



EUROPEAN  
SPALLATION  
SOURCE

# Neutron Guide and Cave Shielding Concepts

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14.02.2018

## **Radiation:**

- Safety requirement for environmental radiation
- Instrument background requirement

## Construction:

***Eurocode 1: Actions on structures*** (EN 1991)

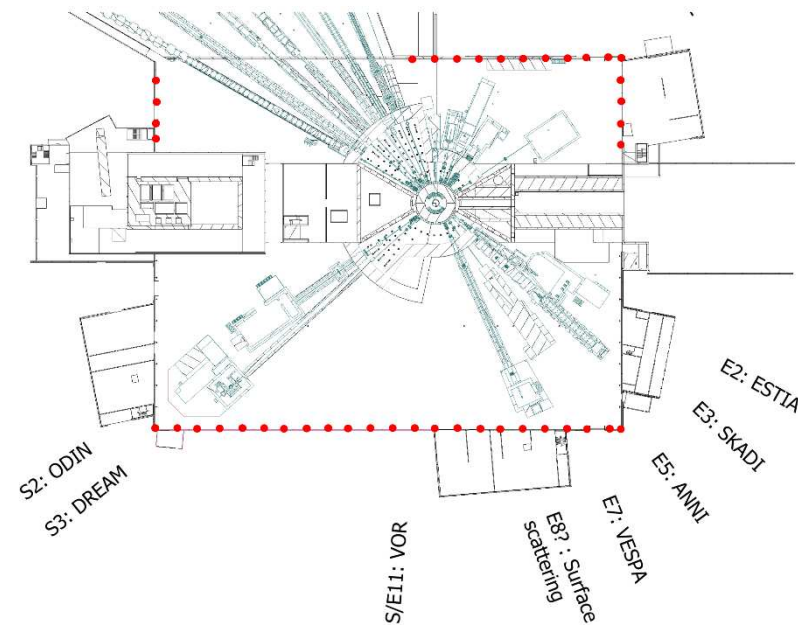
***Eurocode 2: Design of concrete structures*** (EN 1992)

***Eurocode 3: Design of steel structures*** (EN 1993)

# Seismic Requirements (Caves)

**E01 – E02: No Seismic requirements (Eurocode 8)**

**D01 – D03: The shielding should not fall on the structural pillars of the building.**



## **Related documents:**

ESS-0122941: Load Specification Miscellaneous Seismic Topics D Buildings

ESS-0061819: General Civil Design Criteria (GCDC) for D01 D02 and D03

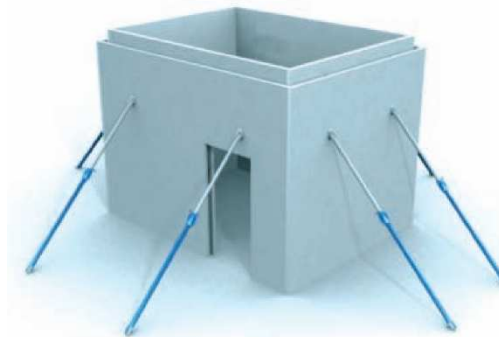
# Construction/Decommissioning Requirements (Caves)



- **Cast concrete**
  - *Strategy for installation with minimal contamination (dust)*
  - *For decommissioning we need an analysis containing:*
    - *No radioactive waste from cast concrete (No or low activation)*
    - *Strategy for decommissioning without contaminating the environment*
  - *Separation from floor*
- **Block structure**
  - *No specific requirement apart from radiation protection*

# Structural Design Approaches (Caves)

- **Full Cast Concrete**

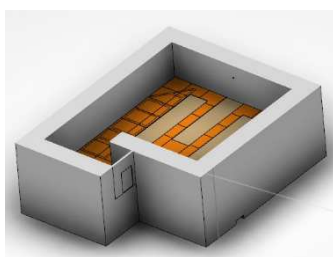
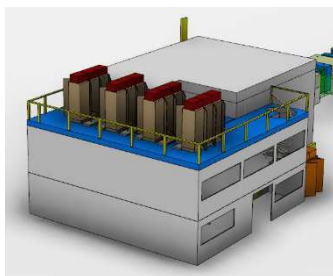


- **Full Block structure**



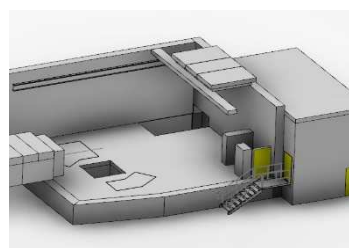
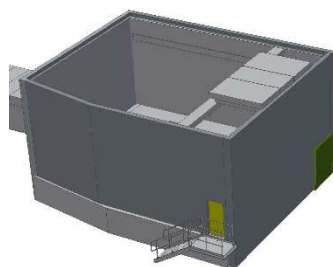
# Structural Design Approaches (Caves)

NMX



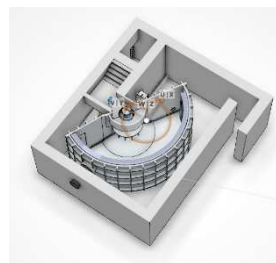
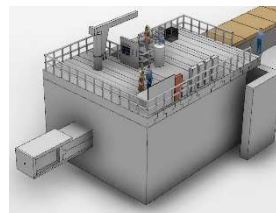
8.8m x 11.1m x 6m  
/900mm  
(W x L x H / Wall)

BEER



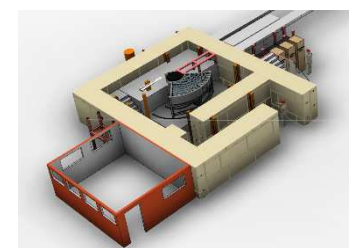
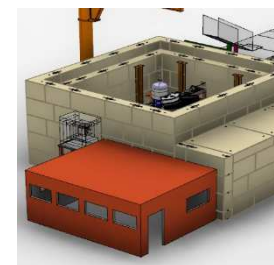
11m x 13m x 6.6m  
/550mm  
(W x L x H / Wall)

CSPEC



8.7m (10.3m) x 11.1m  
x 5.3m / 600mm  
(W x L x H / Wall)

BIFROST

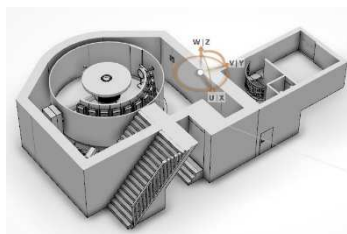
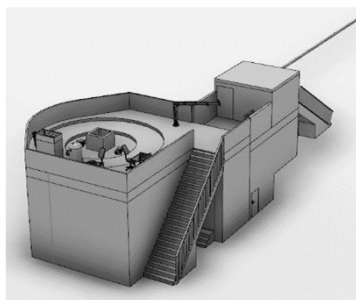


8.5m (11.1m) x 9.4m  
x 4.5m / 1.2m  
(W x L x H / Wall)



# Structural Design Approaches (Caves)

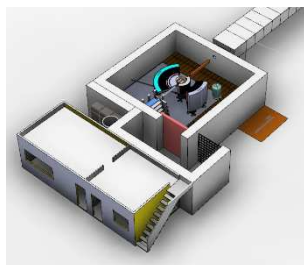
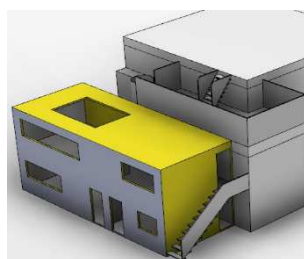
MIRACLES



10.8m x 11m x 5.5m  
/600mm

(W x L x H / Wall)

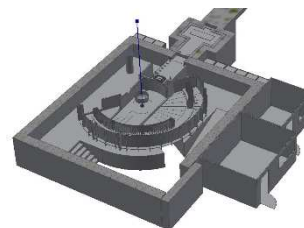
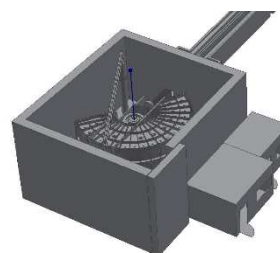
MAGIC



8.2m x 8.2m x 6.4  
m /600mm

(W x L x H / Wall)

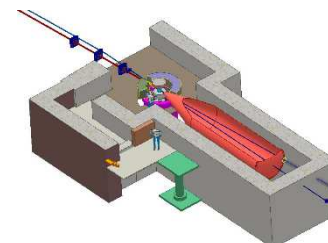
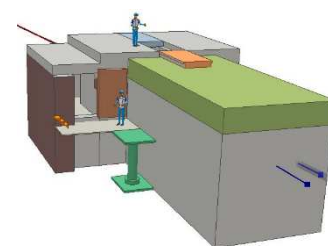
T-REX



10.5m x 12.5m x 7m  
/650mm

(W x L x H / Wall)

HEIMDAL



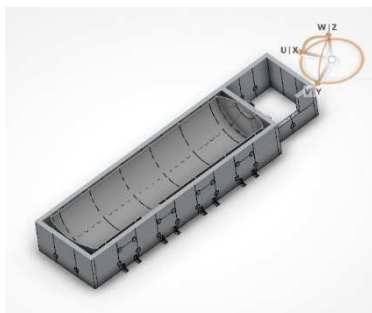
10.5m (5m) x 17.2m  
x 5m /1000mm

(W x L x H / Wall)



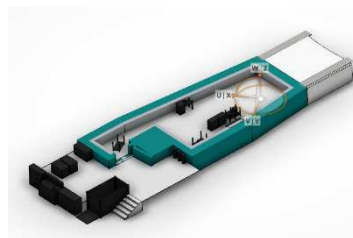
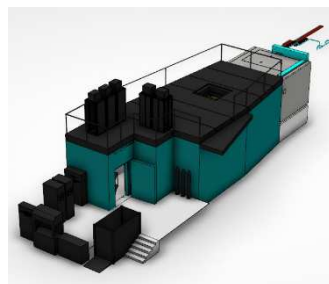
# Structural Design Approaches (Caves)

LOKI



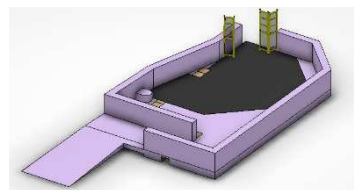
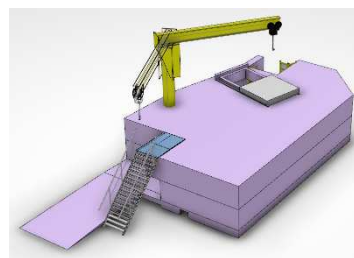
4m x 12.5m (15.5)  
x 4m / 210mm

FREIA



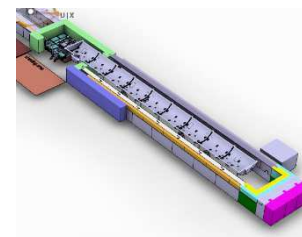
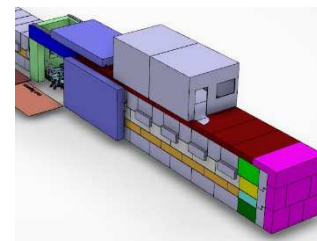
6.3m x 14m x 4  
m / 800mm

ESTIA



9.8m x 15.9m (13.4m)  
x 2.9m / 500mm

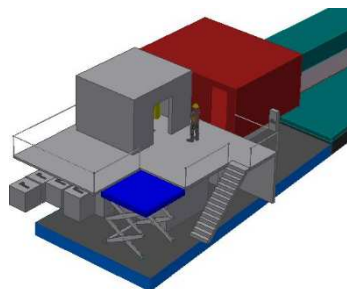
SKADI



3.8m x 27m x 4.3  
m / 600mm

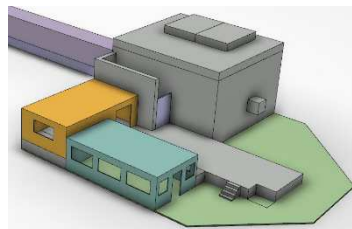
# Structural Design Approaches (Caves)

VESPA



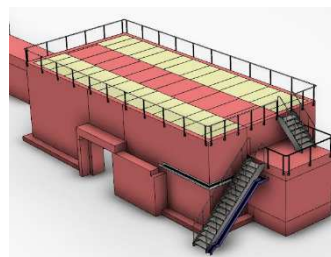
6.5m x 5.3m x 2.15m  
/650mm

DREAM



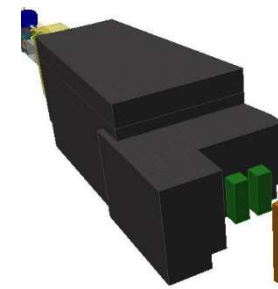
9m x 10m x 5.6m  
/650mm

ODIN

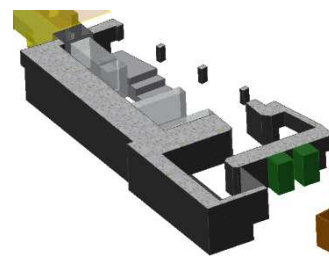
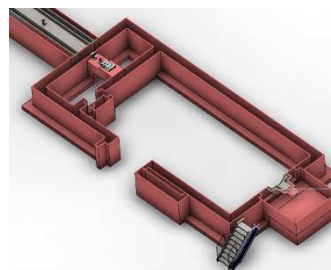
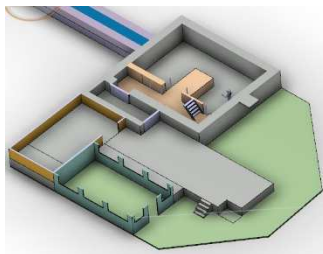
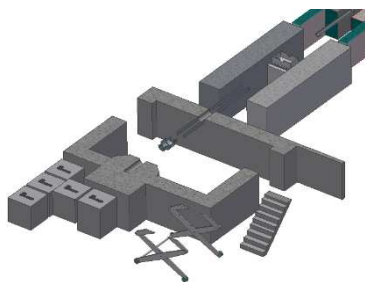


8.2m x 17.8m x 5m  
/600mm

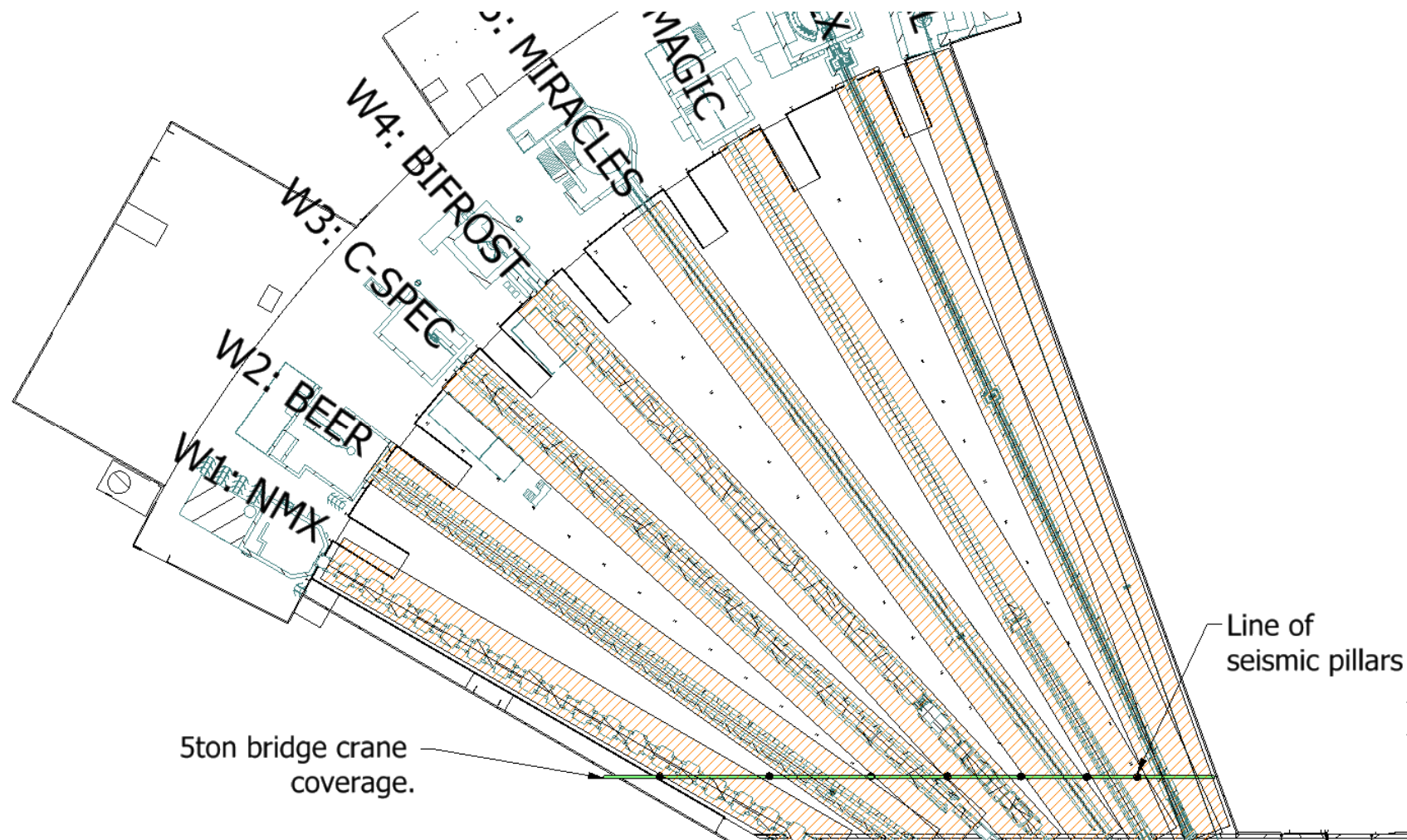
TBL



4.4m x 6.9m (8.7m)  
x 2.8m / 1000mm



# Constrains (Guide Shielding)



# Status

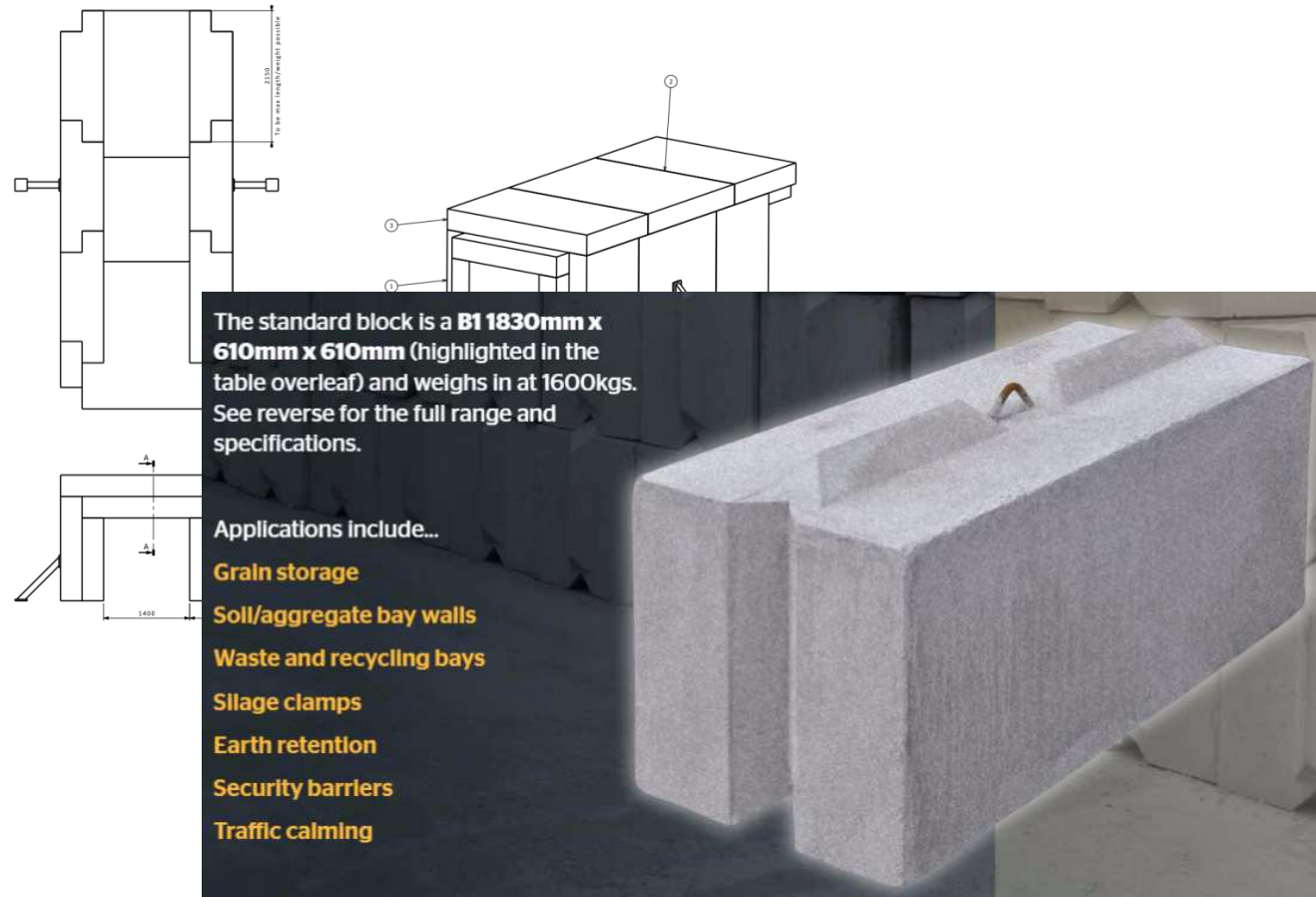
**Choose a preferred design solution!**





# Instrument (guide) shielding concepts /Status/

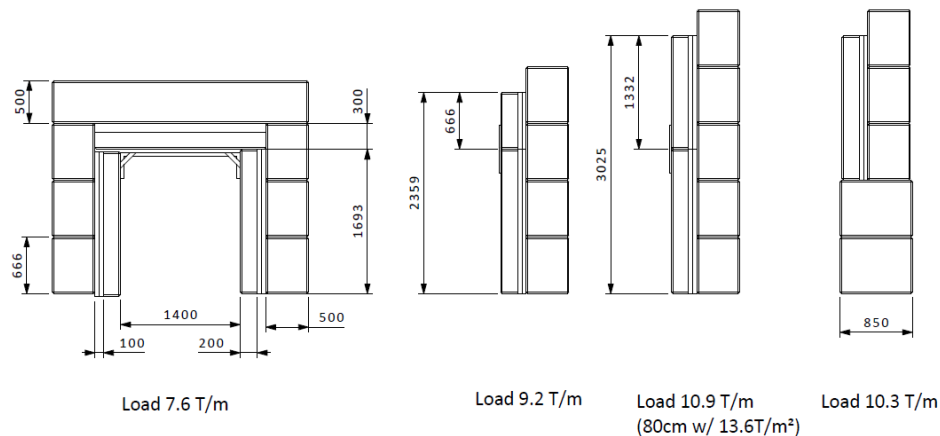
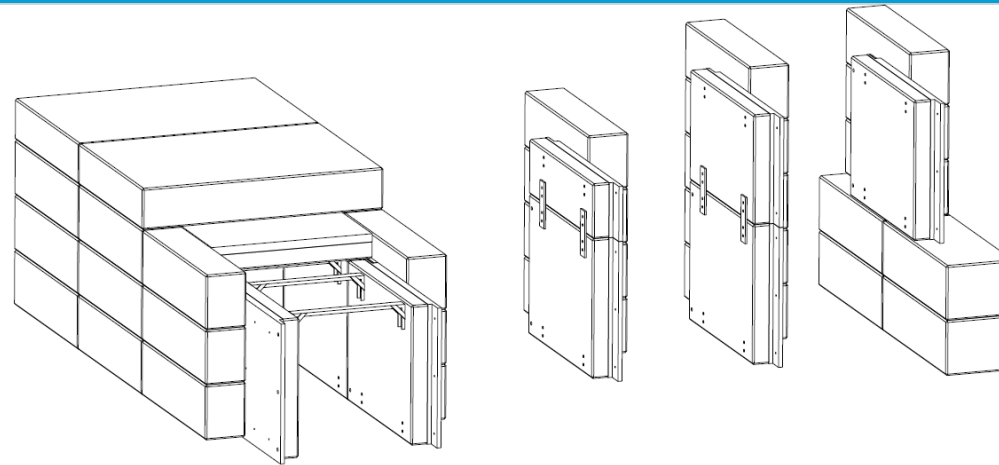
BIFROST:



<https://confluence.ess.lu.se/display/SPD/Instrument+shielding>

# Instrument (guide) shielding concepts /Status/

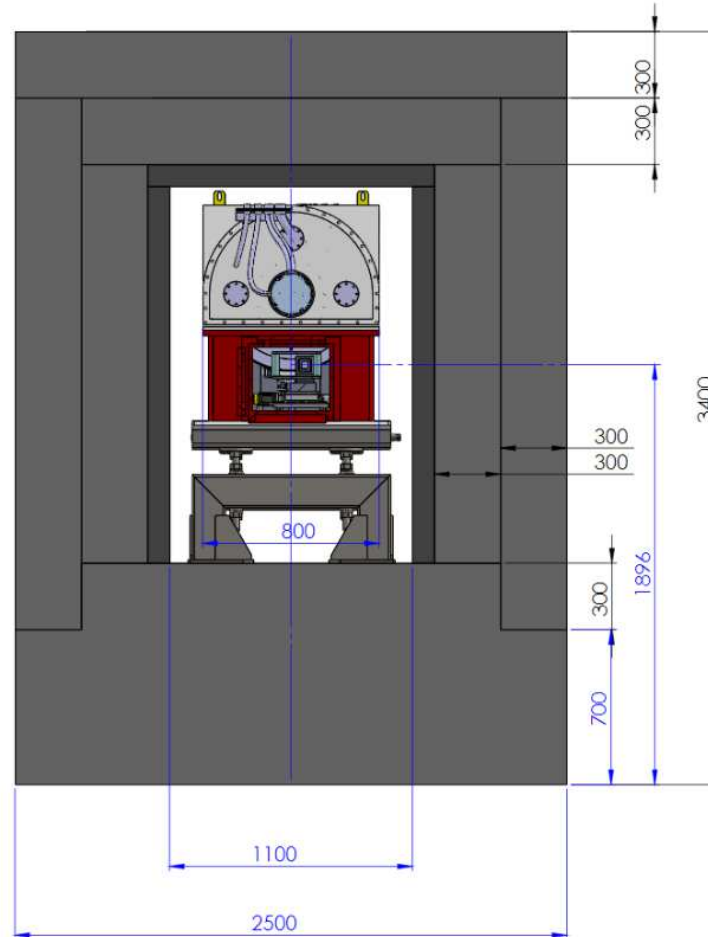
ESTIA:



<https://confluence.ess.lu.se/display/SPD/Instrument+shielding>

# Instrument (guide) shielding concepts /Status/

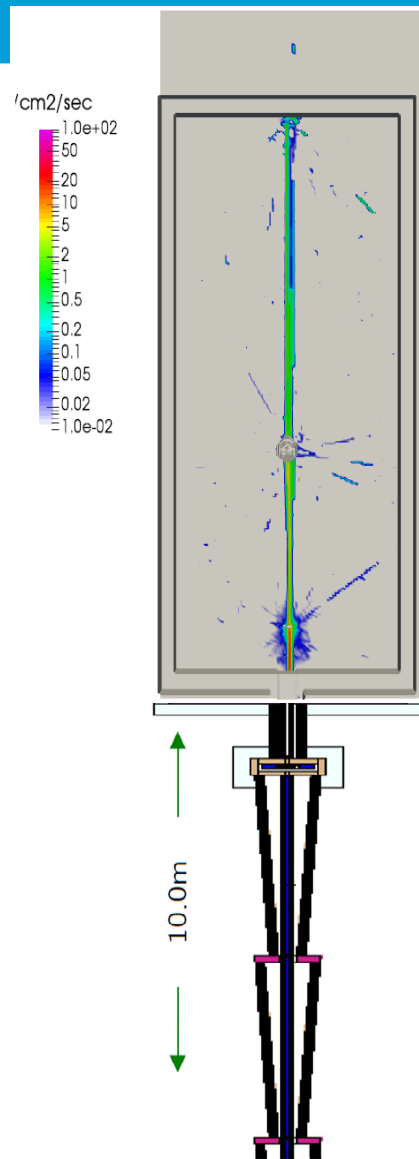
SKADI:



<https://confluence.ess.lu.se/display/SPD/Instrument+shielding>

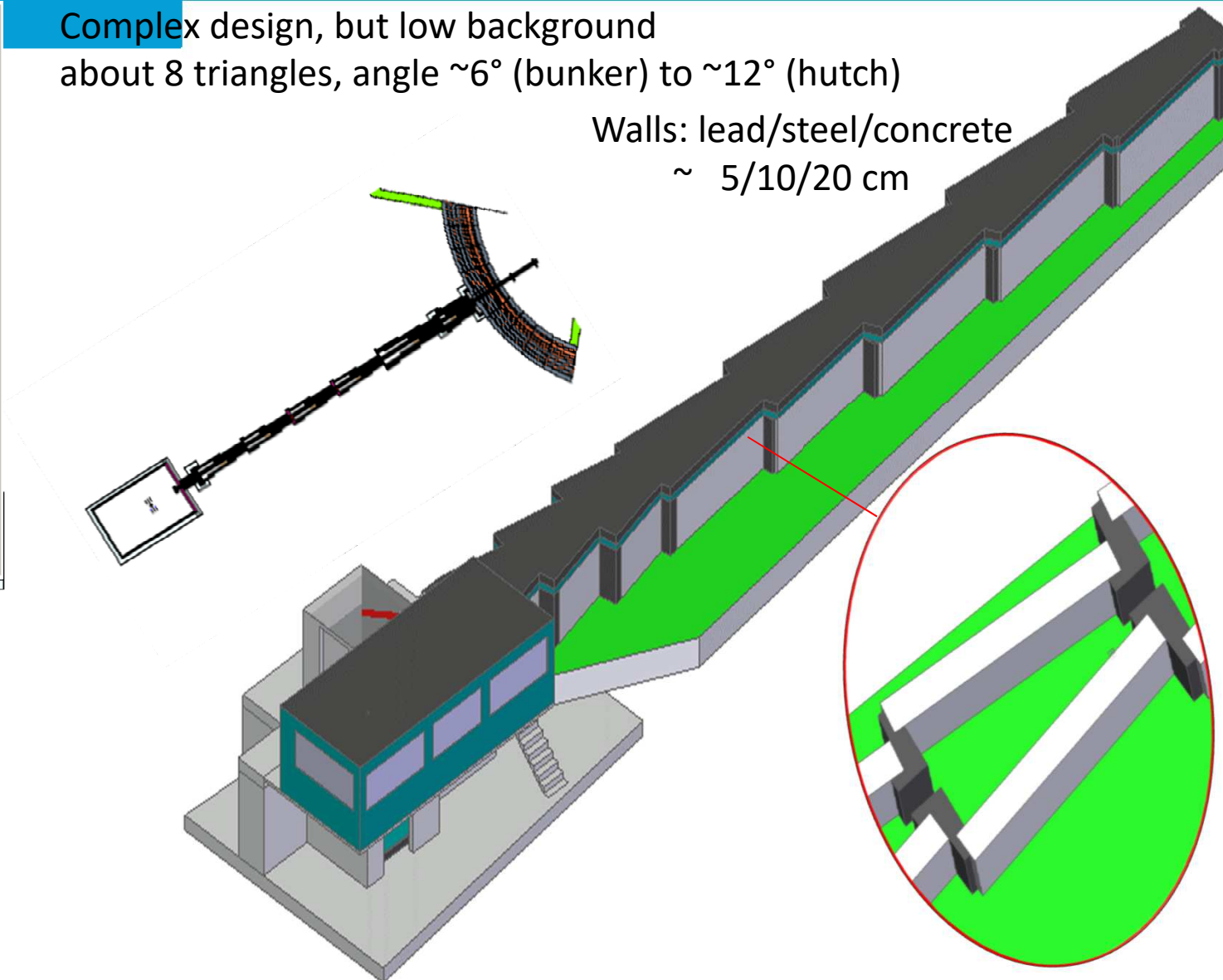


# VESPA triangular shielding option

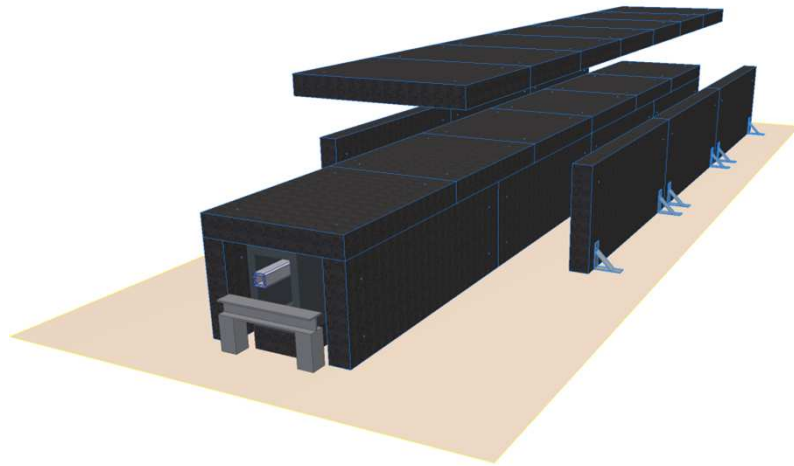


Complex design, but low background  
about 8 triangles, angle  $\sim 6^\circ$  (bunker) to  $\sim 12^\circ$  (hutch)

Walls: lead/steel/concrete  
 $\sim 5/10/20$  cm



# Concepts



No seismic requirement in the E  
buildings only Conventional safety!

Manufacturing Cost: 1

Installation Cost/time: 1

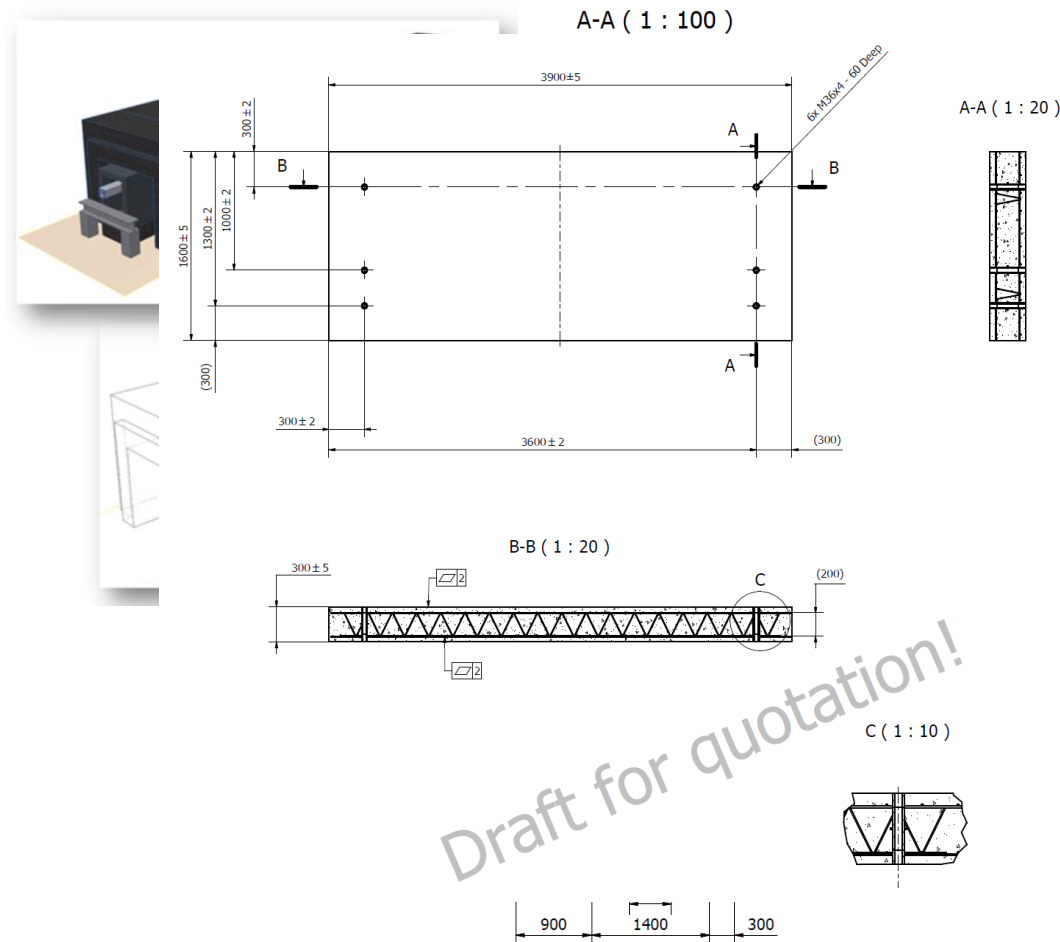
Decommissioning cost: 1

Modularity: 2 level of  
thickness is easily achievable.  
(50-75cm or 60-90cm)

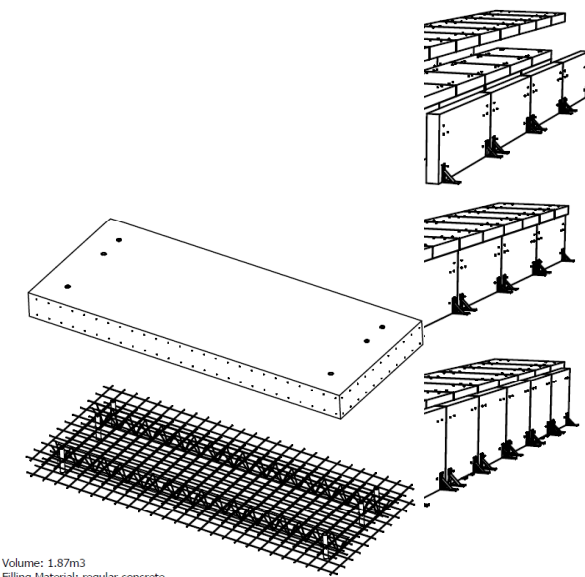
Maintenance of components  
inside: top access by  
removing three pieces

Average weight of a  
component: 3.9t

# Instrument (guide) shielding concepts /Status/



Shielding concept for concrete shielding (E02)



Volume: 1.87m3  
Filling Material: regular concrete

PARTS LIST				
ITEM	QTY	PART NUMBER	DESCRIPTION	MASS
1	6	ESS-xx-001	Lifting pipe	2,906 kg
2	2	Rebar 150x150x6	Steel mesh 150x150x6 /3.9m x1.6m/	33,256 kg
3	2	10 ks 200-10-5-6/1.5 ZDMA/80	FERT Girder Type-E	6,112 kg

ASSEMBLY WEIGHT: 4594.2 kg		DRAWING TYPE: TITLE SUPPLEMENTARY TITLE		
Shielding 1600				
General Tolerances	ISO 2768-mK	MODELED BY	gabrielcicco	DRAWING CREATED
Linear Dimensions	ISO 2768-mK	DRAWN BY	gabrielcicco	DRAWING RELEASED
Form and Position	ISO 2768-mK	CHECKED BY		
Character, Profile and Angular Dimensions	ISO 2768-mK	DATE		
SURFACE FINISH	Painted	PROJECT		
Documentation production as per	ISO 15016	REVISION		

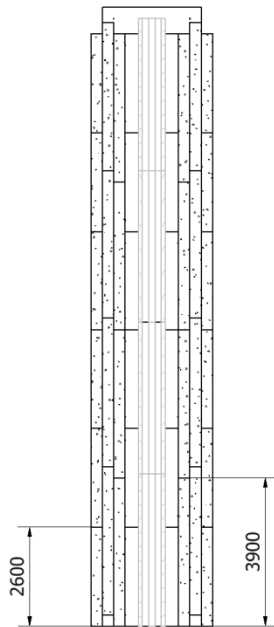
LIST	DESCRIPTION	MASS
1	34 Shielding 2600x2000x300mm	3754,230 kg
2	8 Shielding 3900x1600x300mm	4505,017 kg
3	8 Shielding 3900x1300x300mm	3660,344 kg

Draft for quotation!

<https://confluence.ess.lu.se/display/SPD/Instrument+shielding>

# Concepts

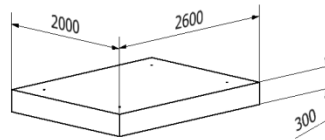
A-A ( 1 : 100 )



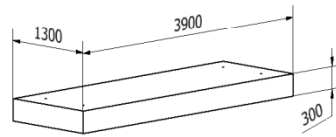
## Shielding concept for concrete shielding (E02)

Floor load: 6.83 t/m<sup>2</sup>

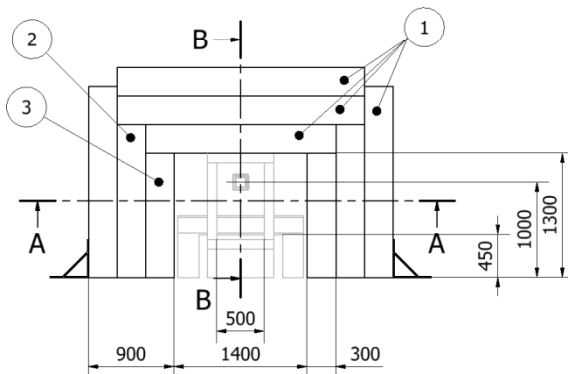
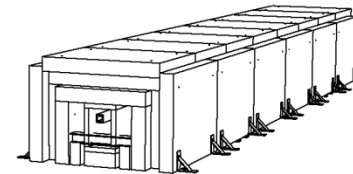
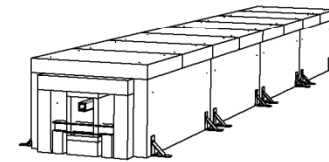
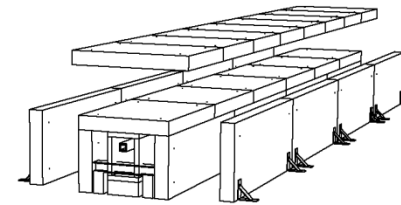
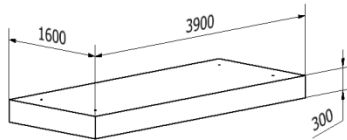
1.



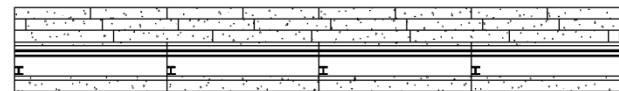
2.



3.

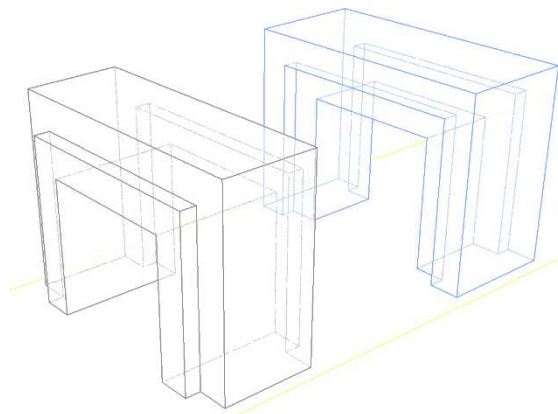
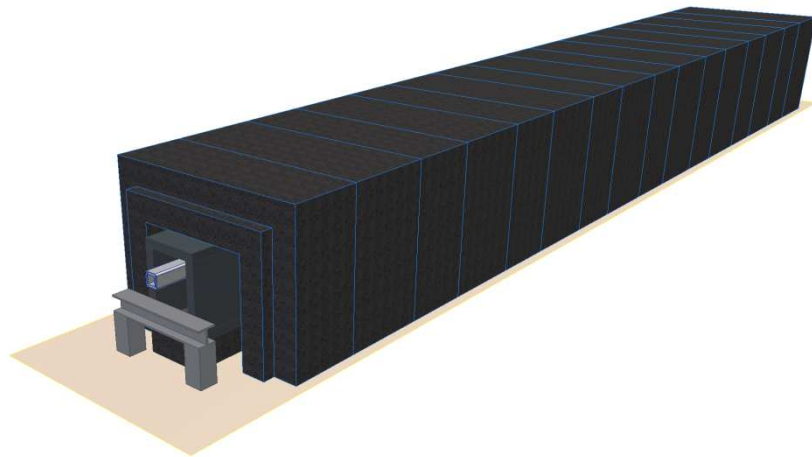


B-B ( 1 : 100 )



PARTS LIST			
ITEM	QTY	DESCRIPTION	MASS
1	34	Shielding 2600x2000x300mm	3754,818 kg
2	8	Shielding 3900x1600x300mm	4505,899 kg
3	8	Shielding 3900x1300x300mm	3660,933 kg

# Concepts



Male - Female

Manufacturing Cost: 1.6

Installation Cost/time: 0.7

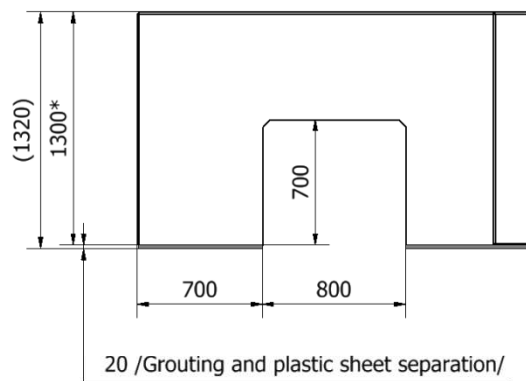
Decommissioning cost: 1.8

Modularity: Not modular

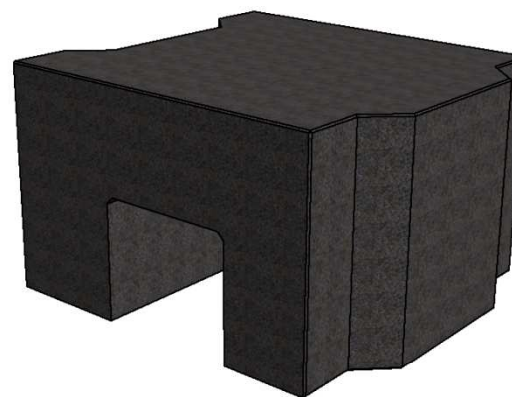
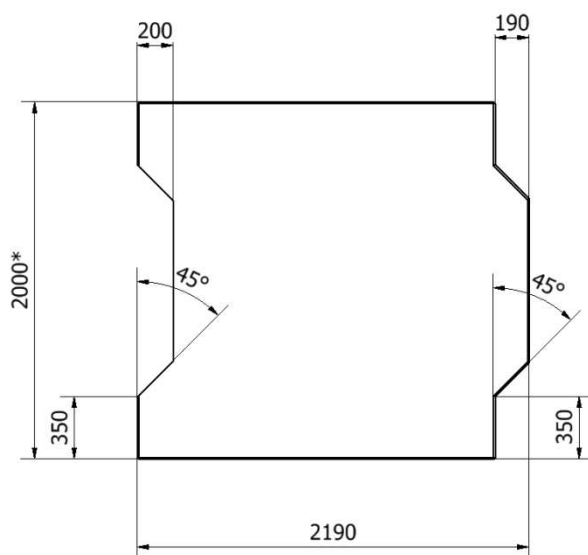
Maintenance of  
components inside : full  
access by removing two  
pieces

Average weight of a  
component: 7.4t

# Concept for Elevation in D01-D03



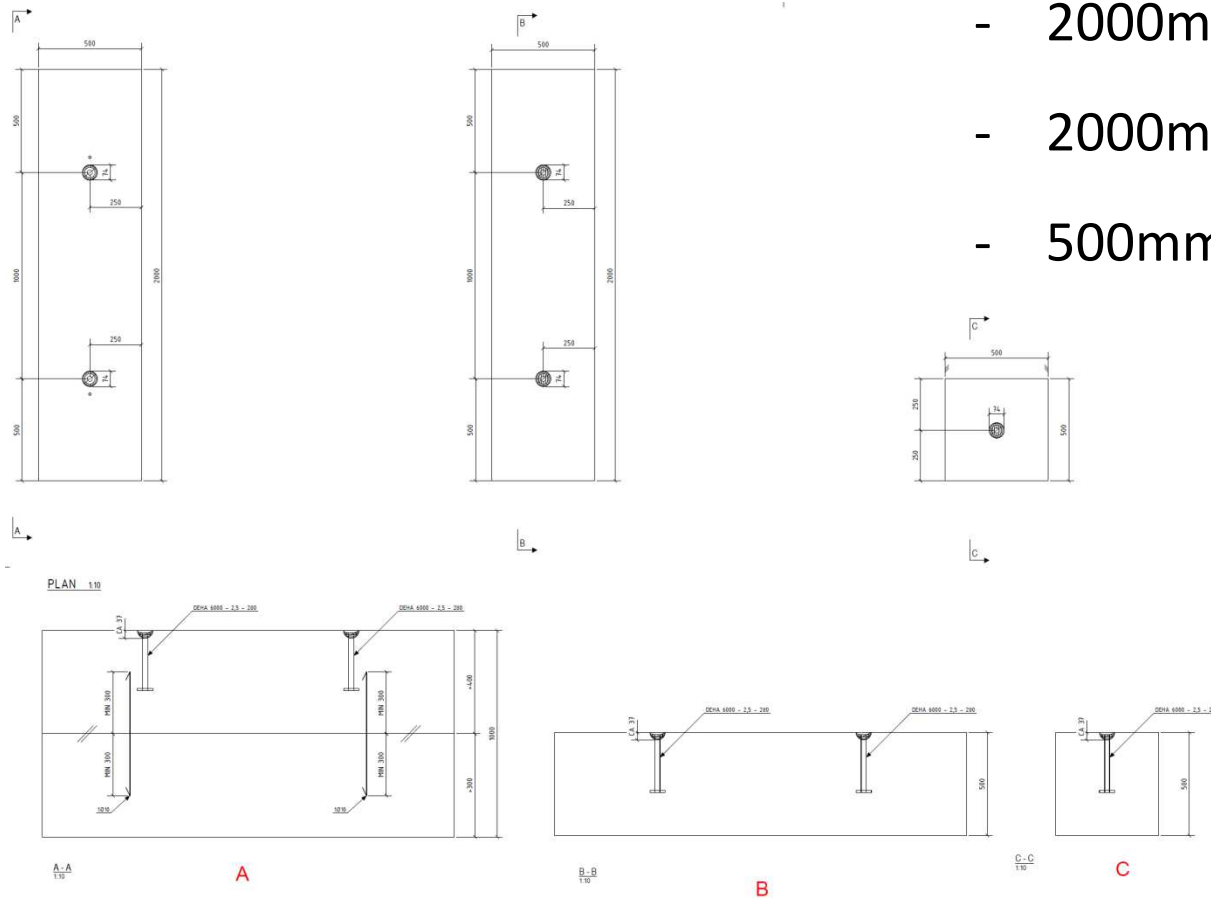
DRAFT



# Shielding blocks from leftover concrete

Size:

- 2000mmx1000mmx500mm
- 2000mmx500mmx500mm
- 500mmx500mmx500mm





**THANK YOU!**

## **Eurocode 1: Actions on structures (EN 1991)**

Part 1-1: Densities, self-weight, imposed loads for buildings (EN 1991-1-1)

Part 1-2: Actions on structures exposed to fire (EN 1991-1-2)

Part 1-3: General actions - Snow loads (EN 1991-1-3)

Part 1-4: General actions - Wind actions (EN 1991-1-4)

Part 1-5: General actions - Thermal actions (EN 1991-1-5)

Part 1-6: General actions - Actions during execution (EN 1991-1-6)

Part 1-7: General actions - Accidental Actions (EN 1991-1-7)

Part 2: Traffic loads on bridges (EN 1991-2)

Part 3: Actions induced by cranes and machinery (EN 1991-3)

Part 4 : Silos and tanks (EN 1991-4)

## **Eurocode 2: Design of concrete structures (EN 1992)**

Part 1-1: General rules, and rules for buildings (EN 1992-1-1)

Part 1-2: Structural fire design (EN 1992-1-2)

Part 1-3: Precast Concrete Elements and Structures (EN 1992-1-3) Part

1-4: Lightweight aggregate concrete with closed structure (EN 1992-1-4)

Part 1-5: Structures with unbonded and external prestressing tendons (EN 1992-1-5)

Part 1-6: Plain concrete structures (EN 1992-1-6)

Part 2: Reinforced and prestressed concrete bridges (EN 1992-2)

Part 3: Liquid retaining and containing structures (EN 1992-3)

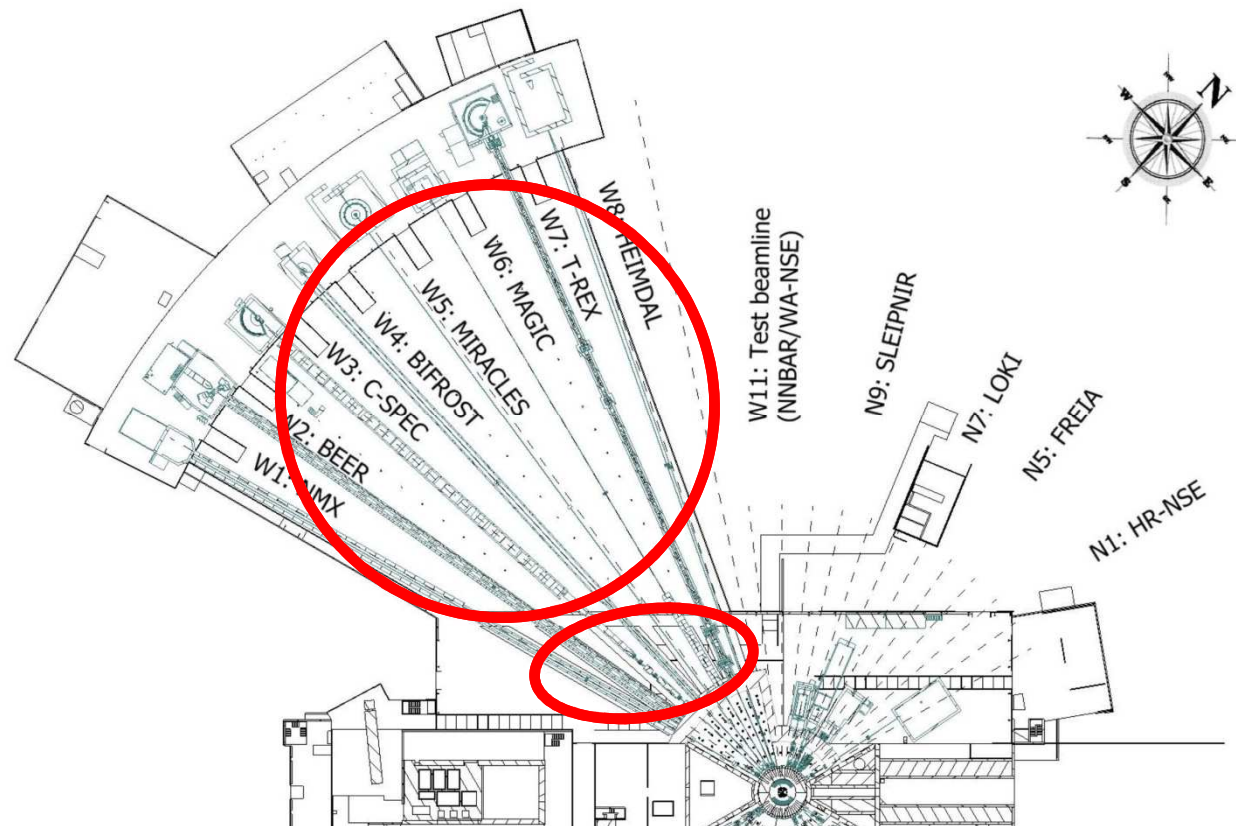
## **Eurocode 3: Design of steel structures (EN 1993)**

Part 1-1: General rules and rules for buildings (EN 1993-1-1)

Part 1-2: General rules - Structural fire design (EN 1993-1-2)

Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting (EN 1993-1-3) Part 1-4: General rules - Supplementary rules for stainless steels (EN 1993-1-4) Part 1-5: Plated structural elements (EN 1993-1-5) Part 1-6: Strength and Stability of Shell Structures (EN 1993-1-6) Part 1-7: General Rules - Supplementary rules for planar plated structural elements with out of plane loading (EN 1993-1-7) Part 1-8: Design of joints (EN 1993-1-8) Part 1-9: Fatigue (EN 1993-1-9) Part 1-10: Material Toughness and through-thickness properties (EN 1993-1-10) Part 1-11: Design of Structures with tension components (EN 1993-1-11) Part 1-12: High Strength steels (EN 1993-1-12) Part 2: Steel Bridges (EN 1993-2) Part 3-1: Towers, masts and chimneys (EN 1993-3-1) Part 3-2: Towers, masts and chimneys - Chimneys (EN 1993-3-2) Part 4-1: Silos (EN 1993-4-1) Part 4-2: Tanks (EN 1993-4-2) Part 4-3: Pipelines (EN 1993-4-3) Part 5: Piling (EN 1993-5) Part 6: Crane supporting structures (EN 1993-6)

# Geometry is affected by the materials



# Geometry is affected by the materials

	Density	Price
<b>Steel</b>	7 850 kg/m <sup>3</sup>	11 800-15 600 EUR/m <sup>3</sup>
Lead	11 340 kg/m <sup>3</sup>	23 800 EUR/m <sup>3</sup>
<b>Concrete</b>	2400 kg/m <sup>3</sup>	450-900 EUR/m <sup>3</sup>
Borated Concrete		800 EUR/m <sup>3</sup>
<b>Heavy Concrete</b>	4000 kg/m <sup>3</sup>	1900-2000 Eur/m <sup>3</sup>
HDPE	970 kg/m <sup>3</sup>	2910 EUR/m <sup>3</sup>
Borated HDPE	1035 kg/m <sup>3</sup>	7245 EUR/m <sup>3</sup>

<https://confluence.ess.lu.se/display/SPD/Instrument+shielding>

# Concrete or Heavy concrete?



Gamma-rays has the main contribution to the dose level in case if **we are out of line of sight.**

Most of the gamma is coming from the Ni-Ti SM.

4.4 MeV photons is the average for Ni/Ti

We need roughly two times thicker regular concrete(2.4t/m<sup>3</sup>) than Heavy concrete (4t/m<sup>3</sup>).

**Regular concrete is more cost effective by 10%-110% in case of simple shapes.**