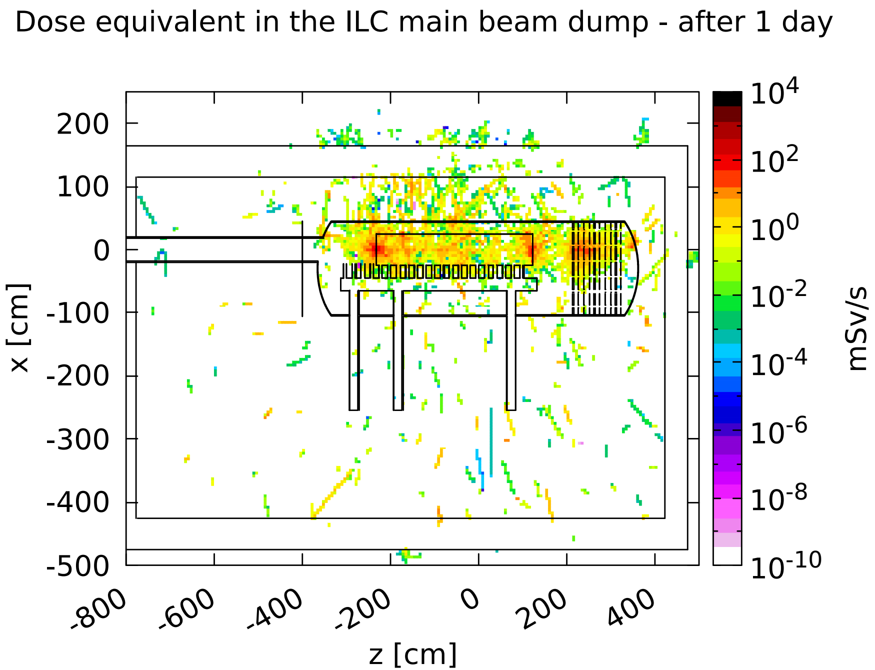


Dose equivalent in the ILC main beam dump
100
50
0
-50
-100
-150
-200
x [cm]
-600
-400
-200
0
200
400
z [cm]
10^6
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
mSv

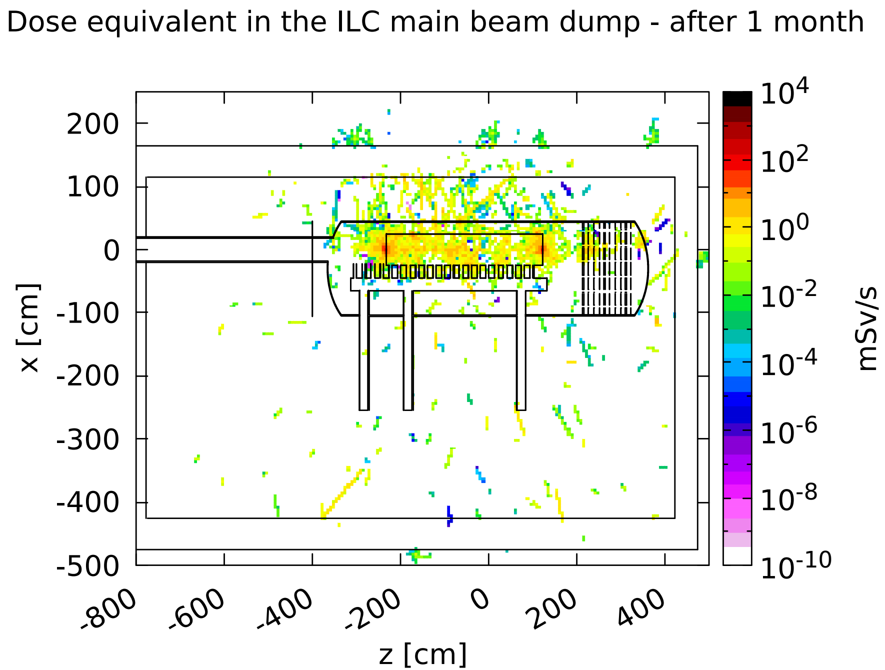


Dose equivalent in the ILC main beam dump - after 1 minute
x [cm]
z [cm]
mSv/s
200
100
0
-100
-200
-300
-400
-500
-800
-600
-400
-200
0
200
400
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}

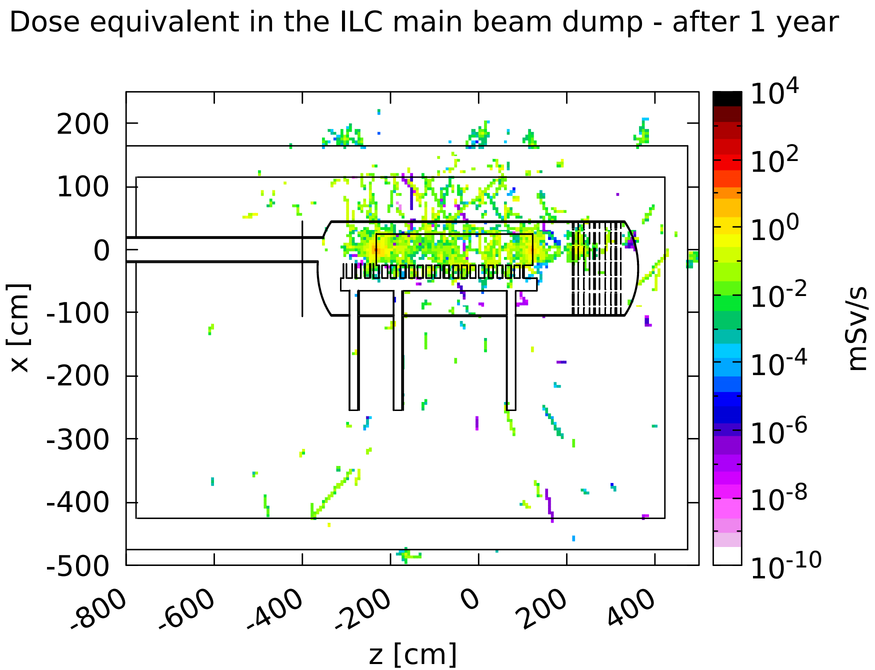

Dose equivalent in the ILC main beam dump - after 1 hour
x [cm]
z [cm]
mSv/s
200
100
0
-100
-200
-300
-400
-500
-800
-600
-400
-200
0
200
400
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}

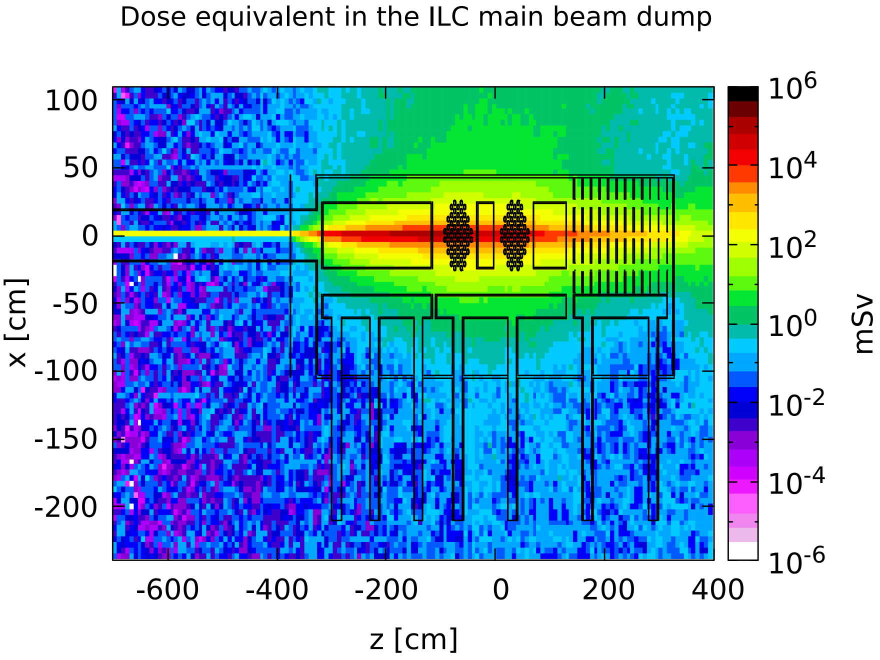


Dose equivalent in the ILC main beam dump - after 1 day
x [cm]
z [cm]
mSv/s
200
100
0
-100
-200
-300
-400
-500
-800
-600
-400
-200
0
200
400
10^{4}
10^{2}
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}

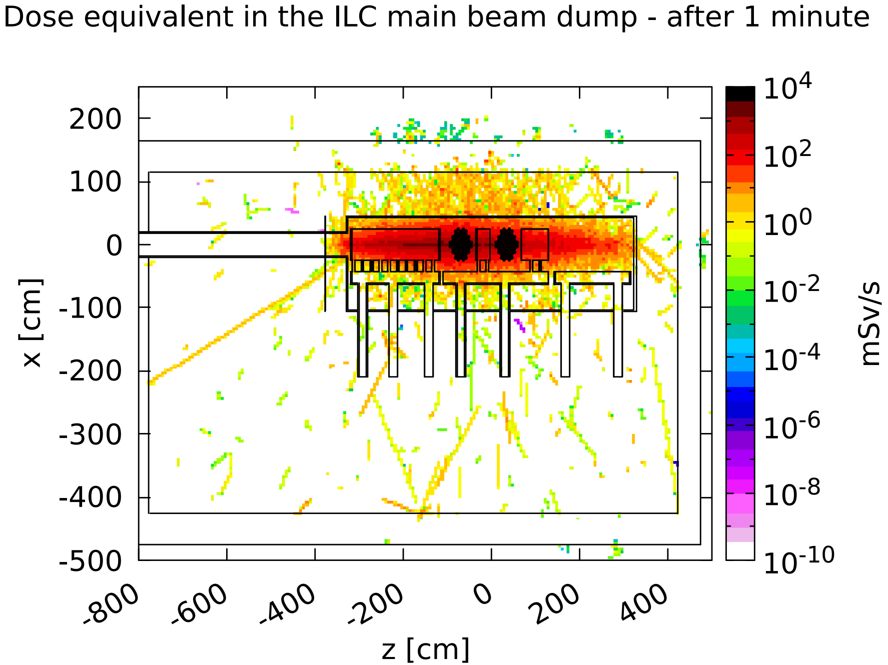


Dose equivalent in the ILC main beam dump - after 1 month
x [cm]
z [cm]
mSv/s
200
100
0
-100
-200
-300
-400
-500
-800
-600
-400
-200
0
200
400
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}

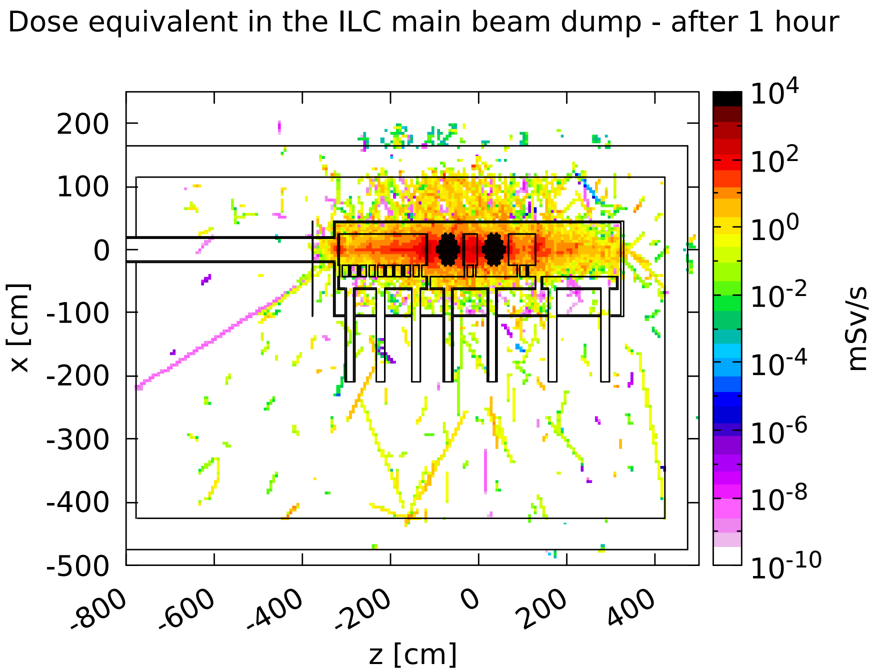

Dose equivalent in the ILC main beam dump - after 1 year
200
100
0
-100
-200
-300
-400
-500
x [cm]
-800
-600
-400
-200
0
200
400
z [cm]
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
mSv/s



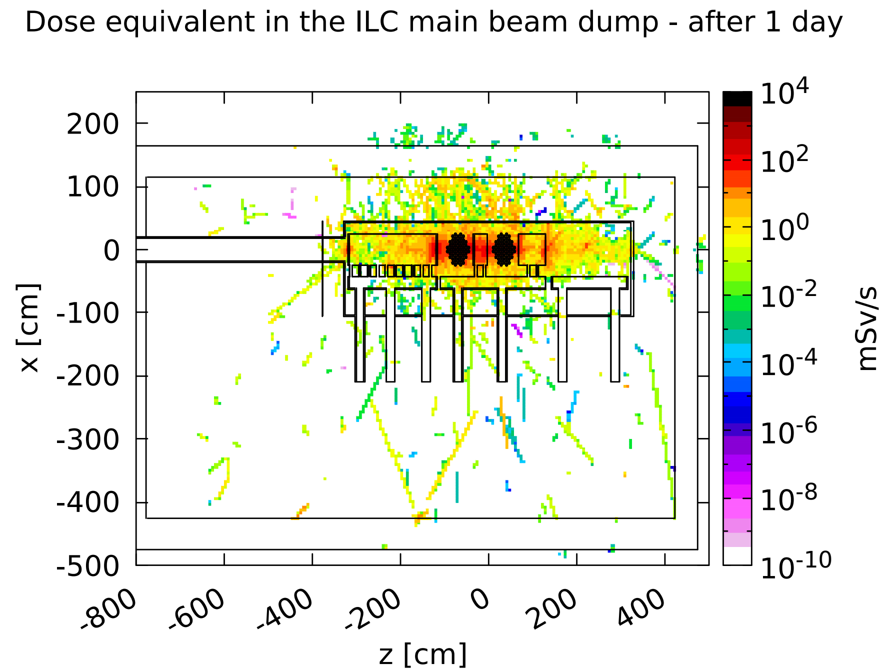
Dose equivalent in the ILC main beam dump
x [cm]
z [cm]
mSv
100
50
0
-50
-100
-150
-200
-600
-400
-200
0
200
400
10^6
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}



Dose equivalent in the ILC main beam dump - after 1 minute
200
100
0
-100
-200
-300
-400
-500
x [cm]
-800
-600
-400
-200
0
200
400
z [cm]
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
mSv/s

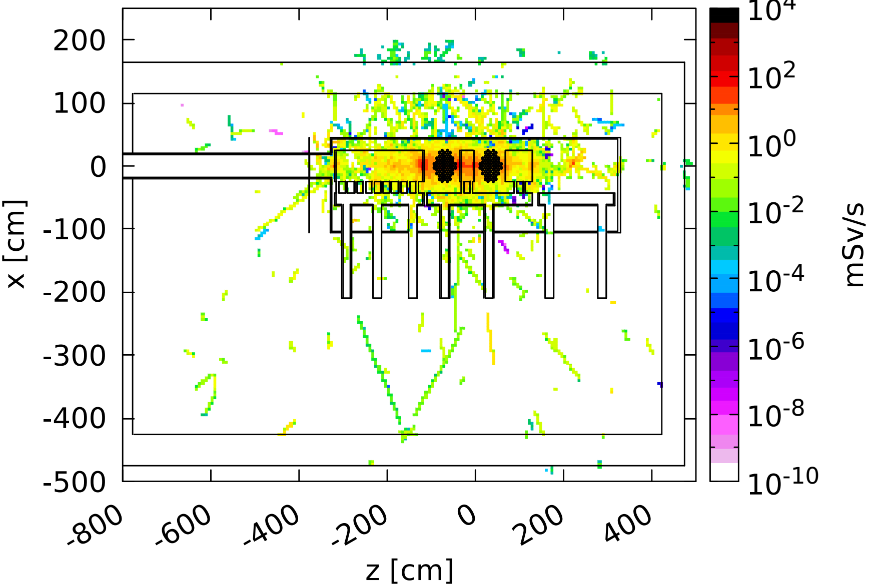


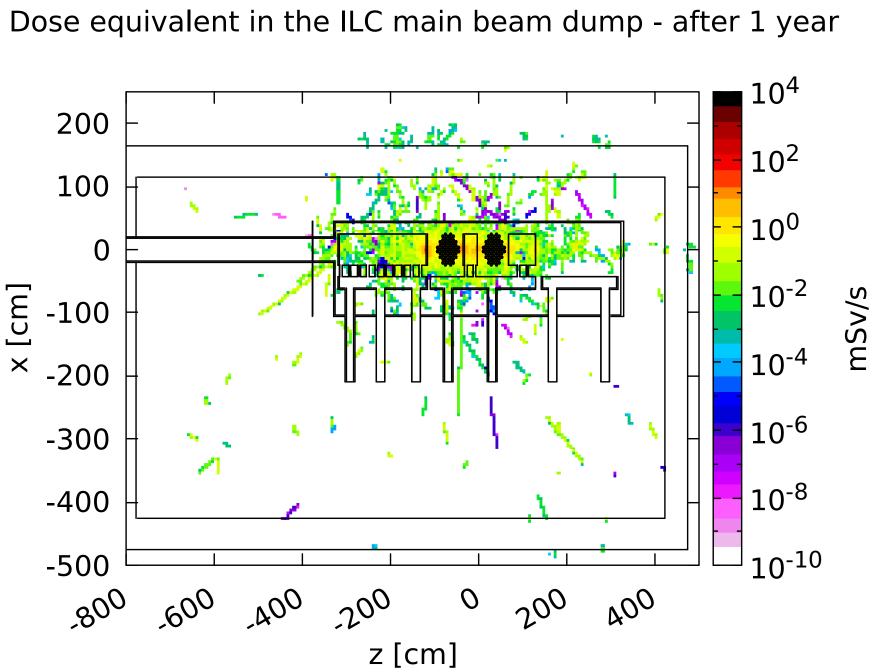
Dose equivalent in the ILC main beam dump - after 1 hour
x [cm]
z [cm]
mSv/s
200
100
0
-100
-200
-300
-400
-500
-800
-600
-400
-200
0
200
400
10^4
10^2
10^0
10^-2
10^-4
10^-6
10^-8
10^-10



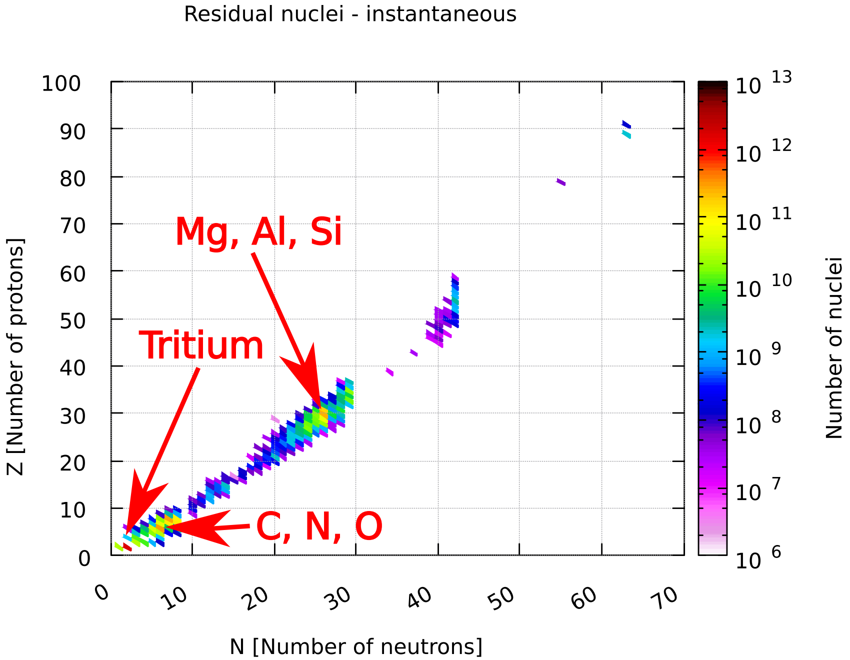
Dose equivalent in the ILC main beam dump - after 1 day
x [cm]
z [cm]
mSv/s
200
100
0
-100
-200
-300
-400
-500
-800
-600
-400
-200
0
200
400
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}

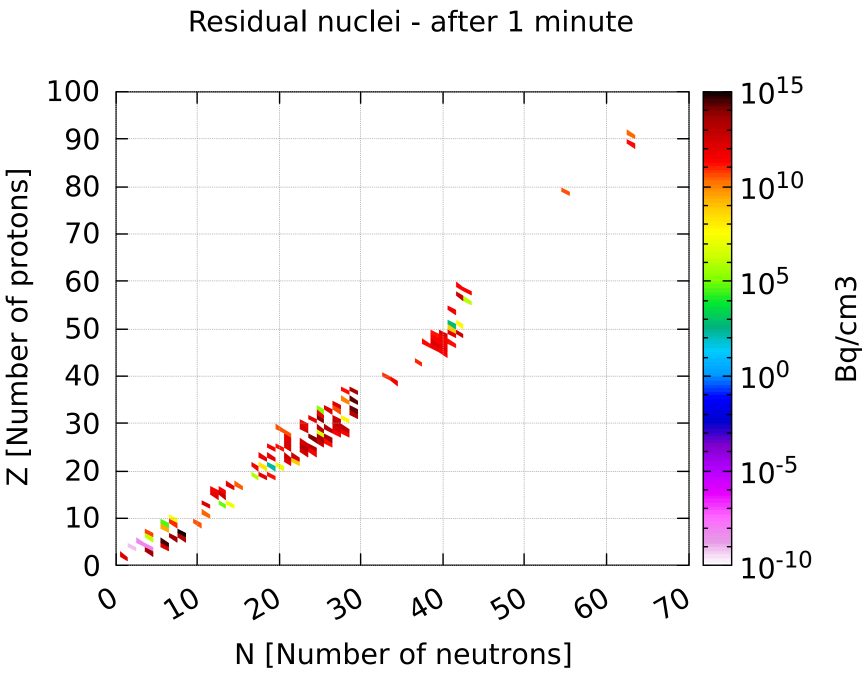
Dose equivalent in the ILC main beam dump - after 1 month



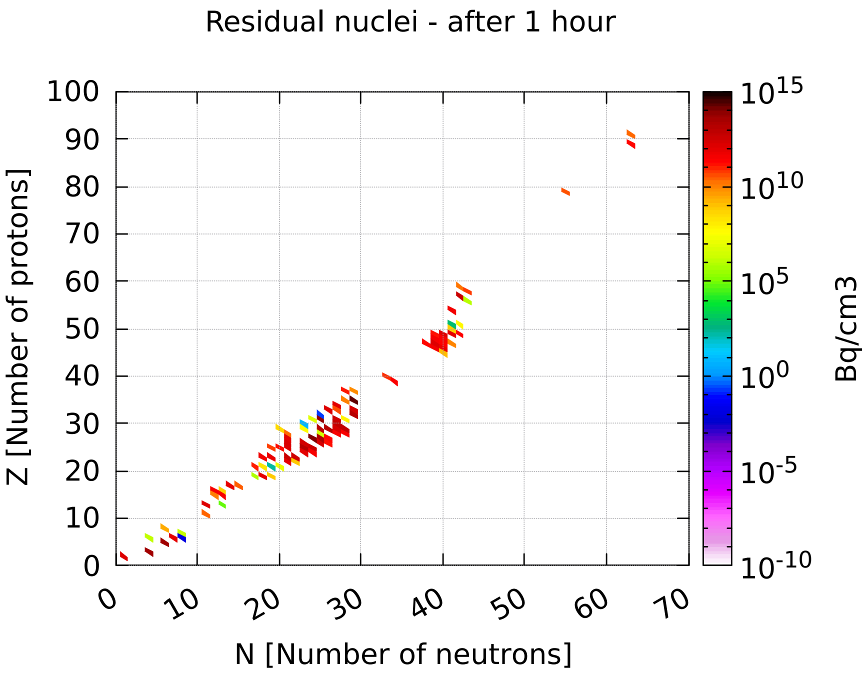


Dose equivalent in the ILC main beam dump - after 1 year
x [cm]
z [cm]
mSv/s
200
100
0
-100
-200
-300
-400
-500
-800
-600
-400
-200
0
200
400
10^4
10^2
10^0
10^-2
10^-4
10^-6
10^-8
10^-10

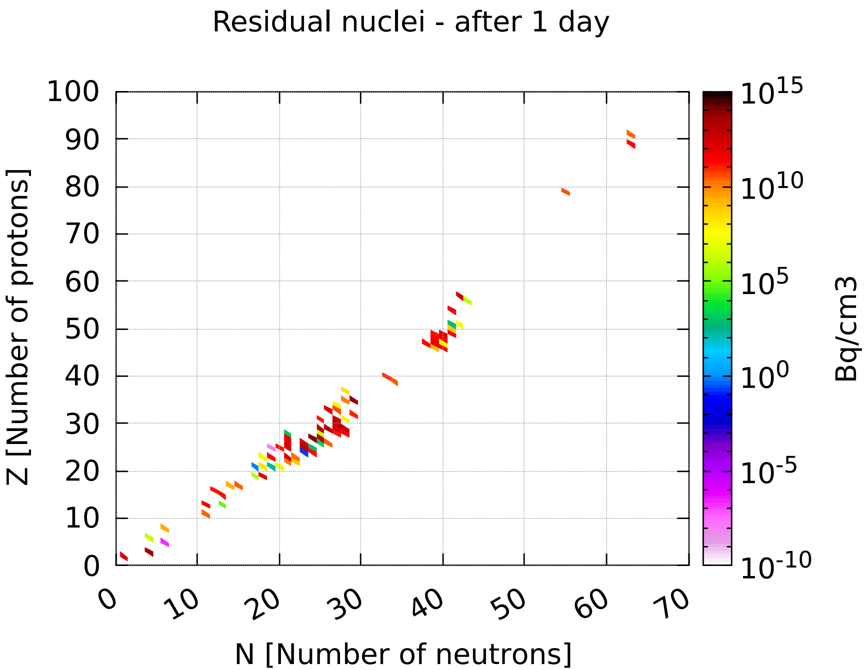

Residual nuclei - instantaneous
Mg, Al, Si
Tritium
C, N, O
Z [Number of protons]
N [Number of neutrons]
Number of nuclei
0
10
20
30
40
50
60
70
80
90
100
0
10
20
30
40
50
60
70
10^{6}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}



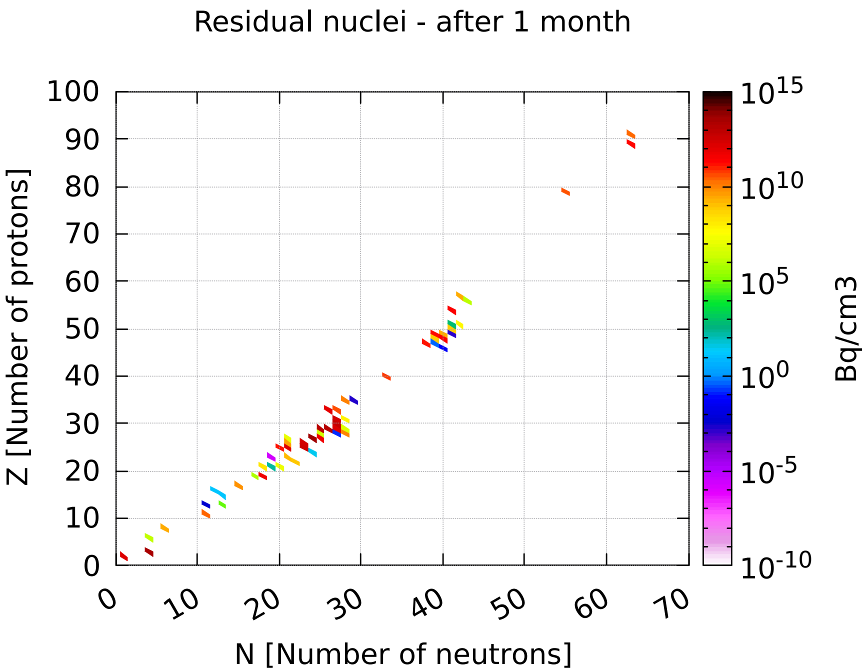
Residual nuclei - after 1 minute
Z [Number of protons]
N [Number of neutrons]
Bq/cm3
0
10
20
30
40
50
60
70
80
90
100
10^15
10^10
10^5
10^0
10^-5
10^-10



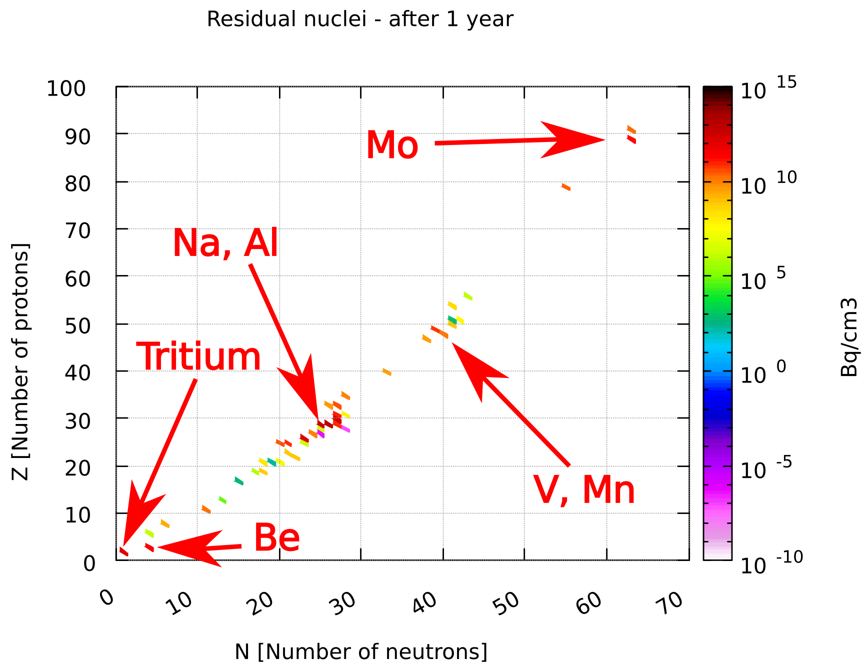
Residual nuclei - after 1 hour
Z [Number of protons]
N [Number of neutrons]
Bq/cm3
0
10
20
30
40
50
60
70
80
90
100
10^{15}
10^{10}
10^{5}
10^{0}
10^{-5}
10^{-10}



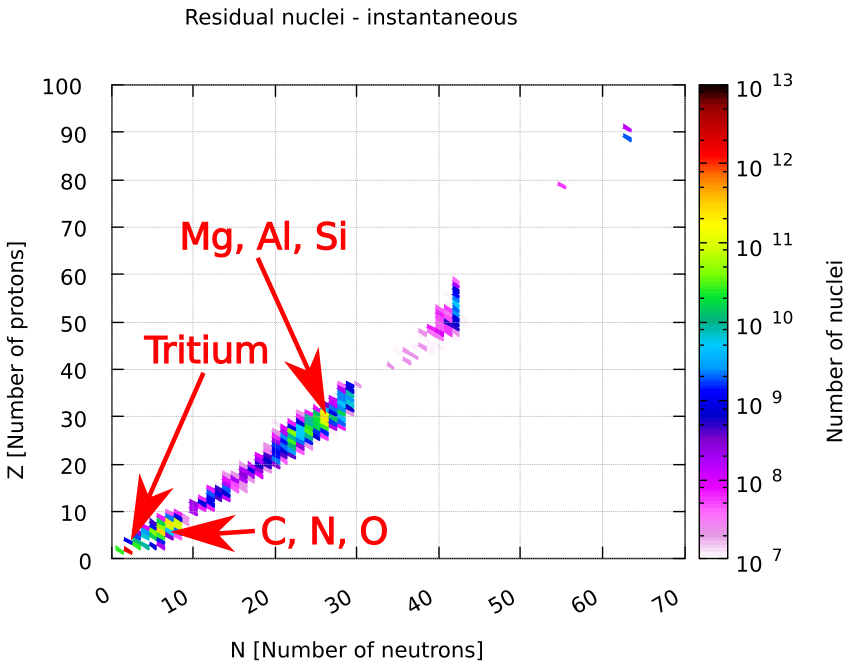
Residual nuclei - after 1 day
Z [Number of protons]
N [Number of neutrons]
Bq/cm3
0
10
20
30
40
50
60
70
80
90
100
10^{15}
10^{10}
10^{5}
10^{0}
10^{-5}
10^{-10}

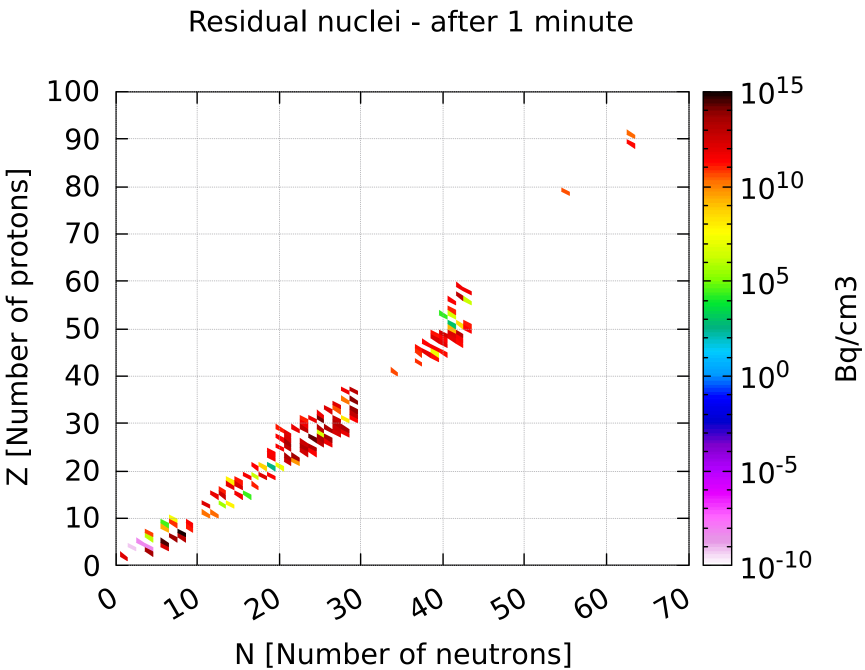


Residual nuclei - after 1 month
Z [Number of protons]
N [Number of neutrons]
Bq/cm3
0
10
20
30
40
50
60
70
80
90
100
10^{15}
10^{10}
10^{5}
10^{0}
10^{-5}
10^{-10}

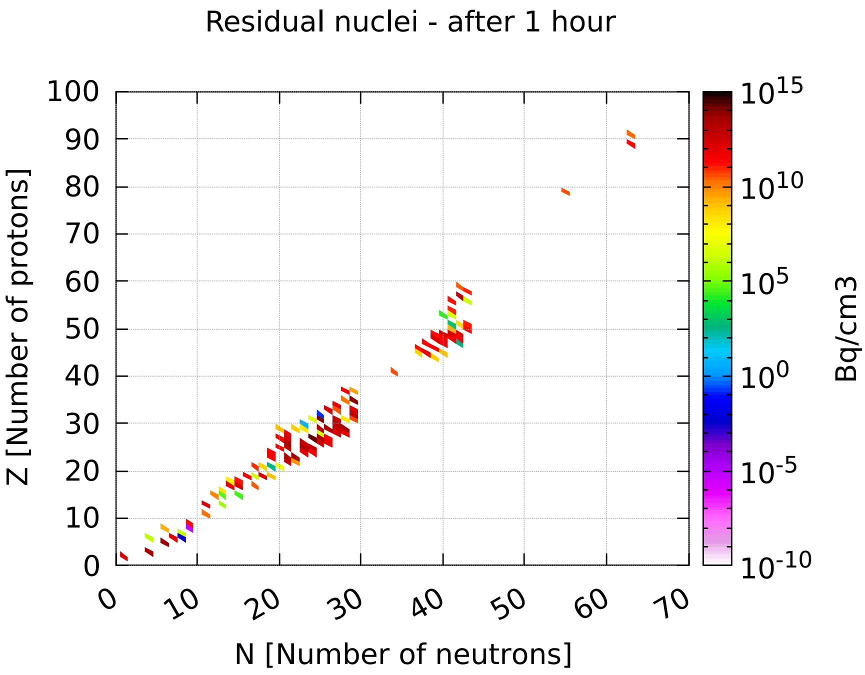


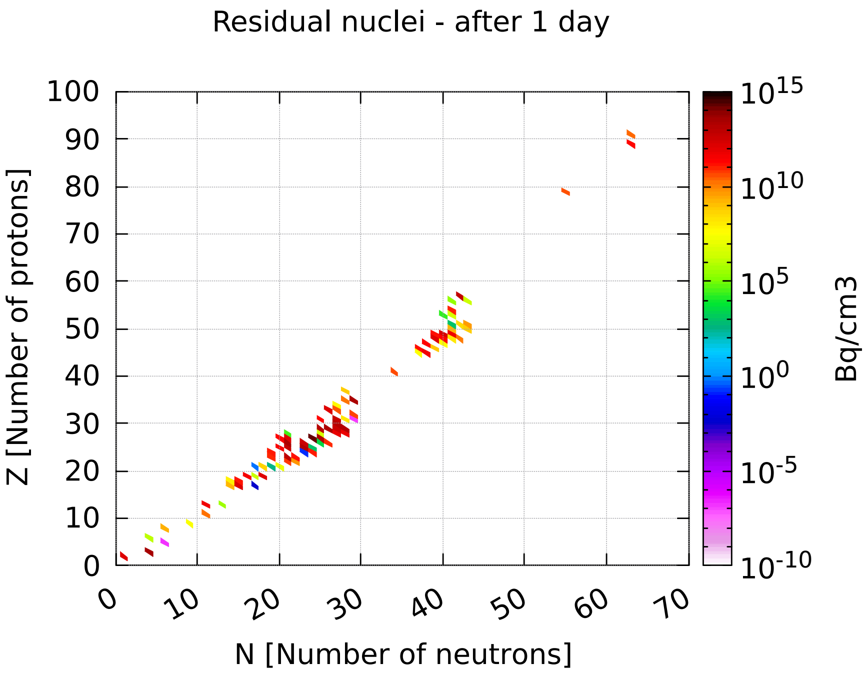
Residual nuclei - after 1 year
Z [Number of protons]
N [Number of neutrons]
Bq/cm3
Mo
Na, Al
Tritium
V, Mn
Be
0
10
20
30
40
50
60
70
80
90
100
0
10
20
30
40
50
60
70
10^{15}
10^{10}
10^{5}
10^{0}
10^{-5}
10^{-10}


Residual nuclei - instantaneous
Mg, Al, Si
Tritium
C, N, O
Z [Number of protons]
N [Number of neutrons]
Number of nuclei
0
10
20
30
40
50
60
70
80
90
100
10^7
10^8
10^9
10^{10}
10^{11}
10^{12}
10^{13}

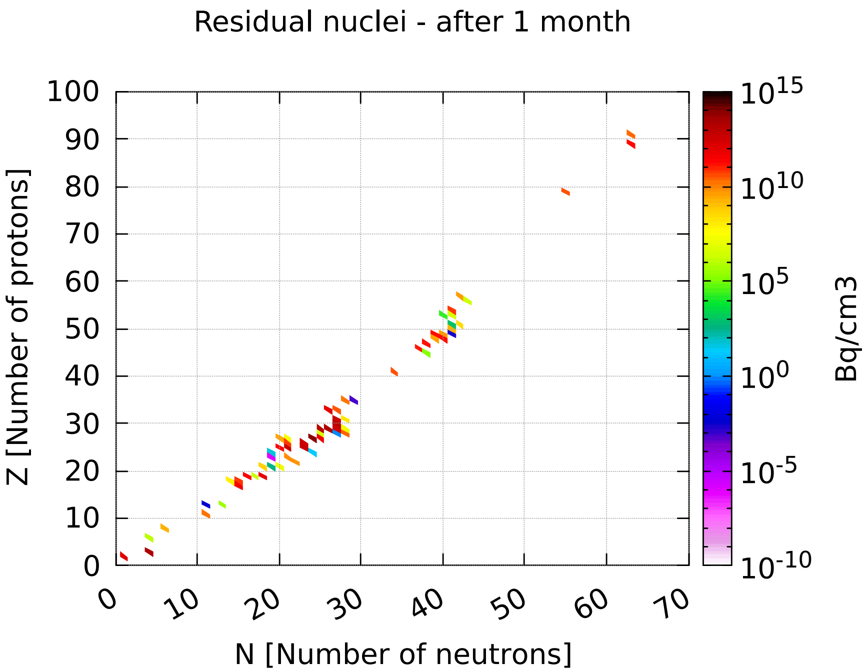


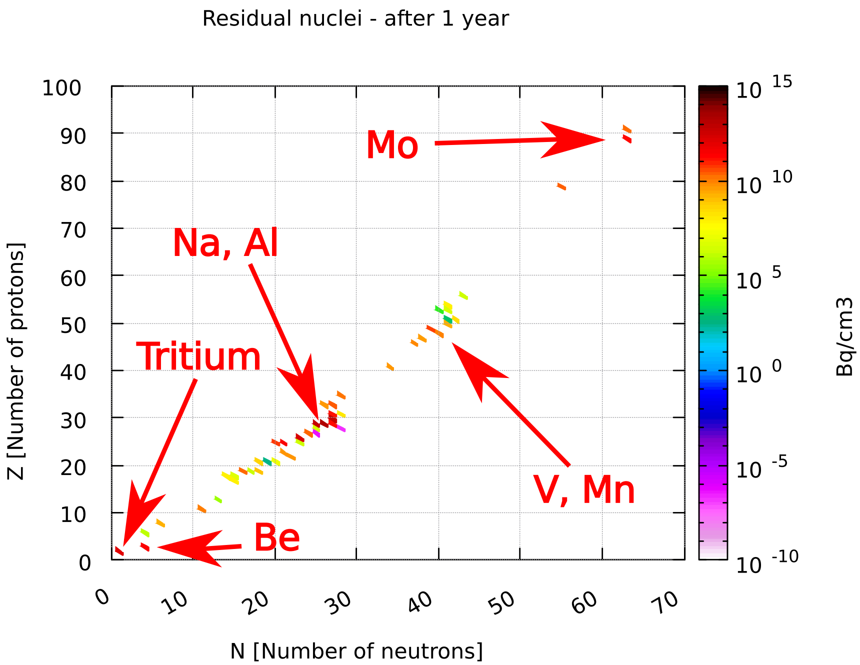
Residual nuclei - after 1 minute
Z [Number of protons]
N [Number of neutrons]
Bq/cm3
0
10
20
30
40
50
60
70
80
90
100
0
10
20
30
40
50
60
70
10^{15}
10^{10}
10^{5}
10^{0}
10^{-5}
10^{-10}


Residual nuclei - after 1 hour
Z [Number of protons]
N [Number of neutrons]
Bq/cm3
0
10
20
30
40
50
60
70
80
90
100
10^15
10^10
10^5
10^0
10^-5
10^-10



Residual nuclei - after 1 day
Z [Number of protons]
N [Number of neutrons]
Bq/cm3
0
10
20
30
40
50
60
70
80
90
100
10^{15}
10^{10}
10^{5}
10^{0}
10^{-5}
10^{-10}


Residual nuclei - after 1 month
Z [Number of protons]
N [Number of neutrons]
Bq/cm3
0
10
20
30
40
50
60
70
80
90
100
10^{15}
10^{10}
10^{5}
10^{0}
10^{-5}
10^{-10}


Residual nuclei - after 1 year
Mo
Na, Al
Tritium
V, Mn
Be
Z [Number of protons]
N [Number of neutrons]
Bq/cm3
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
10 15
10 10
10 5
10 0
10 -5
10 -10