FCC-hh Machine Detector Interface Overview

FCC week Washington
23-27 March 2015

W. Riegler for the FCC-hh MDI working group

MDI working group

NB: FCC-hh drives the design of the new complex

Working group Goals:

1. Forum for interaction:

FCC-hh expts ↔ FCC-hh accelerator

FCC-hh expts ↔ FCC complex infrastructure

2. Oversight of technical design work

interfaces between detectors & accelerator

interfaces between detectors and infrastructure

→ detector requirements correctly taken into account

-during study phases

-in the eventual FCC CDR.

FCC-hh-Machine-Detector Interface WG

Who are we ?

Contact persons … to be adapted / expanded as necessary.

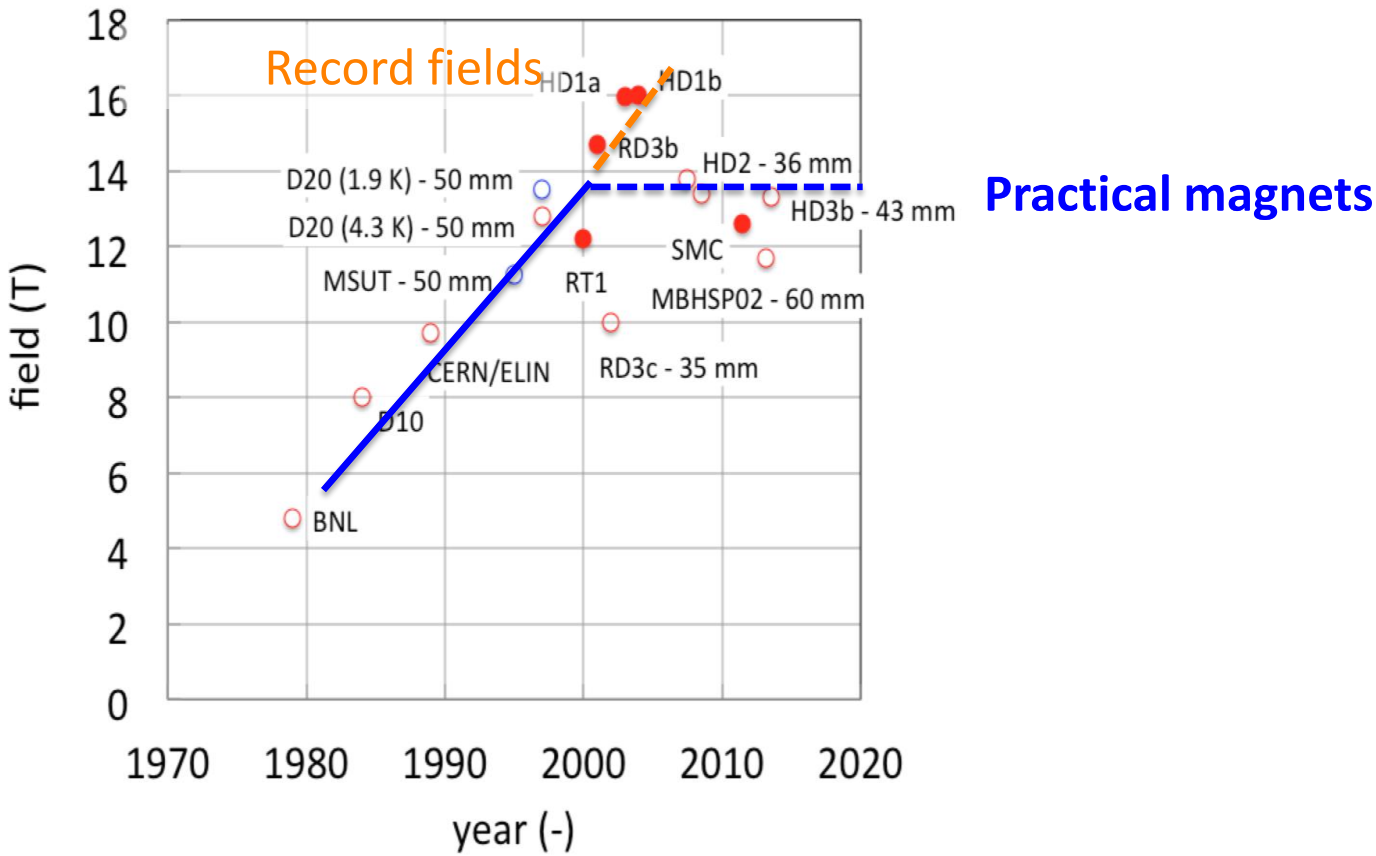
Austin Ball (chair)
Manuela Boscolo (link to FCC-ee MDI WG)
Helmut Burkhardt (link to LHC MDI)
Francesco Cerrutti (FLUKA team representative)
Ilias Efthymiopoulos (co-chair, overall integration)
Herman Ten Kate (detector magnet working group chair)
John Osborne (link to surface and underground civil engineering)
Werner Riegler (scientific secretary)
Daniel Schulte (FCC-hh machine)
Andrei Seryi (H2020 FCC-hh EIR design WP leader)
Rogelio Tomas (overall hadron collider lattice design and parameters)
Markus Widorski (radiation protection)

Meeting approx. every month, Friday afternoons

Responsibilities

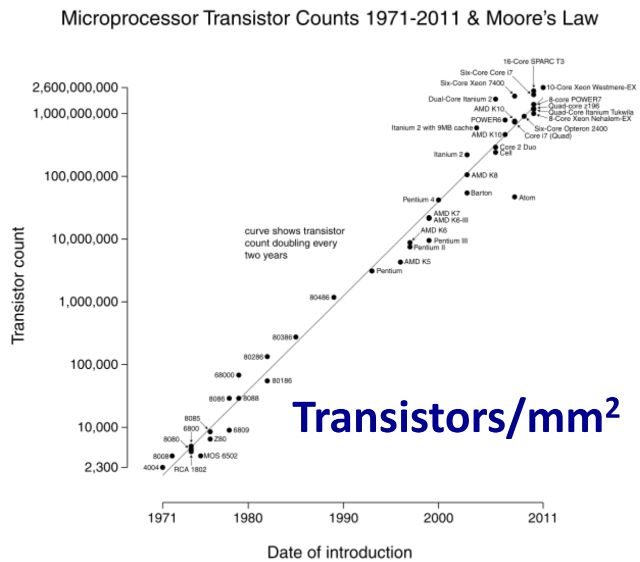
- Engineering interface expts-machine
- Protection of accelerator from collision debris
- Cavern design & integration of detector services
- Definition & delivery schedule of surface facilities
- Safety issues across the MDI (ventilation, cryo, detector gas etc)
- Integration of possible experimental physics detectors in FCC tunnel

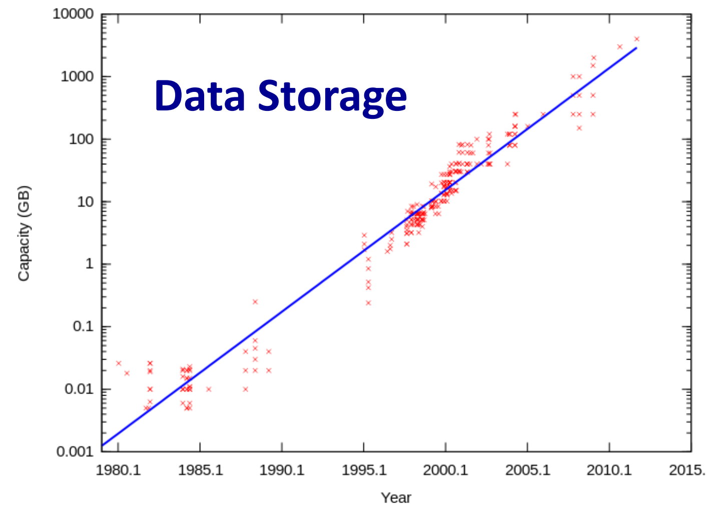
Prospects for Accelerator Magents

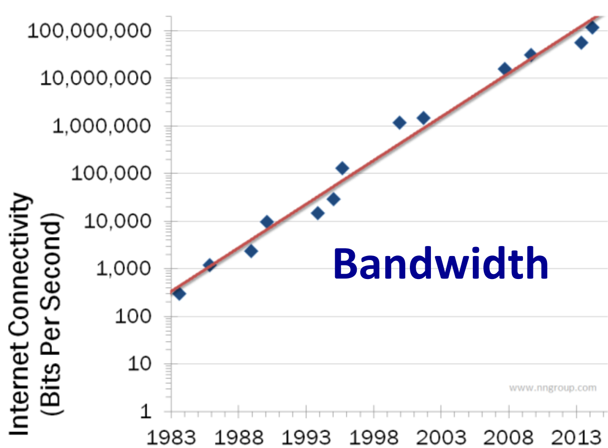


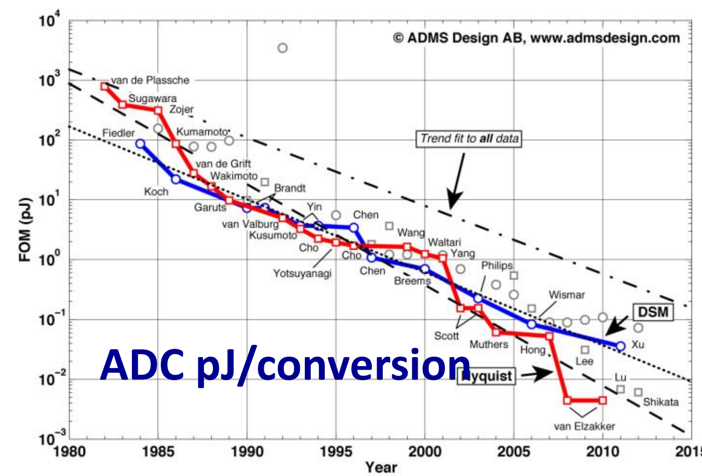
Magnets between 1980 to 2000: factor 3 with difficult prospects ... 16T FCC dipoles are very challenging.

Prospects for ‚Microelectronics‘









All these figures showed doubling times of < 2 years in the past !

One may dream about a factor 2^{10} = 1024 from 2014 – 2034 (of course extremely optimistic)

This will allow major detector improvements !

Key Point and Strategy

If the FCC hadron machine with 16T magnets, 5MW synchrotron radiation and a 100km tunnel can be realized, there is no doubt that a detector, that makes full use of the physics potential, can be built by 2035.

Much of detector technology is driven by silicon technology and computing power i.e. we can count on significant improvements.

Since the maximum energy an delivered luminosity are the key goals for the FCC-hh machine, the detector efforts should put minimal constraints at the machine efforts.

Boundary Conditions for Experiments at the FCC-hh Collider $\rightarrow L^* x\ L_{peak} x\ L_{int} = L^3$

Try to work out a set of Machine Detector Interface (MDI) Parameters that allow detector efforts and machine efforts to explore options with maximum ‚freedom'

L^* ... the distance between IP and triplet magnet, which determines the maximum size of the detector.

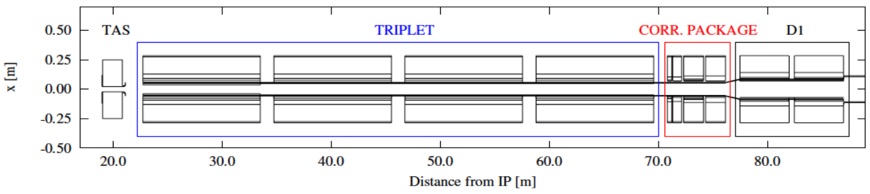
L_{peak} ... The peak luminosity, that determines the detector rates and pileup numbers.

L_{int} ... the total integrated luminosity, that determines the ageing and radiation damage of the detector, as well as radiation damage of the triplet magnets.

L* [25m, 40m] or larger

The L* of LHC is 23m, many FCC-hh studies were performed with an L* of 36m, recently an L* of 60m has become popular.

LHC Triplet and Triplet Shielding (TAS)



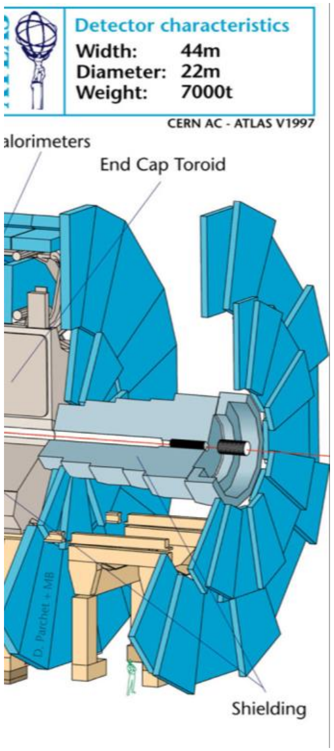
A large value of L* does of course allow easier integration and "all in one central+forward" detector concepts.

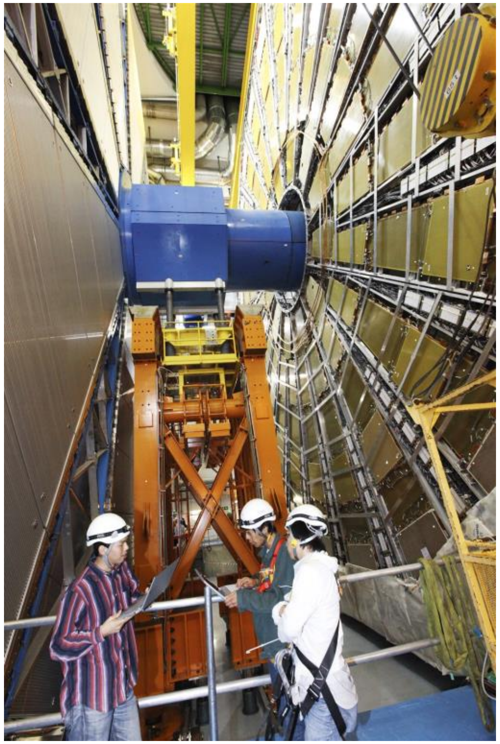
Since one of the key criteria of the FCC-hh machine is the maximum delivered luminosity, one should be very open on this number and not exclude smaller values of L*, if significant performance gains can be achieved.

L*, Triplet Shielding

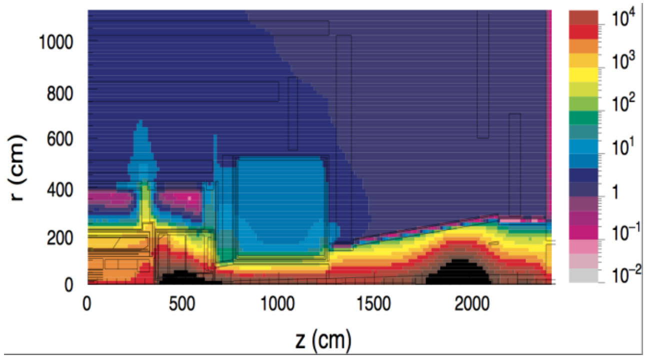
Once L* is chosen, the triplet shielding (TAS) and the shielding around the TAS have to be worked out.

L* of LHC is 23m, heavy shielding around the TAS inside the cavern to avoid large background, mainly neutrons.

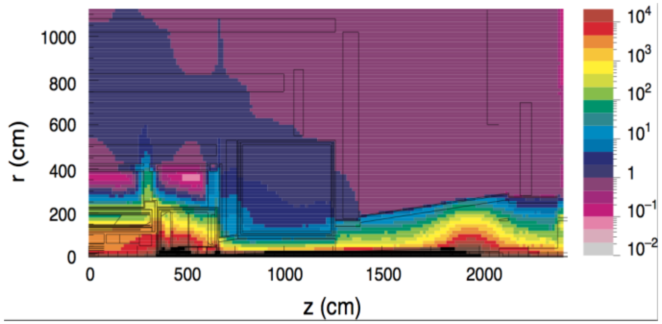




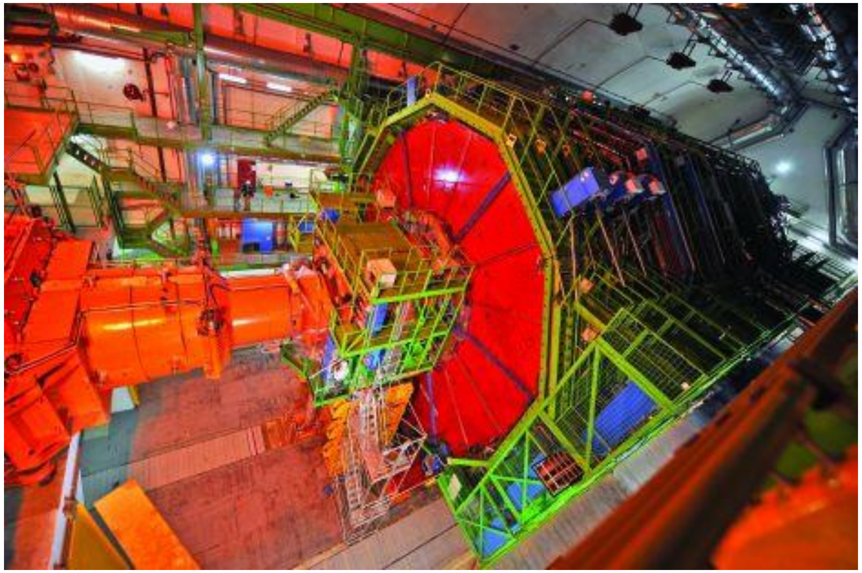
Instantaneous neutron fluence (kHz/cm²)

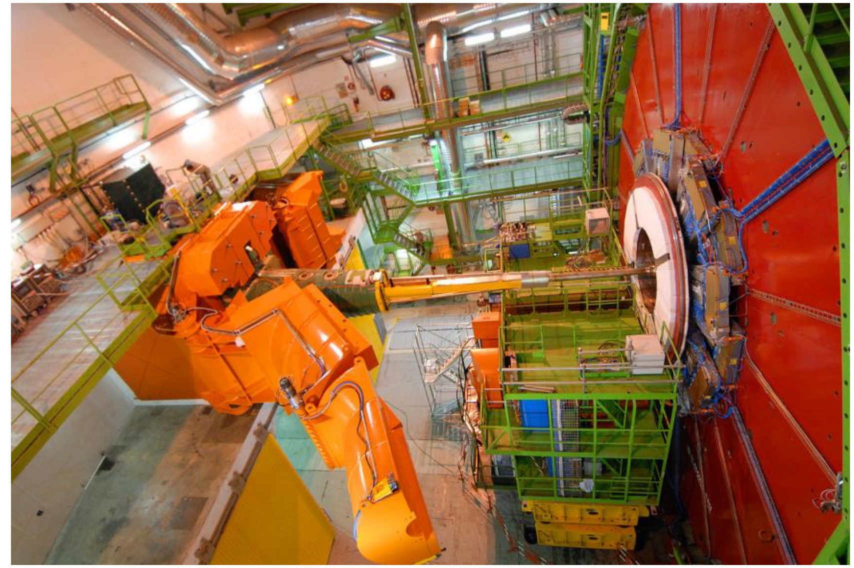


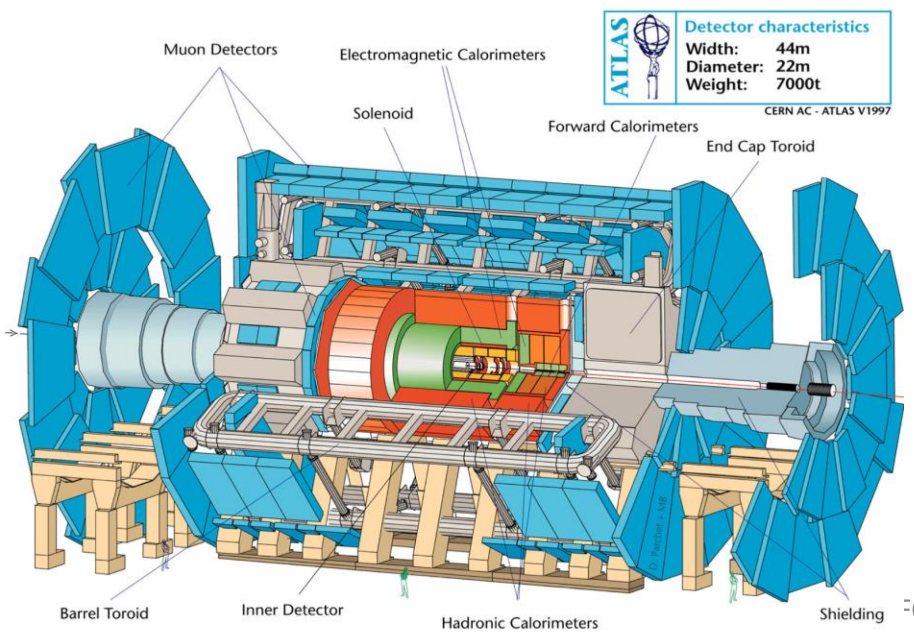
Instantaneous photon fluence (kHz/cm²)

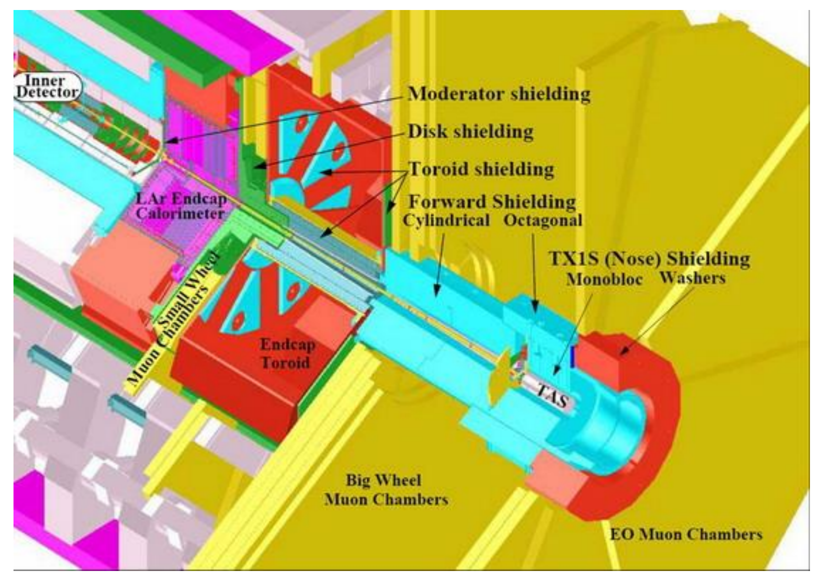


L*, Triplet Shielding





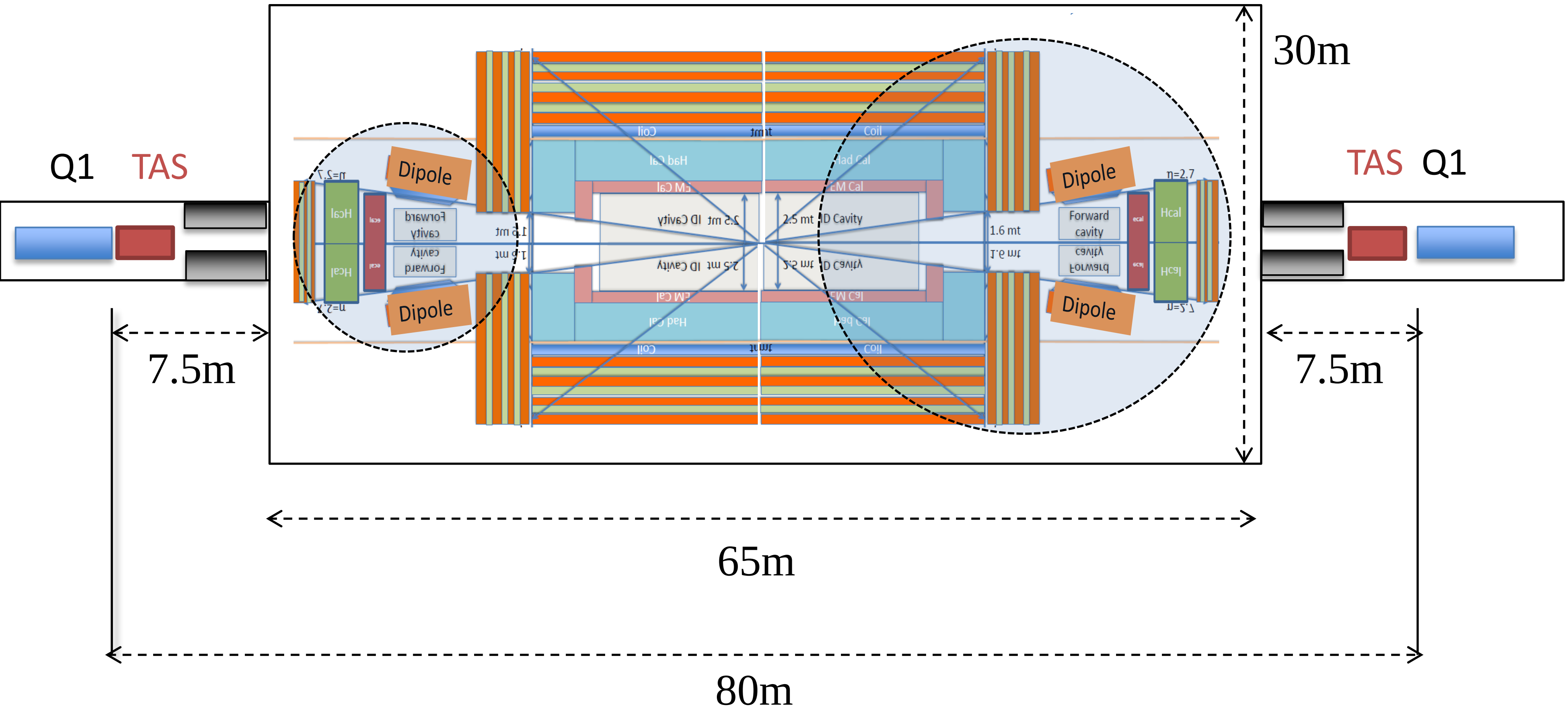




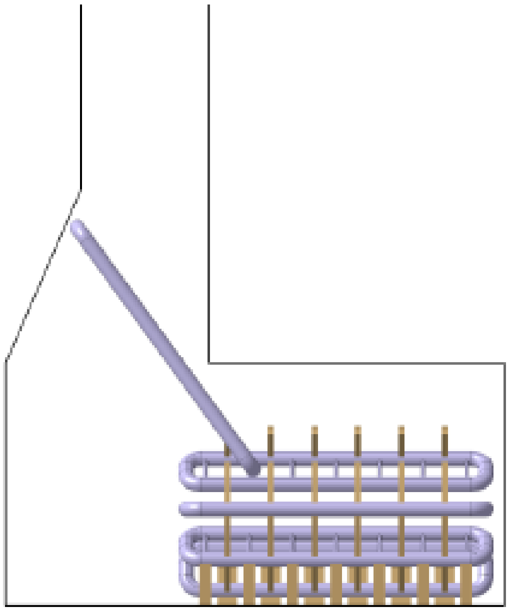
L* > 40m

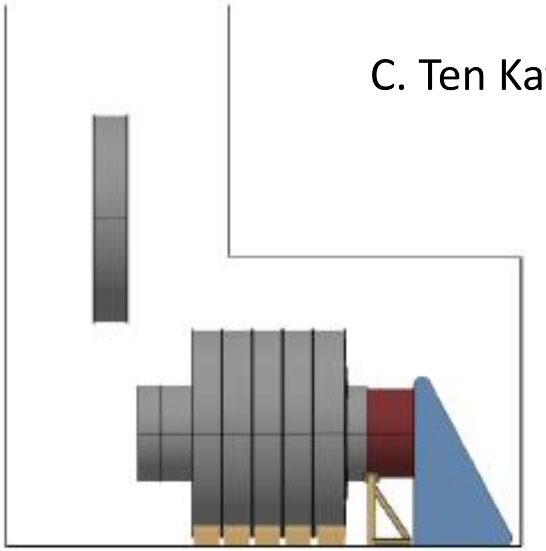
L* >40m allows the the triplet (Q1-Q3) and the triplet shielding (TAS) to be 'hidden' in the tunnel

→ very comfortable situation for cavern infrastructure and ALARA related items.



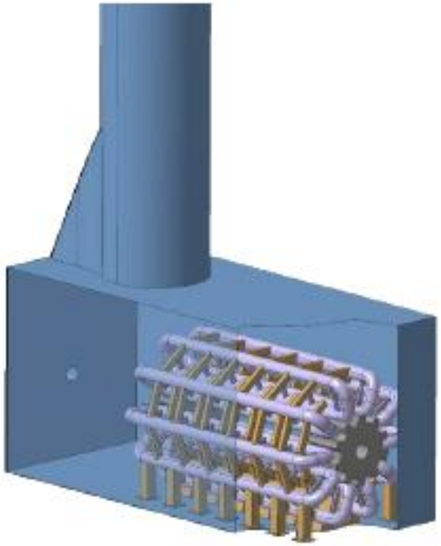
First Concepts of Layout and Shaft Requirements



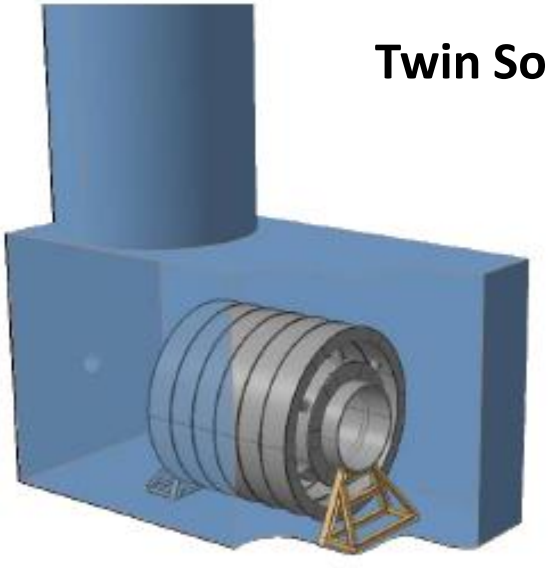


C. Ten Kate

Toroid



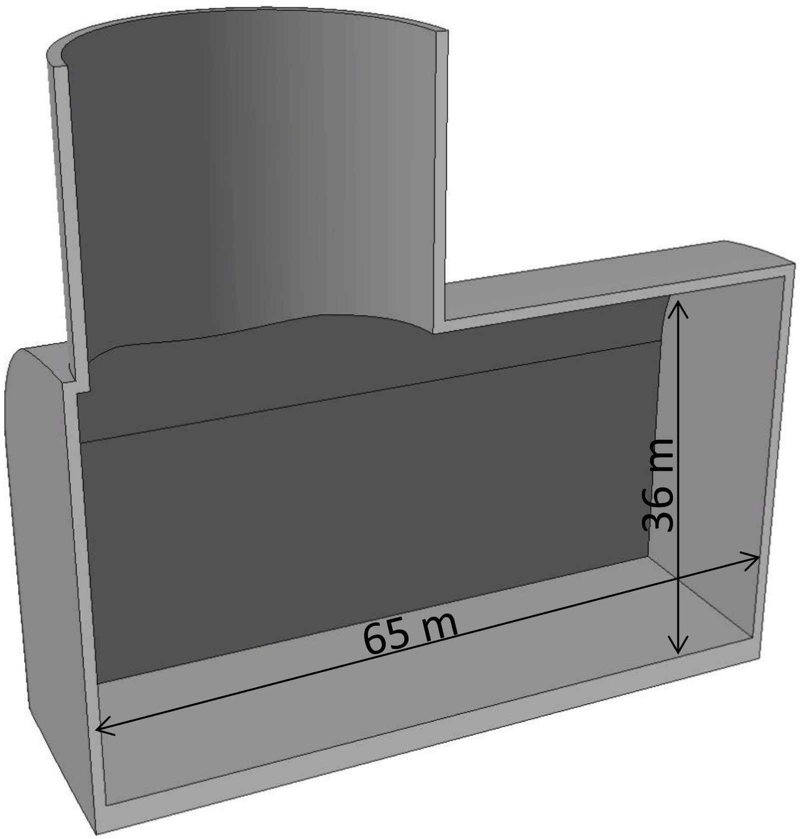
Twin Solenoid

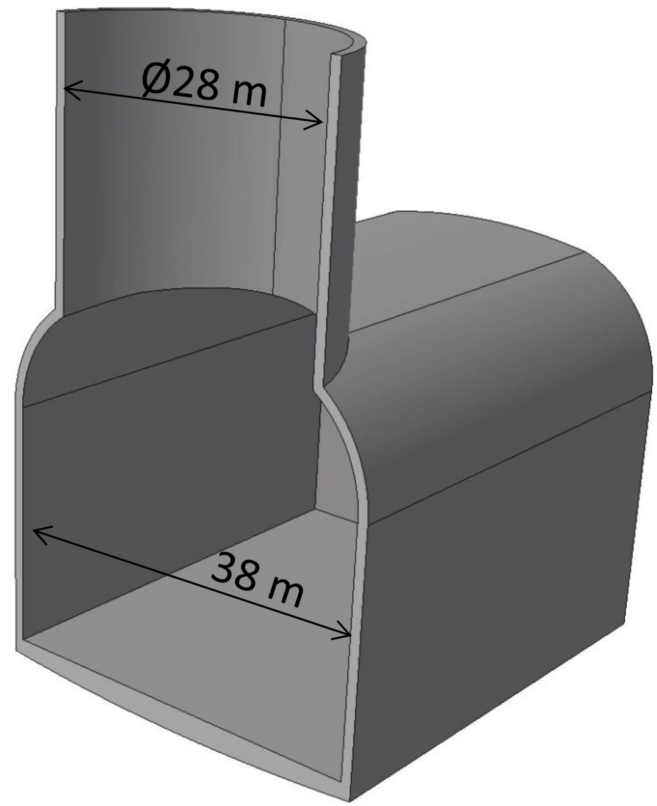


FCC CAVERN
With SHAFT

Twin Solenoid

CATIA Model: ST0666403_01



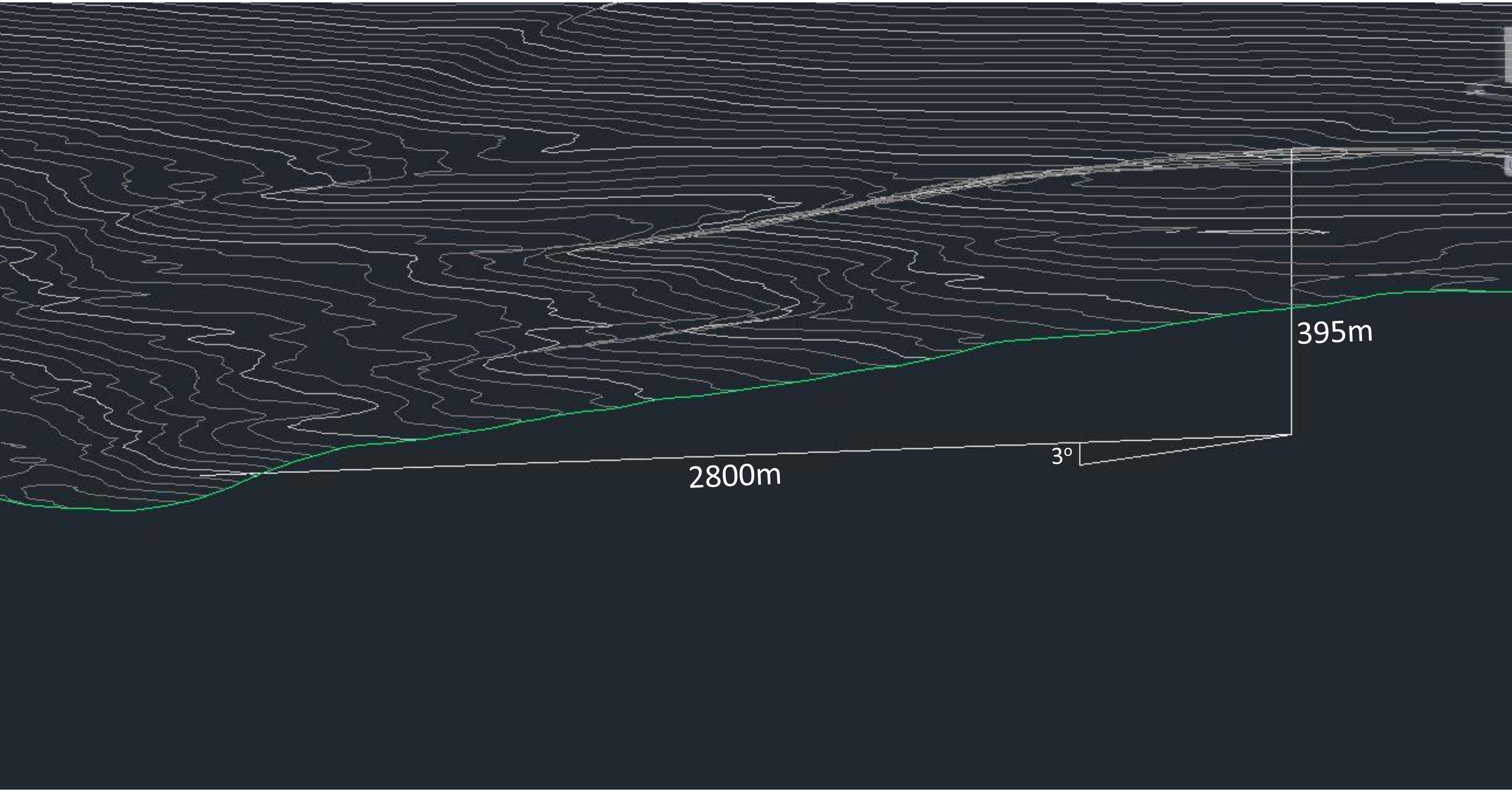


Very large caverns and access shafts are clearly an engineering challenge at potentially large depth (e.g. 300-500m, water column 30-50 bars).

C. Cook, J. Osborne

Cavern Access

Shaft (vertical) vs. Inclined tunnel?



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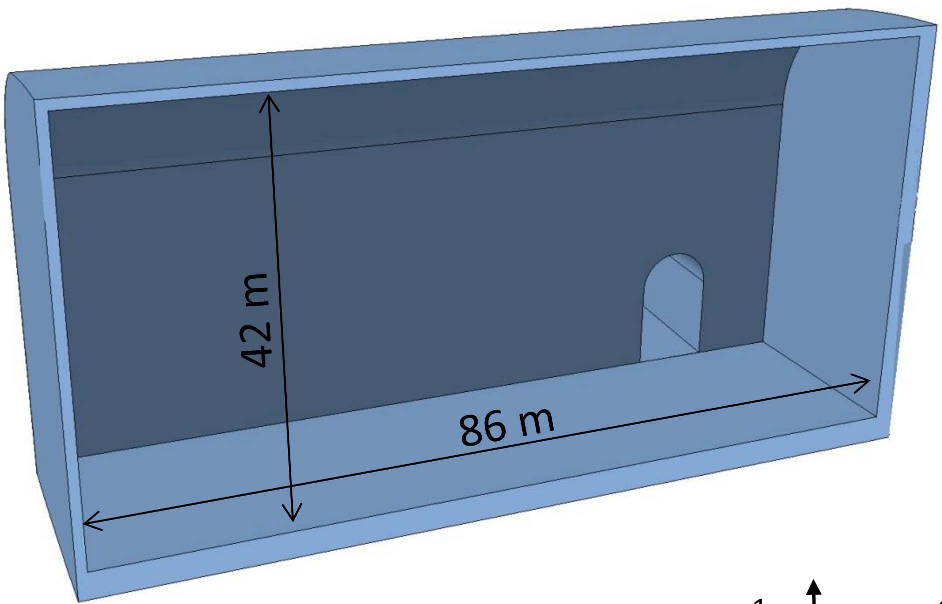
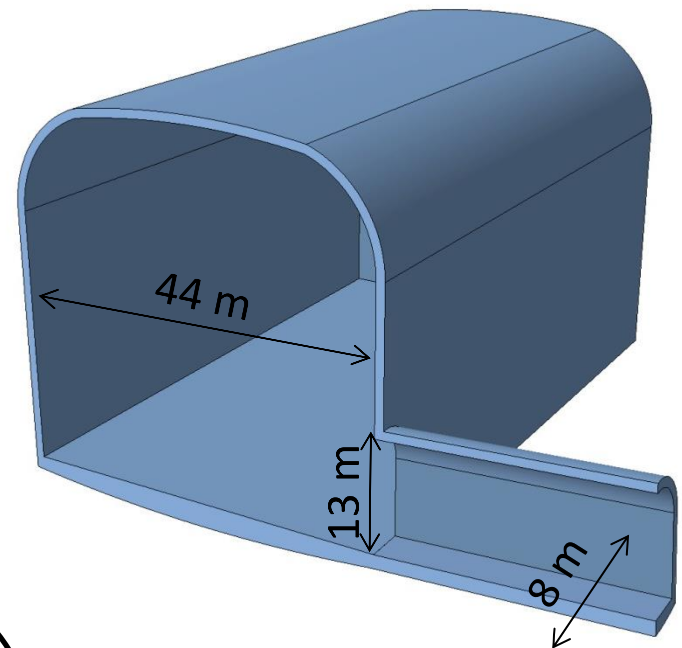
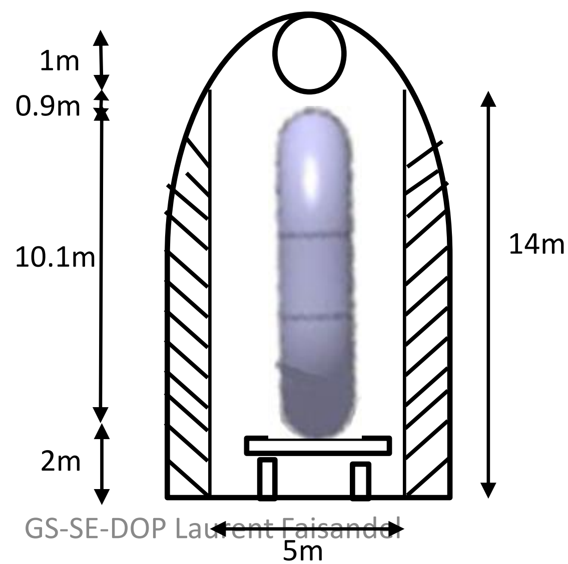
FCC CAVERN
With TUNNEL

Toroid

CATIA Model: ST0666529_01







C. Cook, J. Orborne

Peak Luminosity and Pileup

The baseline peak luminosity for FCC-hh is $5x10^{34}$ (first Phase)

A maximum peak luminosity of $30x10^{34}$ is assumed for the second Phase for detector R&D.

L_{peak} [$5x10^{34}$, $30x10^{34}$]

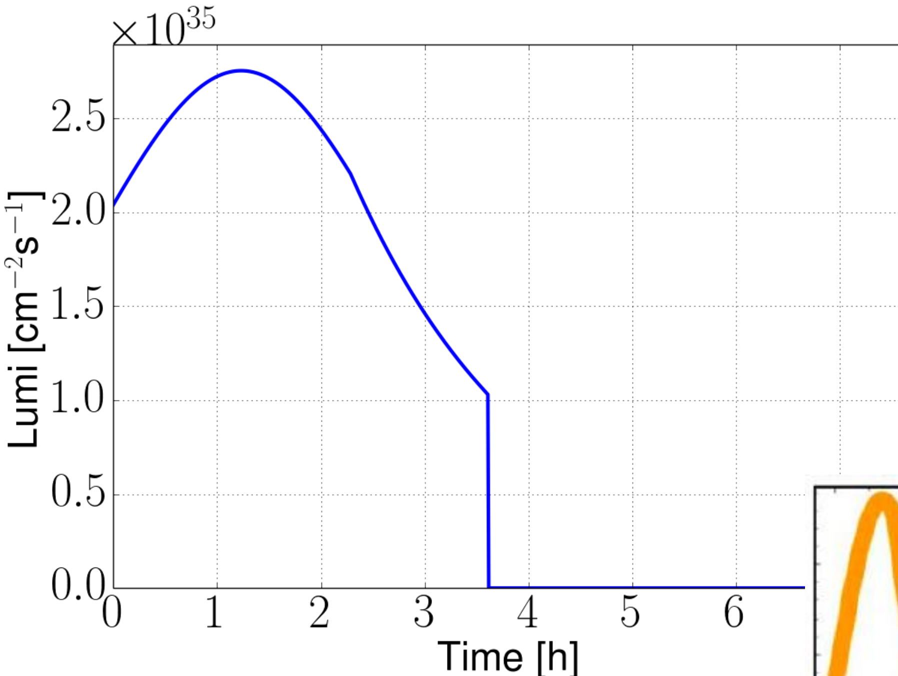
corresponds to an average pileup of (108mbarn):

N_{pileup} [170, 1020] at 25ns bunch spacing and
N_{pileup} [34, 204] at 5ns bunch spacing

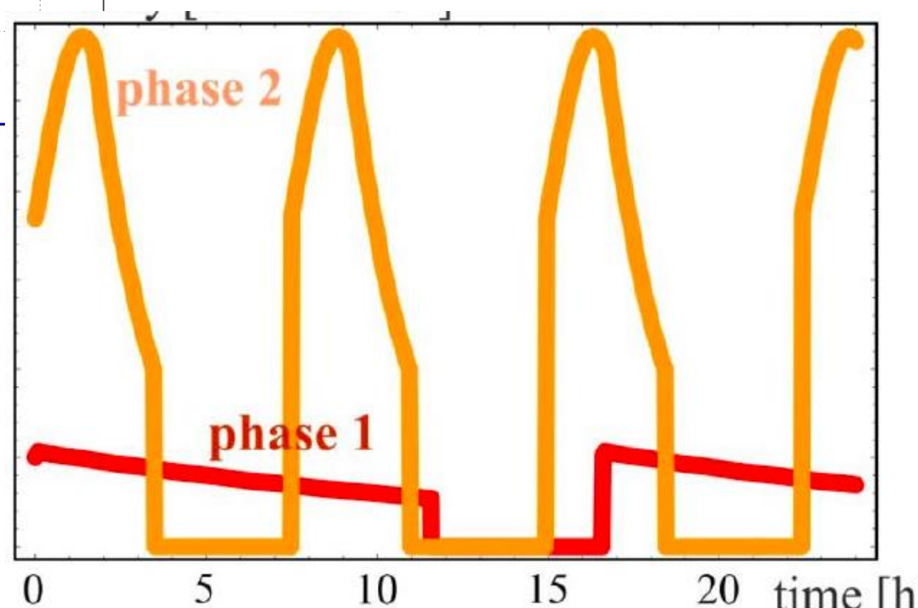
For phase 2, clearly 5ns is preferred, but 25ns probably not excluded with 2035 detectors.

HL-LHC (78mbarn):
Average pileup 120 < maximum average pileup 150 < maximum pileup >200

Peak Luminosity and Pileup



Peak luminosity for Phase2 is determined by a complex interplay of burn off and synchrotron radiation damping.



Integrated Luminosity

The machine target for integrated luminosity [$3ab^{-1}$, $20ab^{-1}$] for the first and second phase.

For radiation studies, safety factors of many kinds have to be included, so we assume $30ab^{-1}$ as a nominal number for FCC Phase II detector simulations.

Estimate for radiation load of first Pixel Layer at r=3.7cm:

HL-LHC $3ab^{-1}$
1MeVneq Fluence = 1.5×10^{16} cm^{-2}
Dose = 5MGy

FCC $3ab^{-1}$
1MeVneq Fluence = 3×10^{16} cm^{-2}
Dose = 10MGy

FCC $30ab^{-1}$
1MeVneq Fluence = 3×10^{17} cm^{-2}
Dose = 100MGy

Summary MDI Parameters

L* [25, 40]m or larger

Presently 60m is popular, we however stick to these numbers for now.

L_{peak} [$5x10^{34}$, $30x10^{34}$] $cm^{-2}s^{-1}$

→ N_{pileup} [170, 1020] at 25ns
→ N_{pileup} [34, 204] at 5ns

L_{int} [3, 30] ab^{-1}

The upper limits of L_{peak} and L_{int} should be read as Phase2 assumptions for the MDI effort, and not as numbers specified for or promised by the machine.

Conclusion

A minimum set of MDI parameters was defined.

Radiation and shielding studies for triplet and detectors have started
→ See talks my Maria Ilara Besana and Nikolai Mokhov on Thursday

Cavern layout and magnet systems are being studied
→ See talk by Herman ten Kate on Wednesday

First detector concepts are being investigated
→ Session on Wednesday and Thursday

Next Steps:
Coarse formulation of beampipe and detector material for radiation studies
→ detector & triplet combined.