# Engineering Challenges for detectors at the ILC

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ICHEP 2014, Valencia (Spain)

# Physics Requirements

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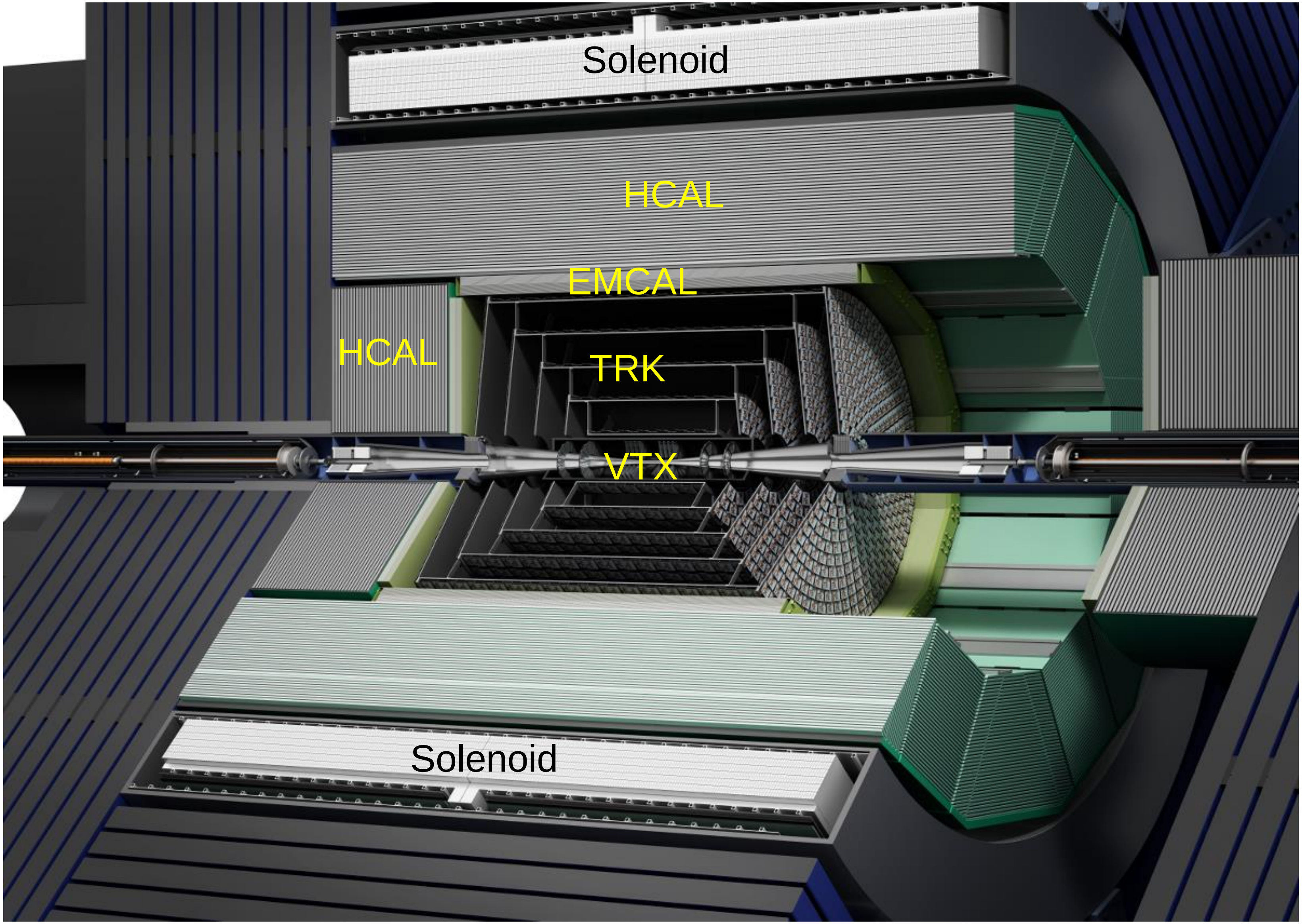
1. The strategy of the ILC Detectors is based on the assumption that Particle Flow Calorimetry will be important.

2. This leads directly to a reasonably large value of $BR^2$ and to an electromagnetic calorimeter (EMCal) design with a small Moliere radius and small pixel size. Silicon/Tungsten is the best approach.

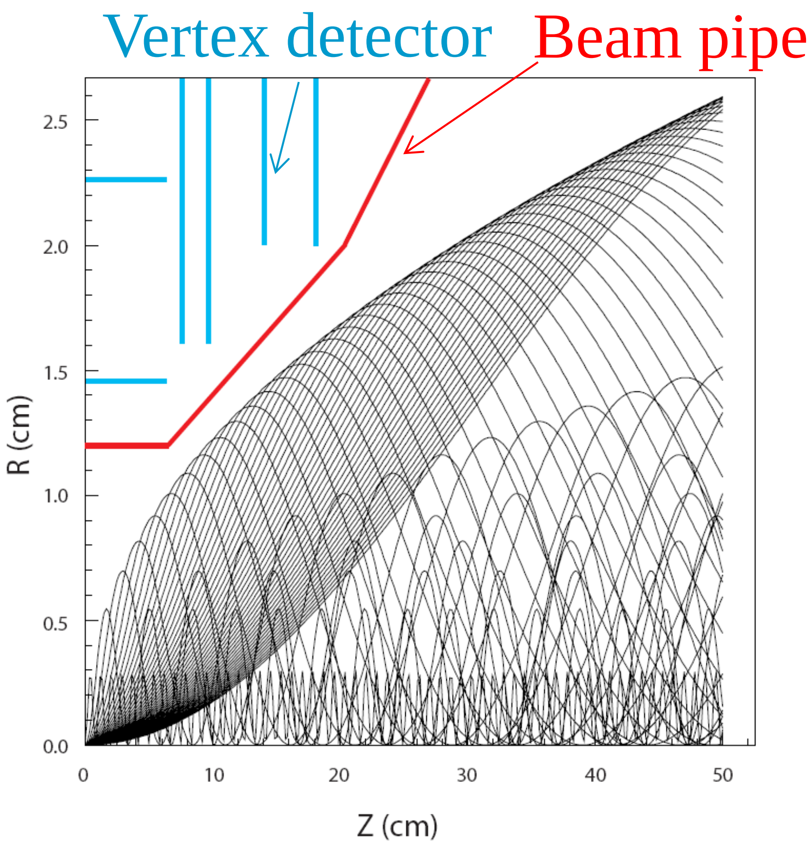
3. Such a calorimeter is expensive, and its cost is moderated by keeping the scale of the inner detectors down. This has many implications:
   - Maintain $BR^2$ by pushing the central field B (~5T for SID and 3.5T for ILD)
   - Excellent tracking and momentum resolution required in smaller volume
     - Full Silicon SID, Silicon+TPC for ILD
   - Large B field is desirable to contain electron-positron pairs in beamline

# Strong B central field with High Granularity Calorimetry

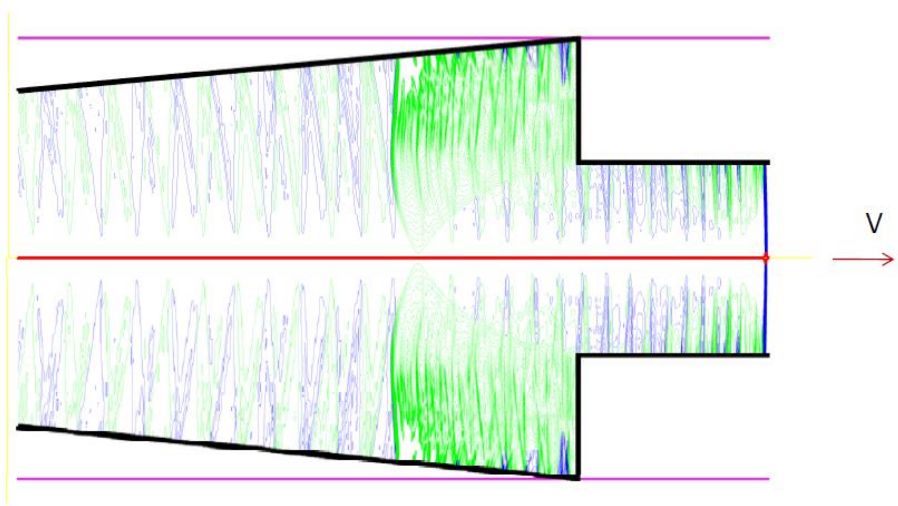


# Beampipe Design

1. Impedance issues that can generate wakefields and heating have been checked. Very Small energy loss in IR, ~30W nominal (6W pulsed)
2. Scattering inside the detector is negligible up to 1'000 nT. Luminosity backgrounds (pairs, $\gamma\gamma \rightarrow$hadrons) are much higher




Example of Wakefields



# LC Duty Factor: Power Pulsing

1. ILC: 1 ms spill @ 5 Hz. LC detectors currently uses power up 1 ms before train; 1 ms train; 10 μs fall, with 1% effective duty factor.

2. SLC power cycling worked ~ok at 120 Hz.

3. Development of KPiX, a 1024 channels "System on Chip" for the Si strip tracker and for highly pixellated, dense readout for the EMCal. Mean power/channel <20 μW.

4. Estimated Tracker power consumption is <600 watts : gas cooling of the VXD and Si Tracker.

**Vertex power pulsing design + first lab tests:**

- With vertex analog powering in mind: ~2 A at 1.2 V for ~15 μs
- **Low-mass !**

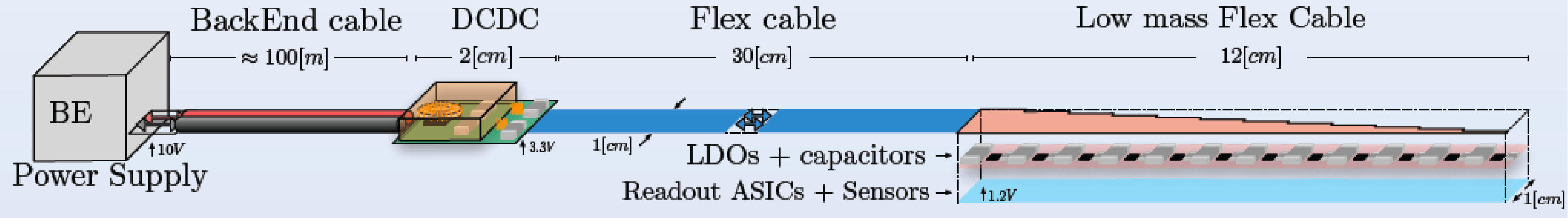
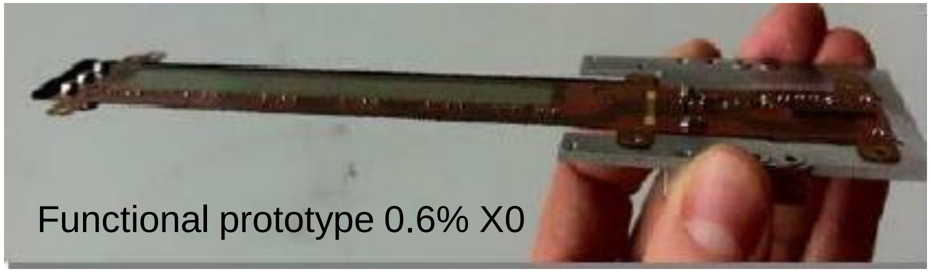


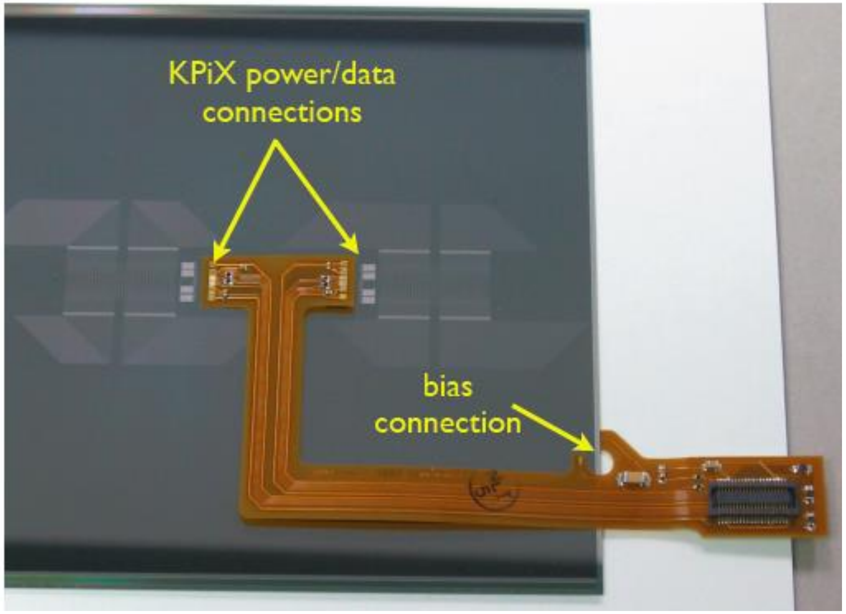

Figure: Half ladder proposed powering scheme

# Vertex and Tracker Local Supports

1. Very high granularity
2. Dense integration of functionalities
3. Super-light materials: less than 0.3% Xo/layer (VTX) and 0.1% Xo/layer (Tracker)
    - As reference…..ATLAS IBL Layer ~1.8Xo
4. Low-power design + power pulsing: average VTX power < 130 $mW/mm^2$
5. Air cooling and CO2 cooling options




**MIMOSA-31 :** Larger pixel for reduced power consumption (35x35 μm)




Silicon Tracker Module w/ KPix

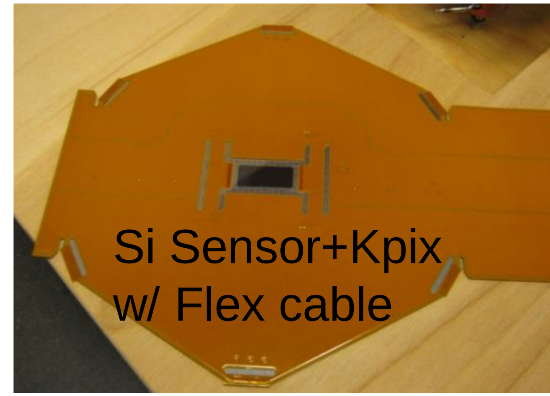
# Vertex and Tracker Global Supports

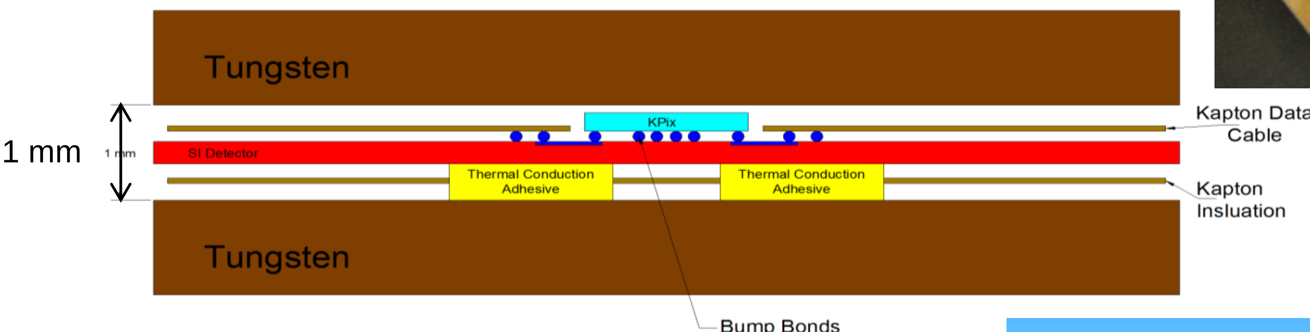
1. Global supports made by a double-walled carbon-fibre cylinders (vertex) and Rohacell sandwich (Tracker).
2. Double function to supporting the vertex detector to stiffening the beampipe in the vertex region.
3. It serves as a cooling gas transport and manifold, and provides locations to mount cables and power converters.
4. Vertex split design on the horizontal plane, to allow the assembly about the beampipe and later servicing.

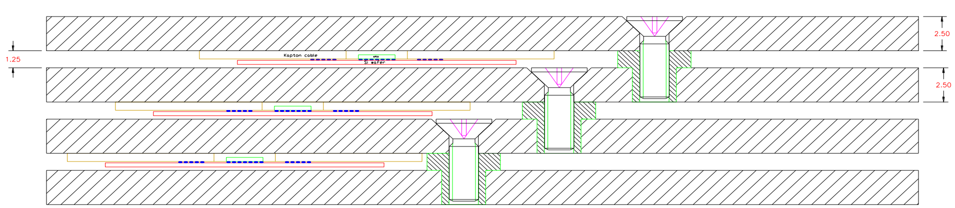

Vertex Heat load ~ 20W

# EMCal Design

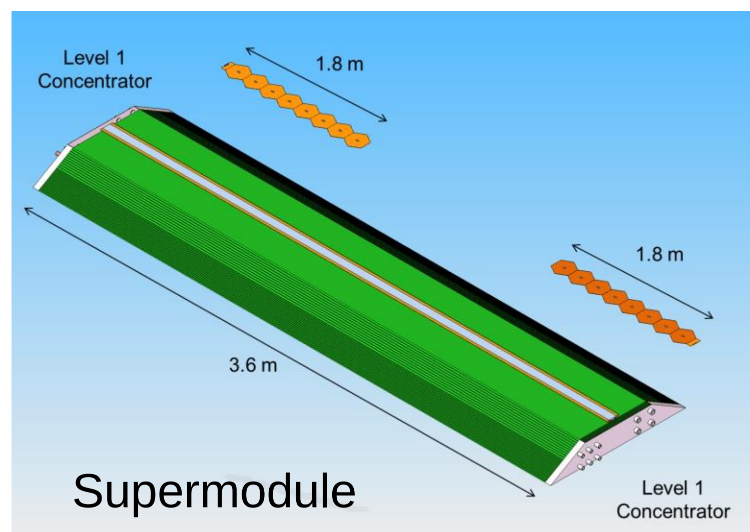
1. Fine segmentation in R, phi, Z
2. Ultra – compact active layers
3. Pushing integration to limits



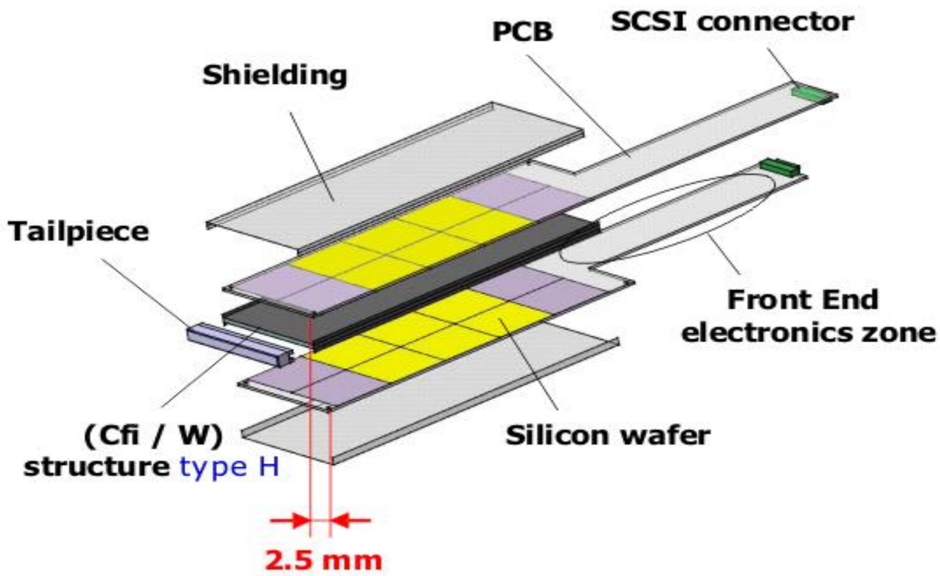



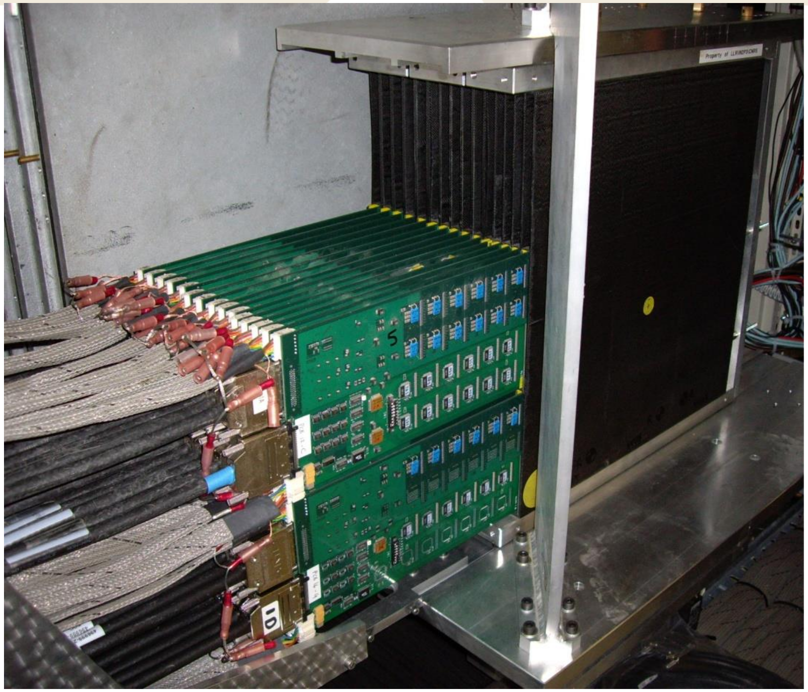
Mechanical Assembly



# ILD EMcal Design

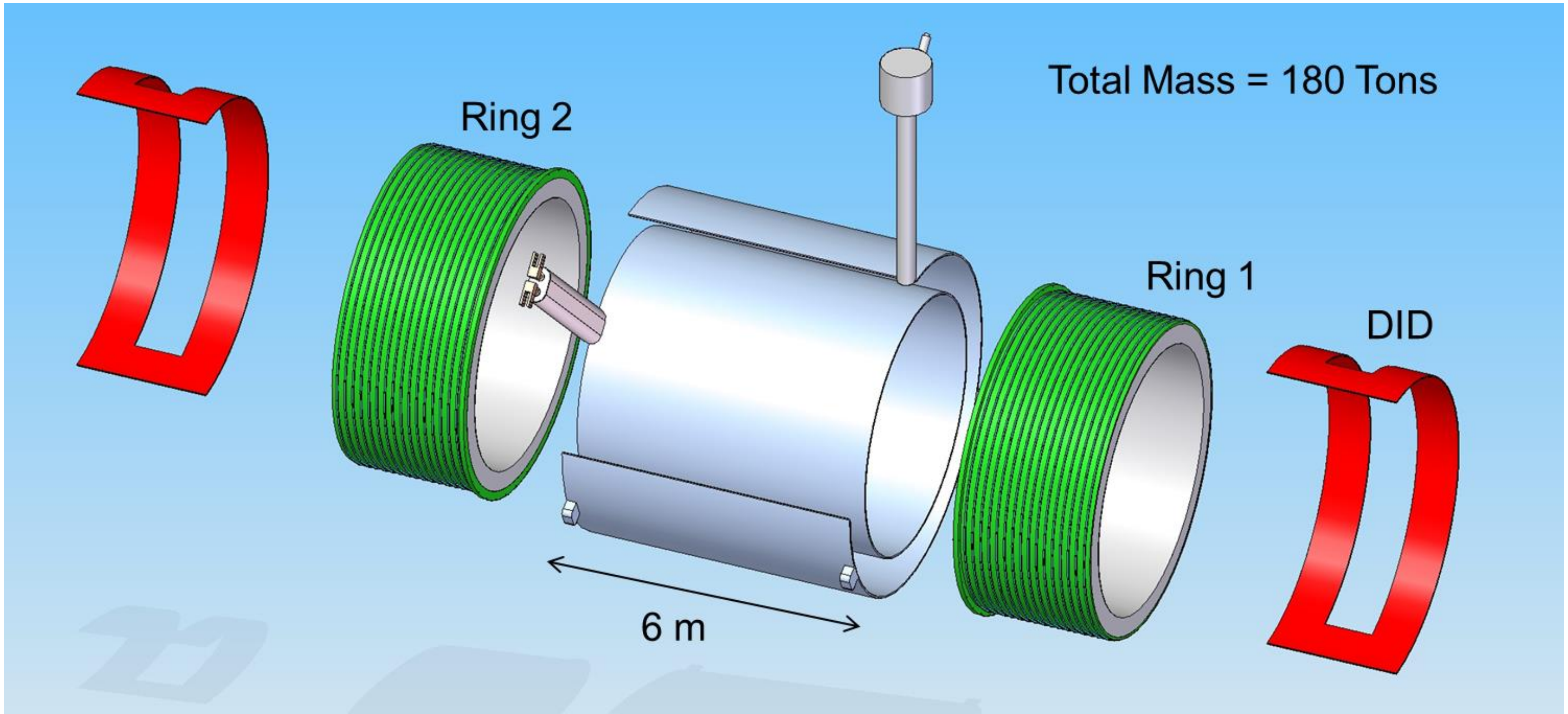
1. 30 layers - ~10000 channels
2. Alveola mechanical structure: carbon fibre composite, incorporating tungsten layers
3. Standard printed circuit slabs hold silicon sensors & electronics
4. 7 mm tick detector slab slided into alveola



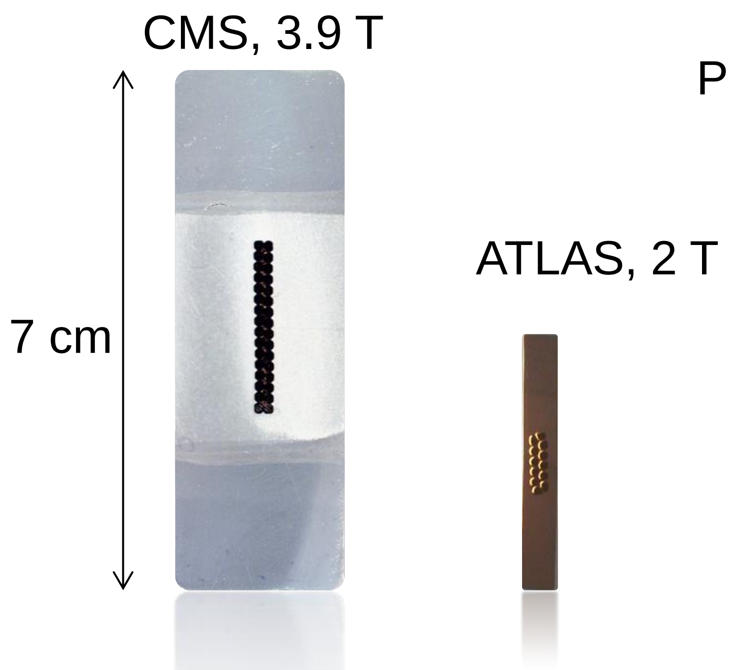



# SID Solenoid, 5T

1. Evolutionary design of the CMS solenoid, from 3.9T to 5T
2. Large hoops stresses on the superconducting cable require R&D on new configuration of the cable and on the alloys
3. Six layers winding, two rings split in zee
4. Integrated Dipoles (DID) to compensate the effect of the crossing angle



# Solenoid Superconducting Cable



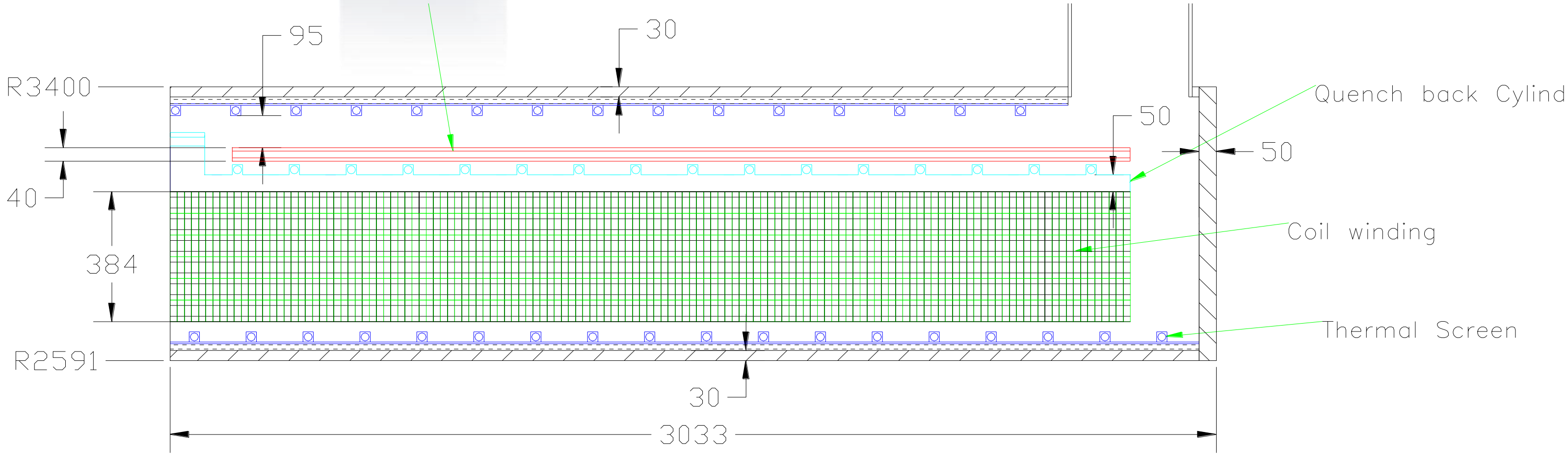

## Prototyping for a 60 kA critical current

Hybrid solution

- preservation of resistivity properties ✓
- mechanical reinforcement ✓
- homogeneous deflection ~
- conductor manufacturing ~

Microalloying

- preservation of resistivity properties ✓
- mechanical reinforcement ~
- homogeneous deflection ~
- conductor manufacturing ~

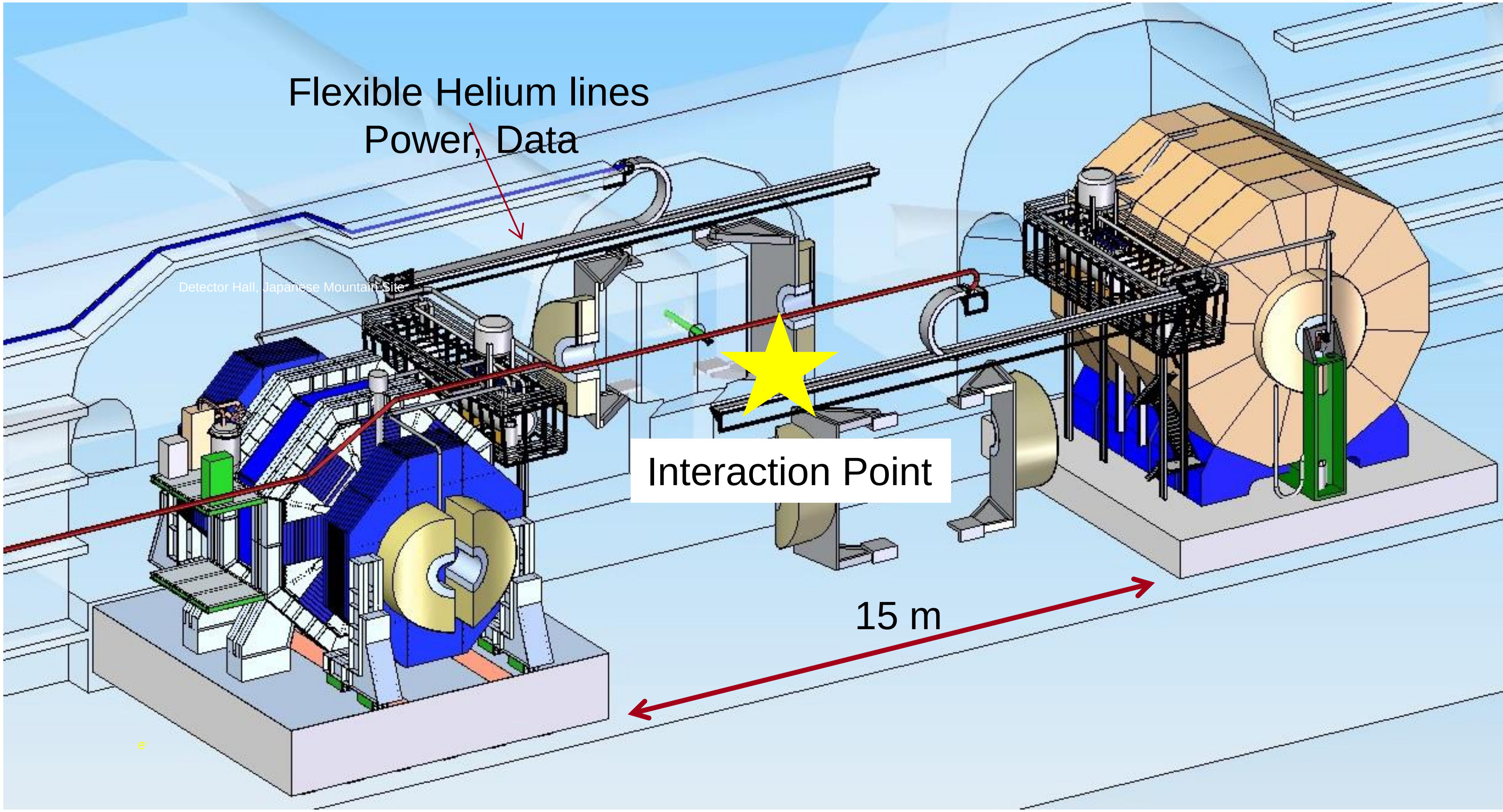


# Accelerator Requirements

1. Two detectors operating on single Beam delivery System, Push-Pull
   - Detector Hall ~100 m deep
   - Motion of Large Detectors ~15'000 tons
   - Repeatable alignment ±1 mm
   - Fast interchange ~ few days
   - Self Shielding, personnel safety
   - Cryogenics and Services Integrations
2. Nanometric size beams with short L* (3.5 m SID, 4.5m ILD)
   - High beam stability with very low vibrations
   - Final Focus System captured in the detector

Strong Machine-Detectors Coordination

# Push-Pull : Engineering Concept




Platform on Rollers

# Self-Shielded Detectors

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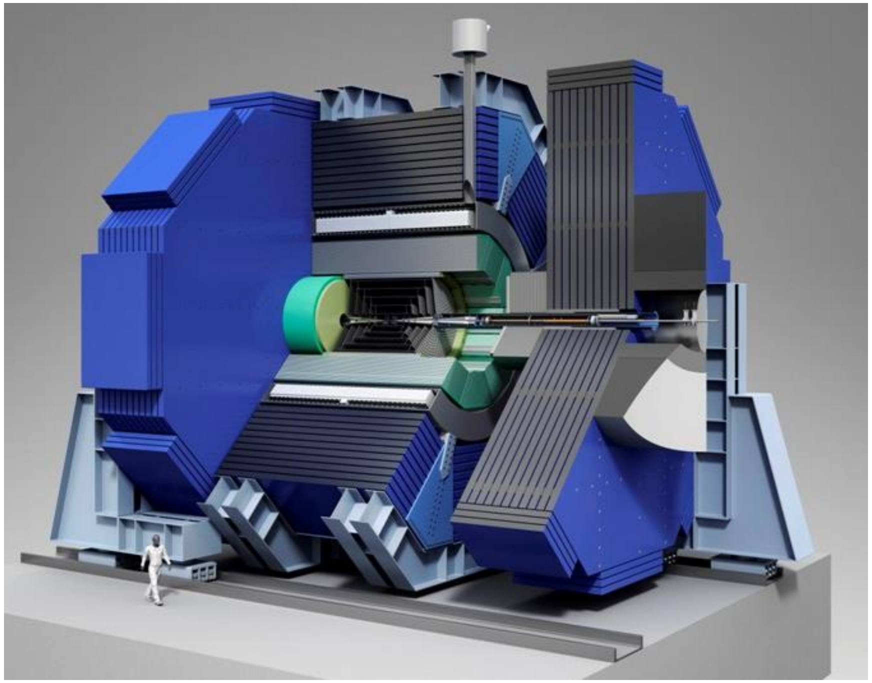
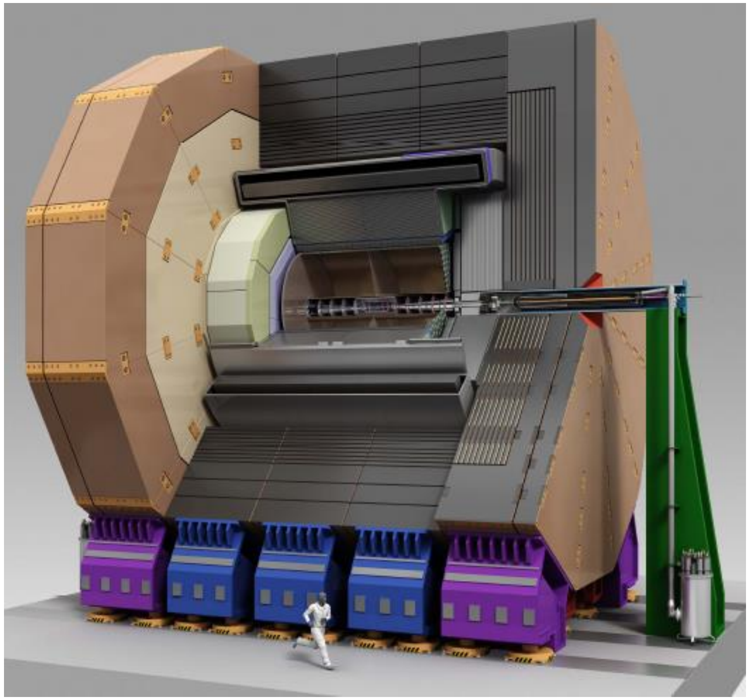
1. Iron design driven by the requirements of self shielding of Magnetic Field and the Radiation dose for the protection of the personnel working on the off-beam detector.

2. Larger Iron volume for an effective magnetic flux return with low fringe field.

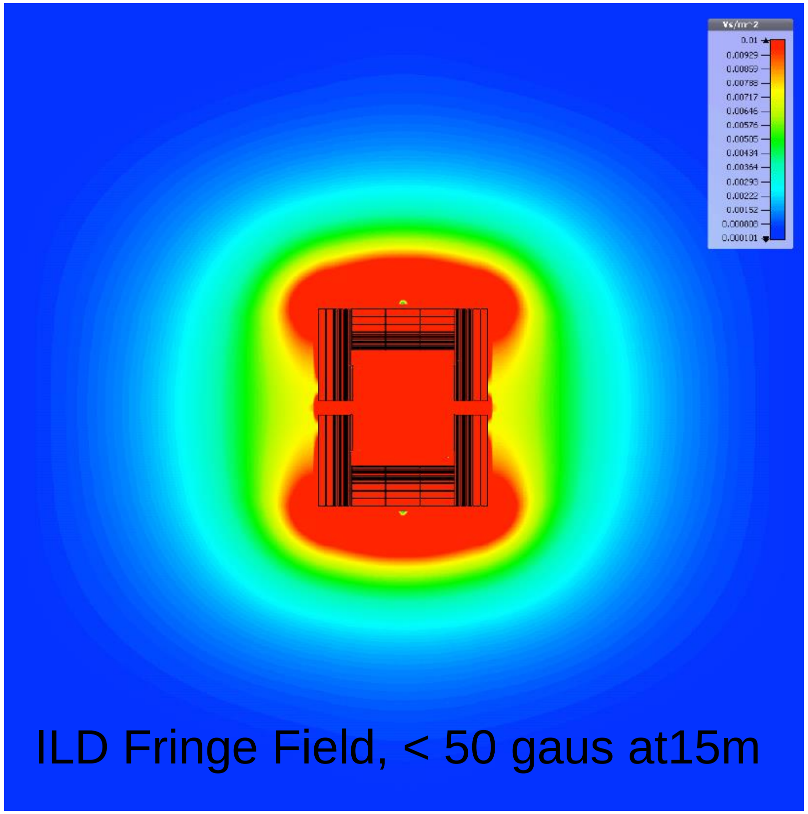
3. Increased costs, Optimization required



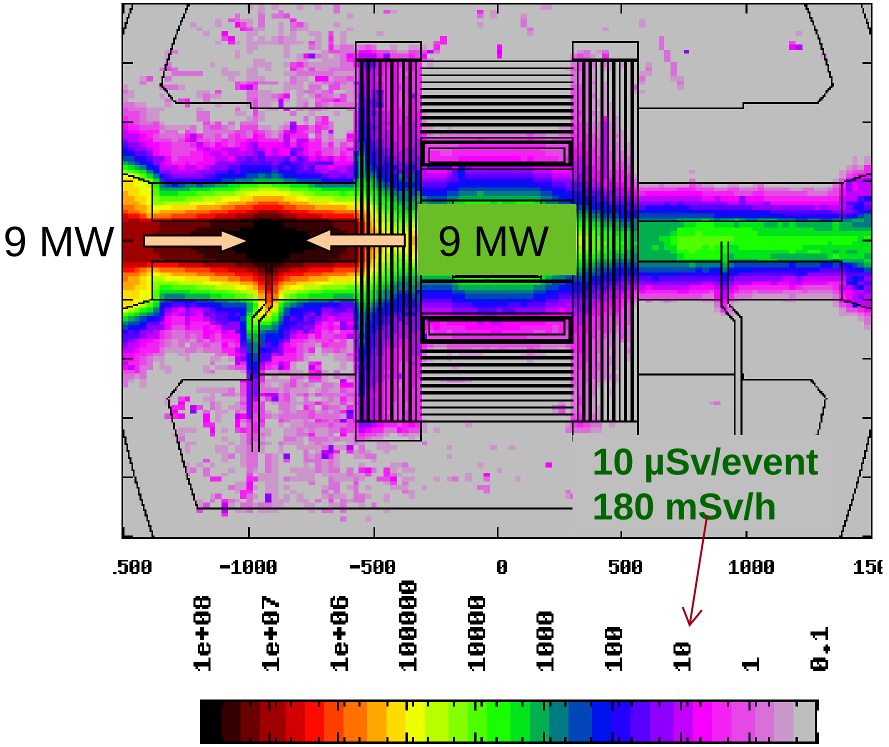


# Self Shielding – Magnetic Field and Radiation

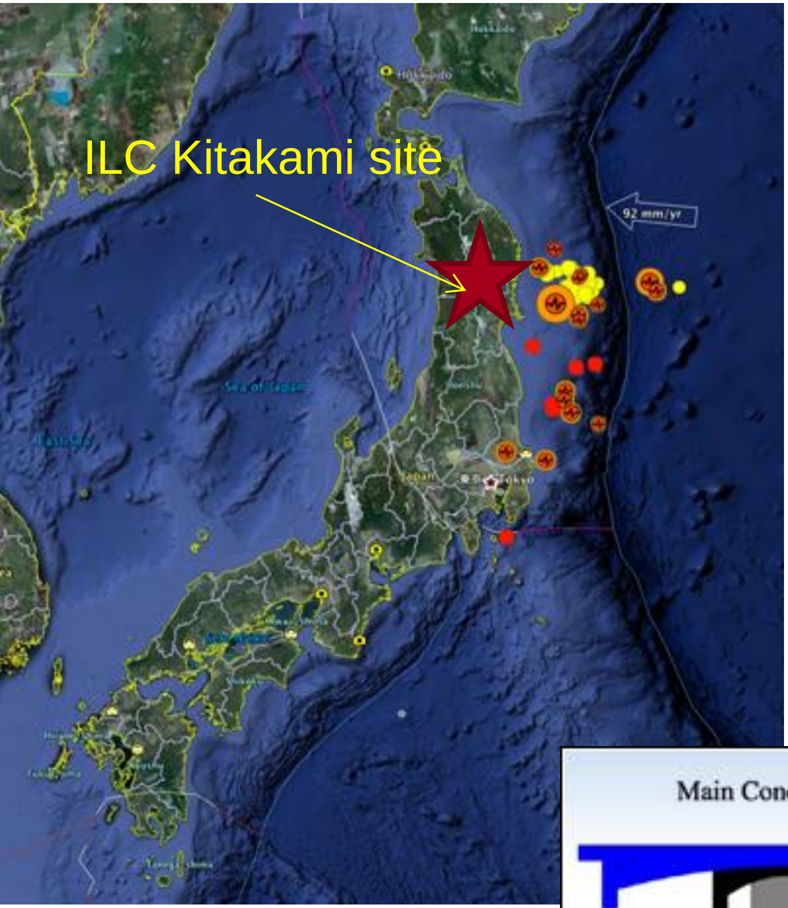
1. Exposure limits to static magnetic field fixed by Local Authorities, 2T head, 8T limbs
2. Max. field set by not requiring special handling for tools ~50 gauss@15 meters
3. Max. radiation exposure, 10uSv/event or 180 mSv/h

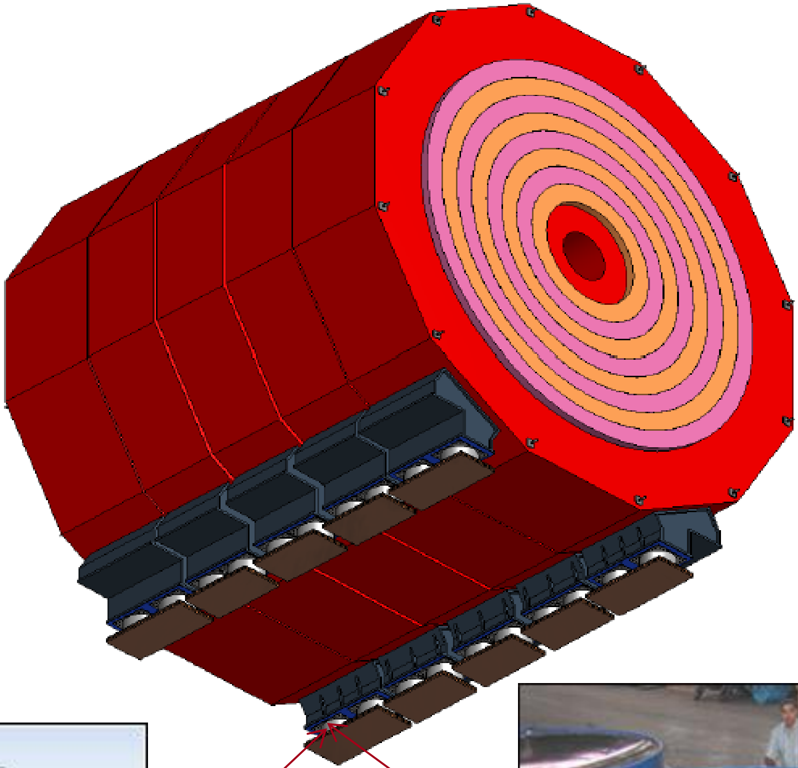


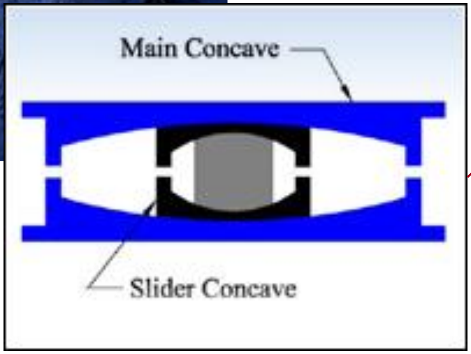

Full Train Beam Loss 9+9 Mw on 20Xo Copper



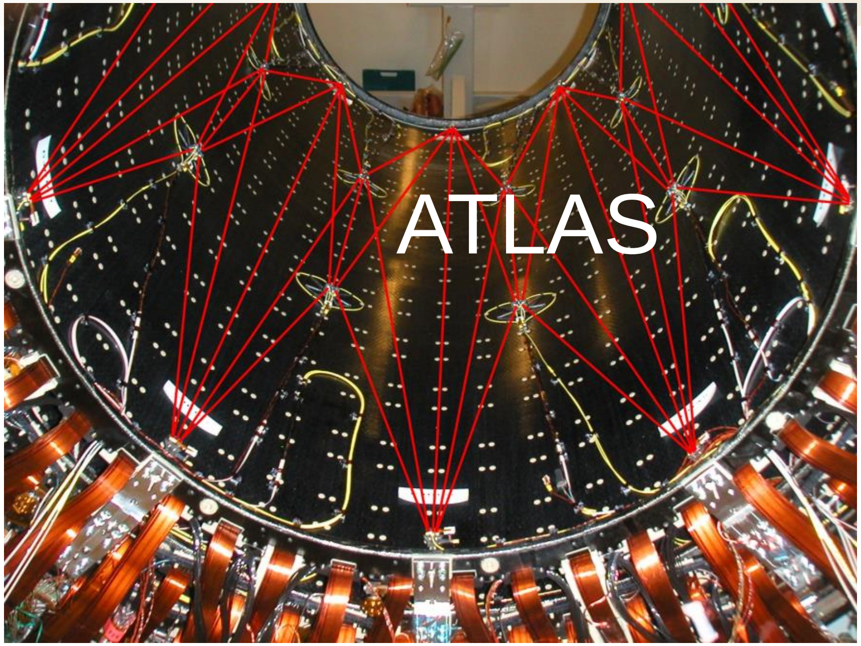
# Detector Seismic isolation- Friction Pendulum

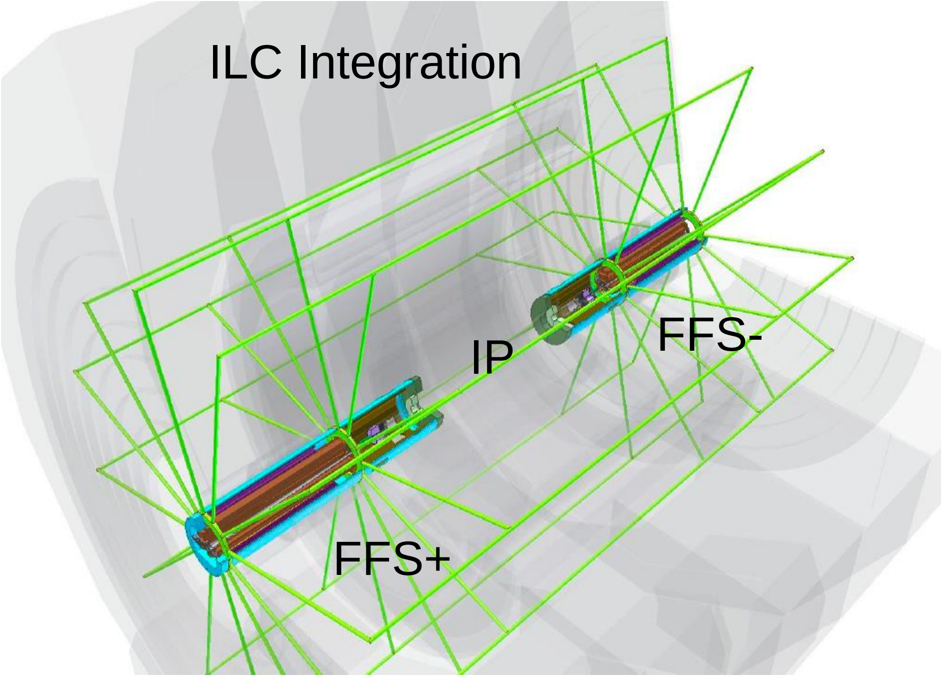





# FSI alignment system, precision ~1um

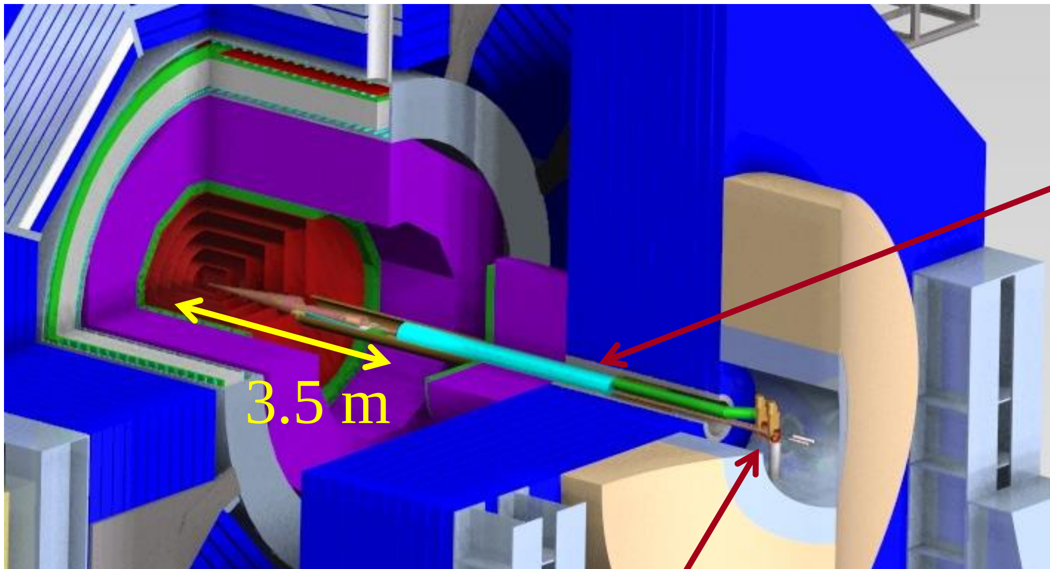


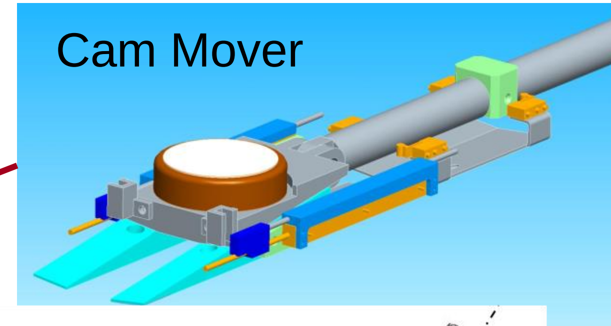





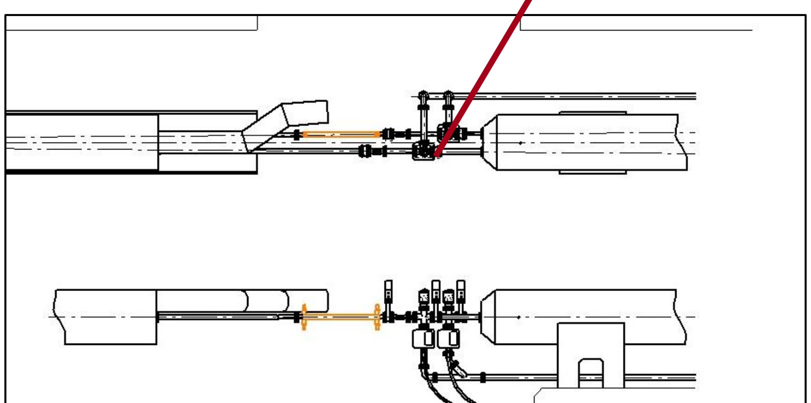
minimal mass high radiation tolerance

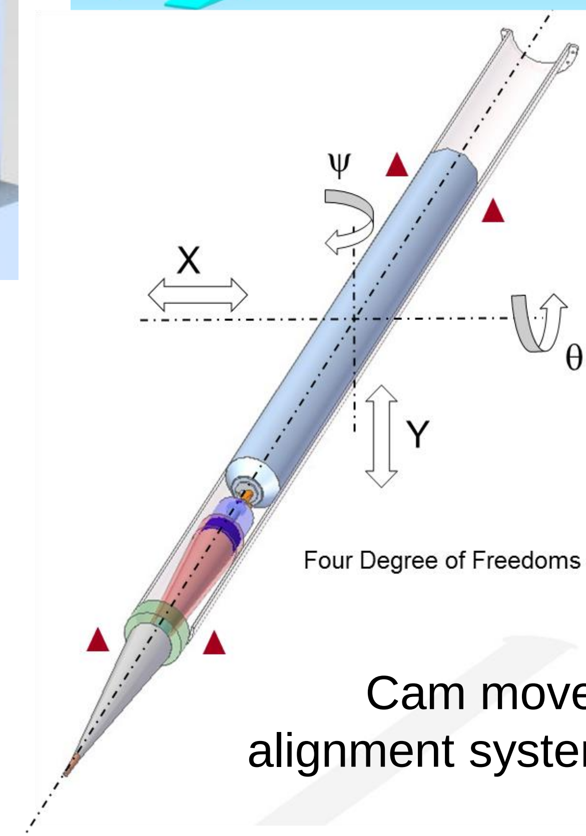
# Final Focus System captured in the detector, short L*




Fast Vacuum Interconnection for the Push-Pull



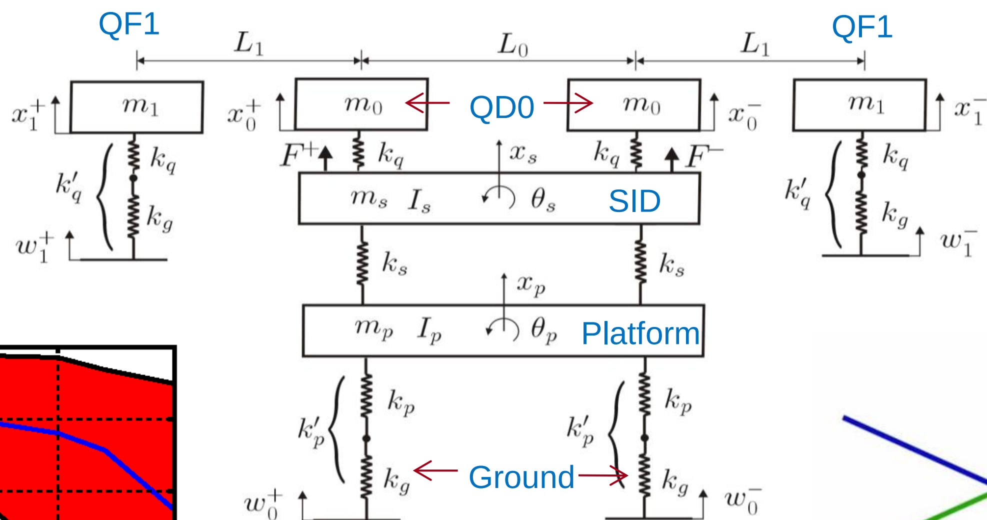


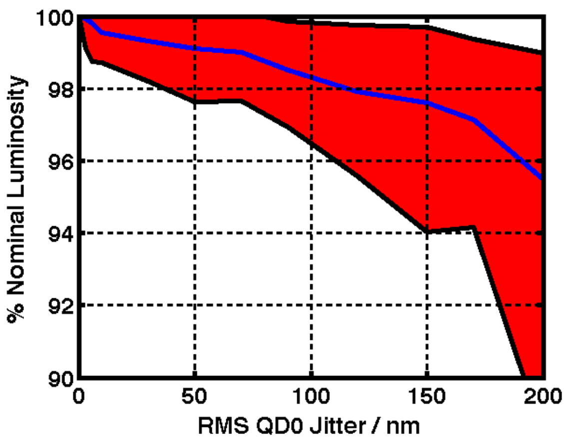

Cam movers
alignment system ~5um

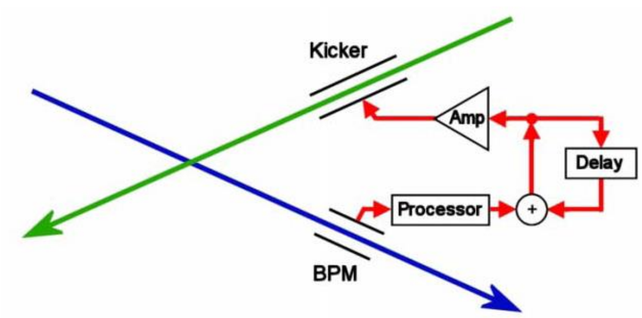
# Luminosity Loss Mechanisms and Feedbacks

Mechanical Vibrations on the final focus system causes Luminosity Loss by the growth of the beam size and Colliding Beams misalignment at IP.

Ground Motion and the noise of the technical systems must be quantified with detailed model and kept under control with specific strategies




IP Feedback System

**Luminosity Loss 1% with 50nm RMS jitter.**

# Kitakami Mountain site
# Moving to a real site (a real project !)

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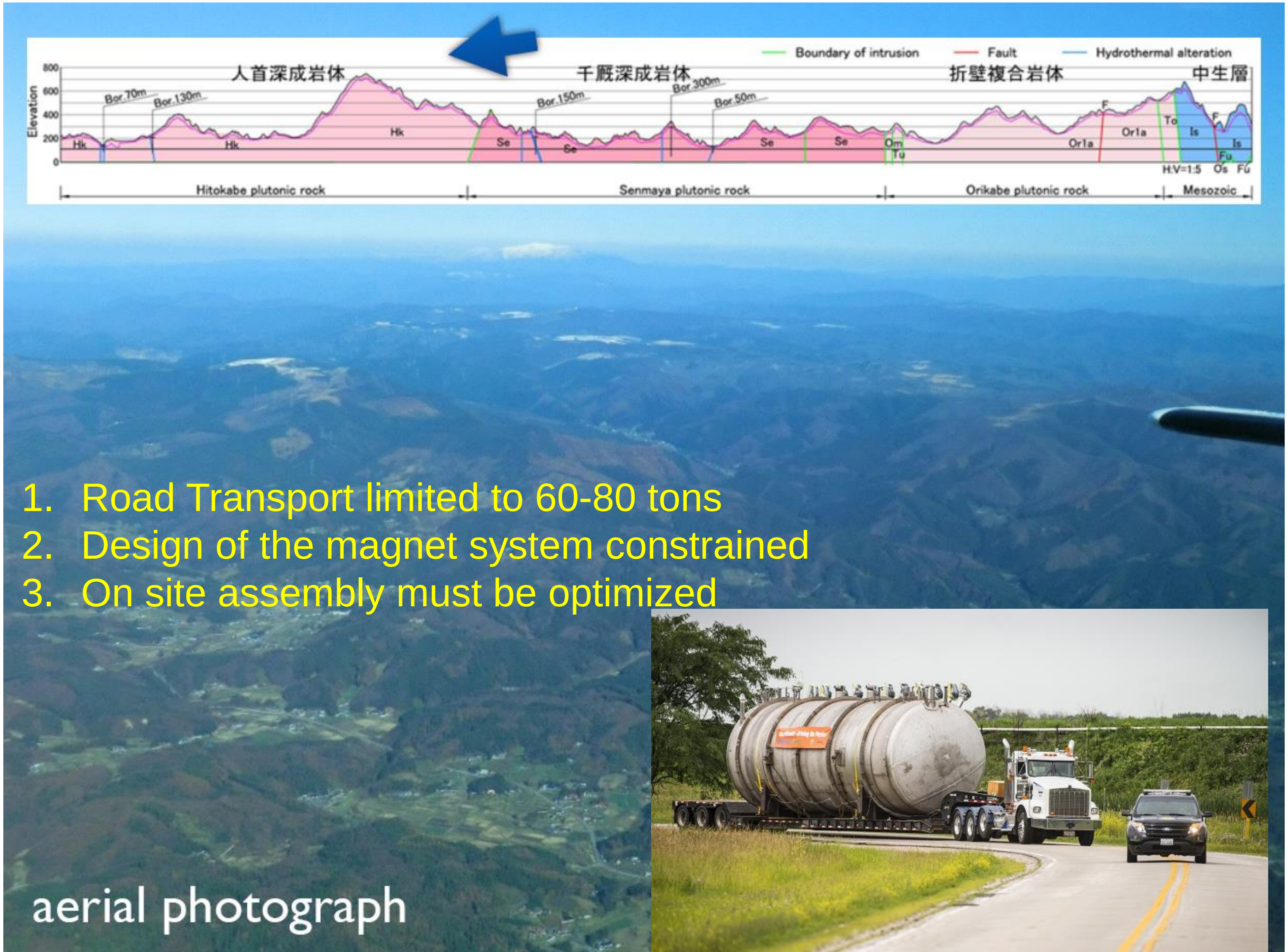


1. Road Transport limited to 60-80 tons
2. Design of the magnet system constrained
3. On site assembly must be optimized

# ILC Site – Detector Hall Access

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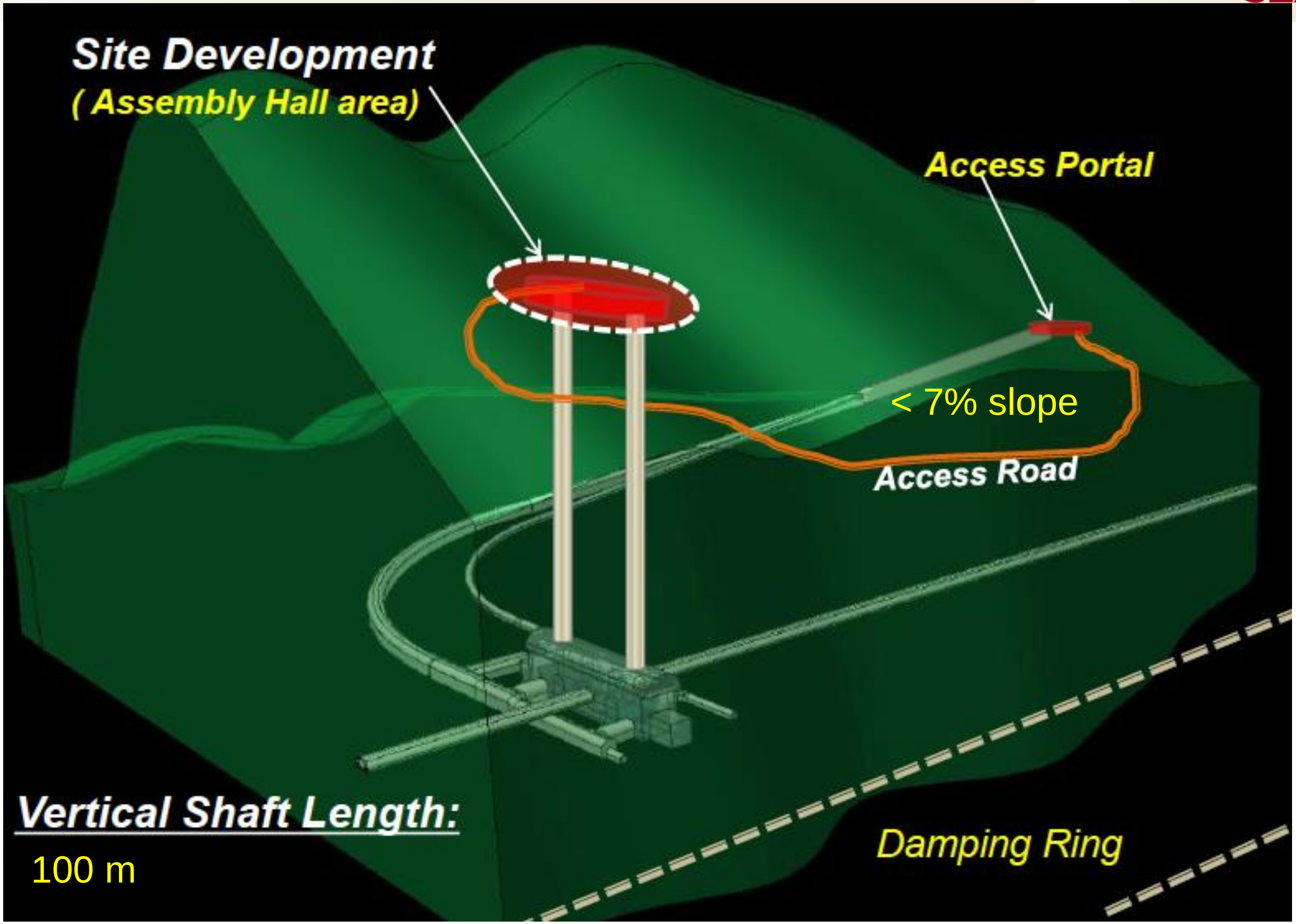
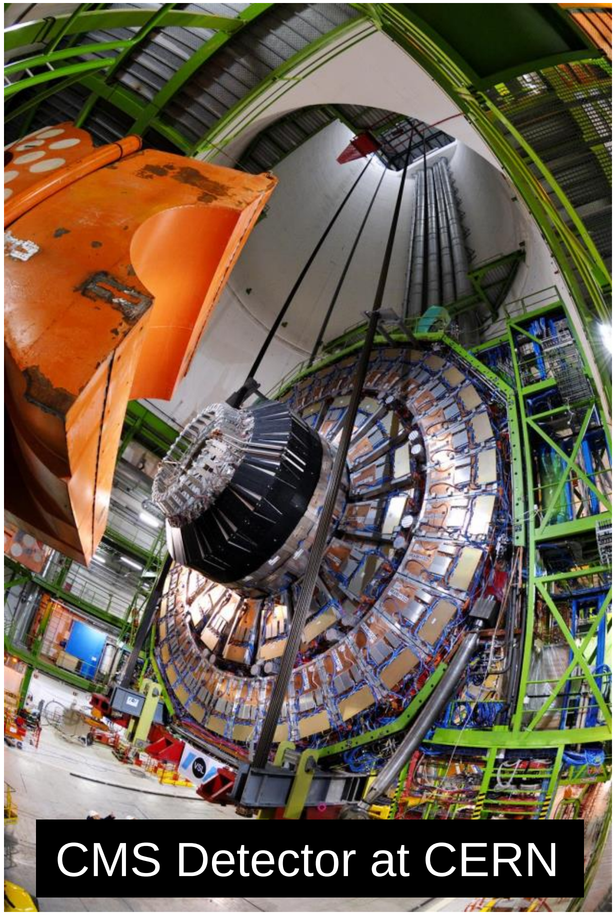


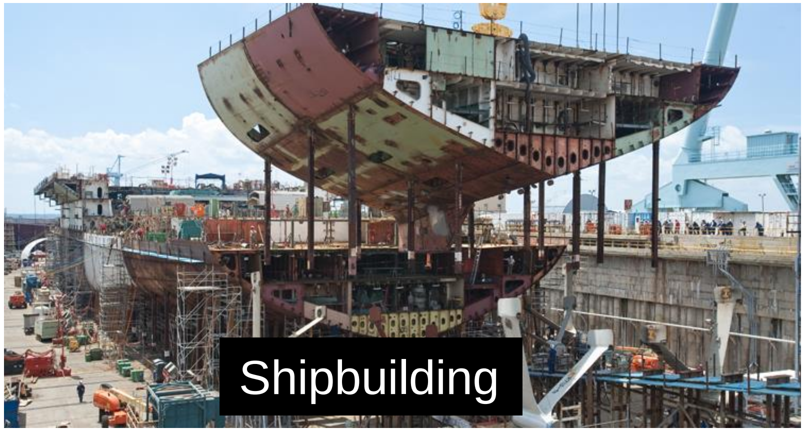
# Optimized On -Site Assembly Procedure:

1. Construction and Testing of large sub-assemblies in  remote sites (Institutes/Factories).
2. Checking after transport and pre-commissioning  on Surface.
3. Complete the construction underground.



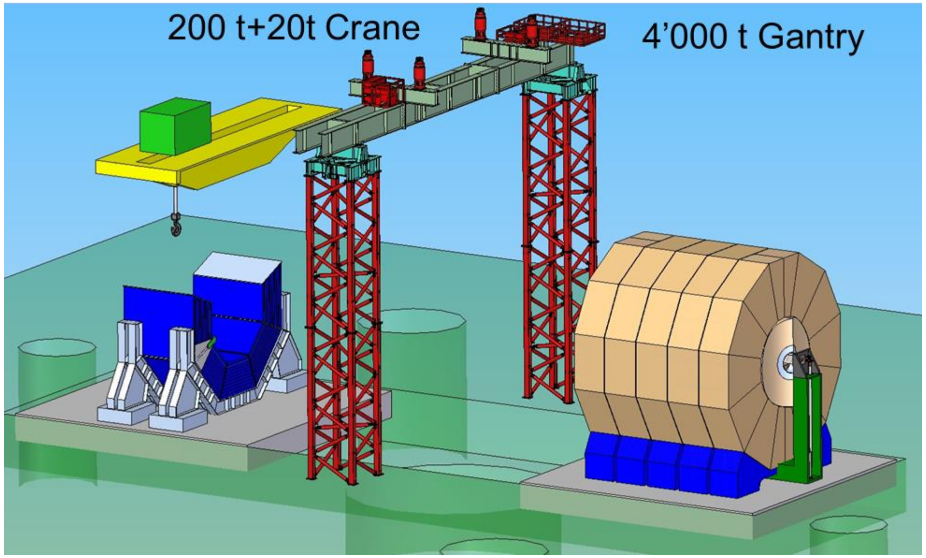
CMS Detector at CERN

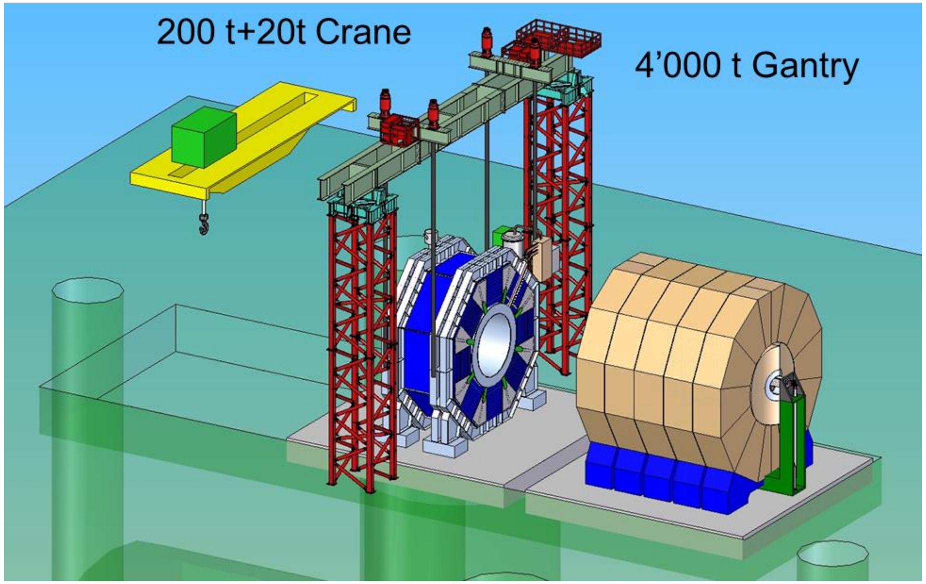

Aerospace

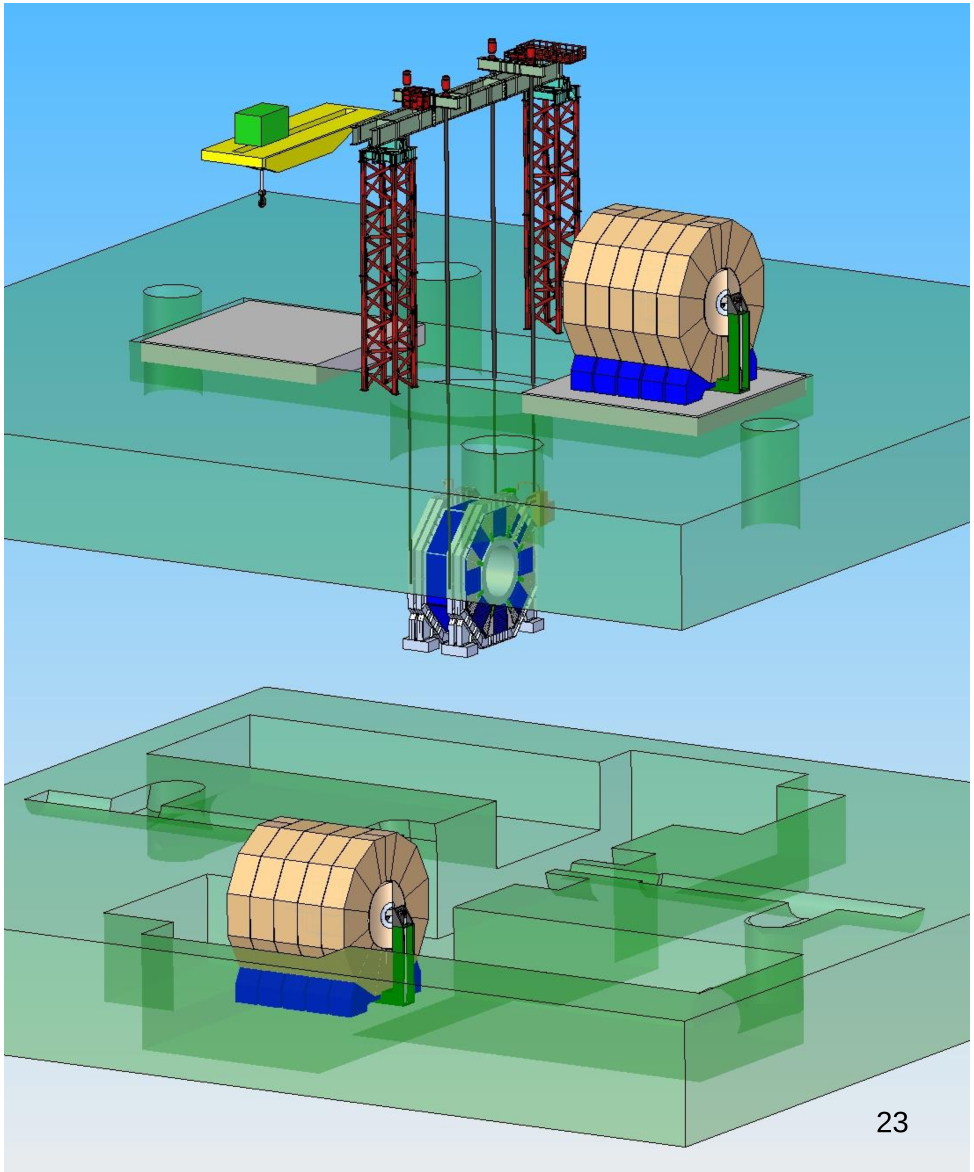


Shipbuilding

# Option #1: Vertical shafts



# Summary

**Sub-Detectors Technology**

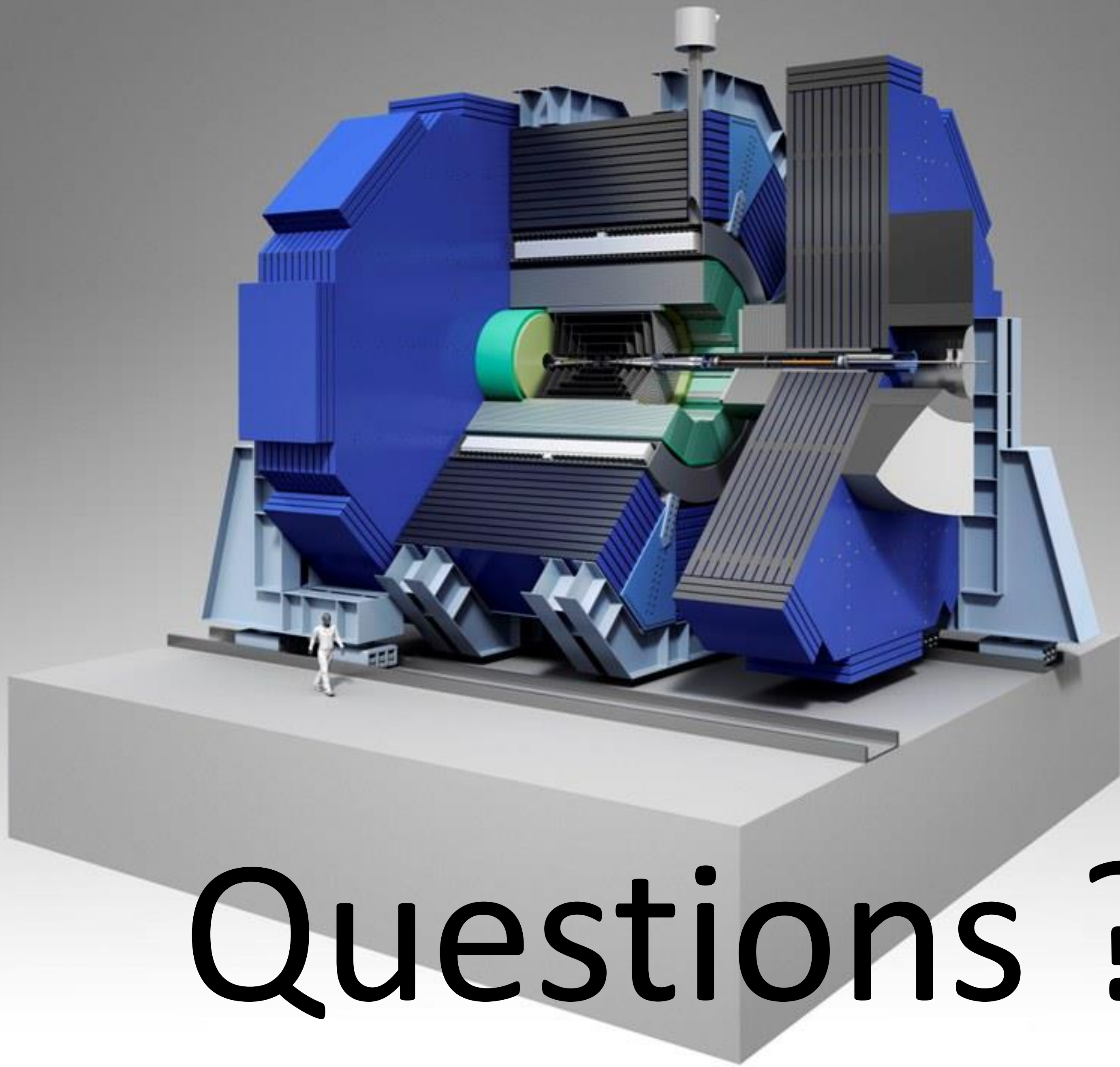
- There is a broad ongoing detector R&D program on the technologies
- Prototyping at level of large subsystems in progress to study the very dense integration and the power pulsing system test.

**Machine Interfaces**

- The Push-Pull of the detectors present unique opportunities but also challenges. First Time !
- Self Shielding rise cost optimization issues for the magnet
- Design and Integration constrained by geographical factors: seismicity and assembly on a mountainous region.

**<u>With the selection of the Kitakami site, ILC is becoming a real project</u>**

…… it is time to join !



# Questions ?

# Spares Slides

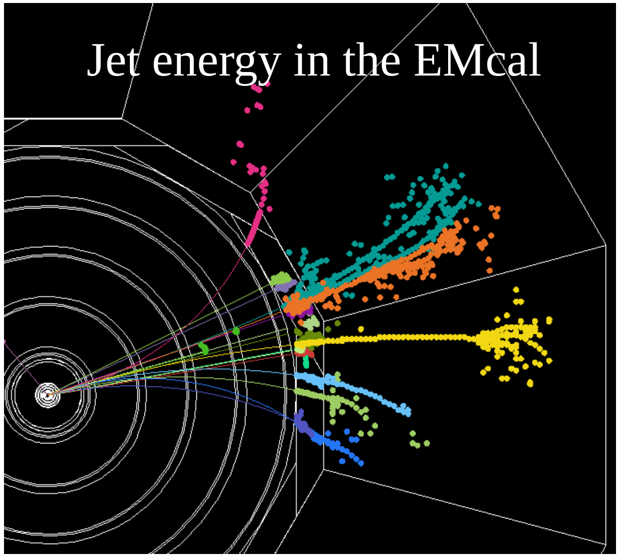
# Calorimetry

SiD EMCAL Tungsten absorber

20+10 layers

20 x 2.5mm (0.64 $X_0$) + 10 x 5mm (1.30 $X_0$ )

Baseline Readout using 5x5 mm$^2$ silicon pads




SiD HCAL Steel Absorber

40 layers, 19 mm

4.5 $\Lambda_i$

Baseline readout 1x1 cm$_2$ RPCs

Contender: 3x3cm$^2$ scintillator w/ SiPM's