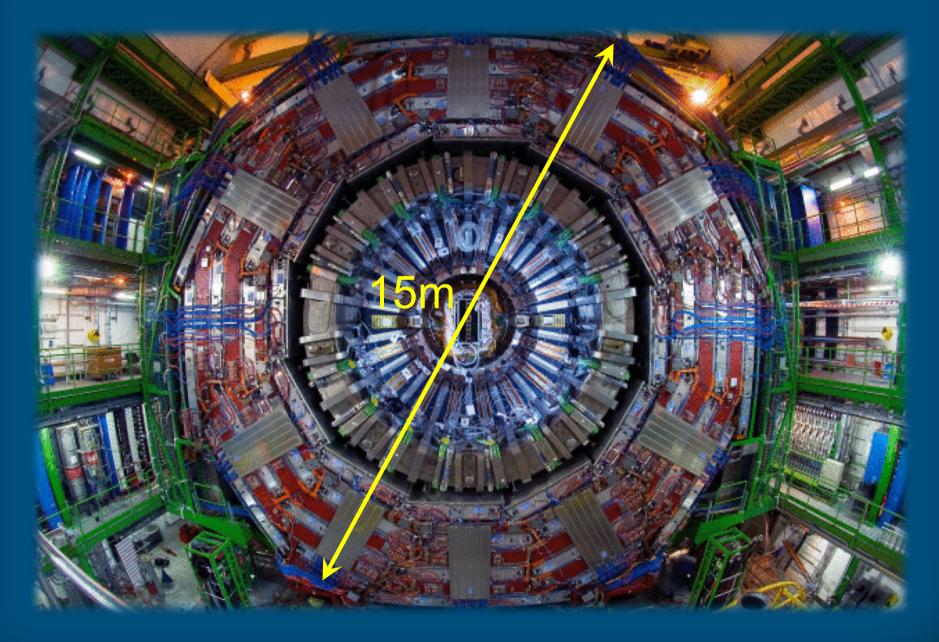


(Some) Future detector needs with focus on R&D

Richard Jacobsson

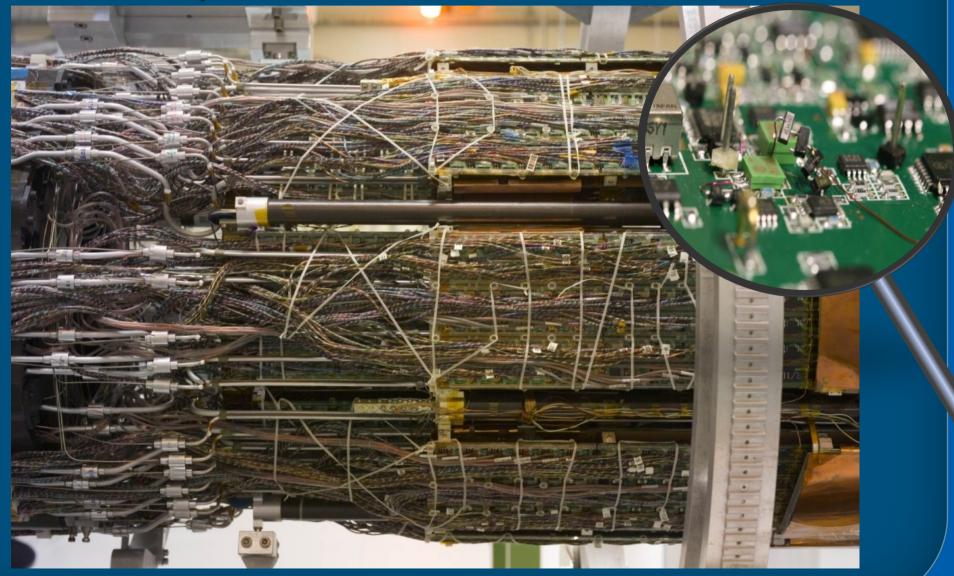
Detector complexity & integration!

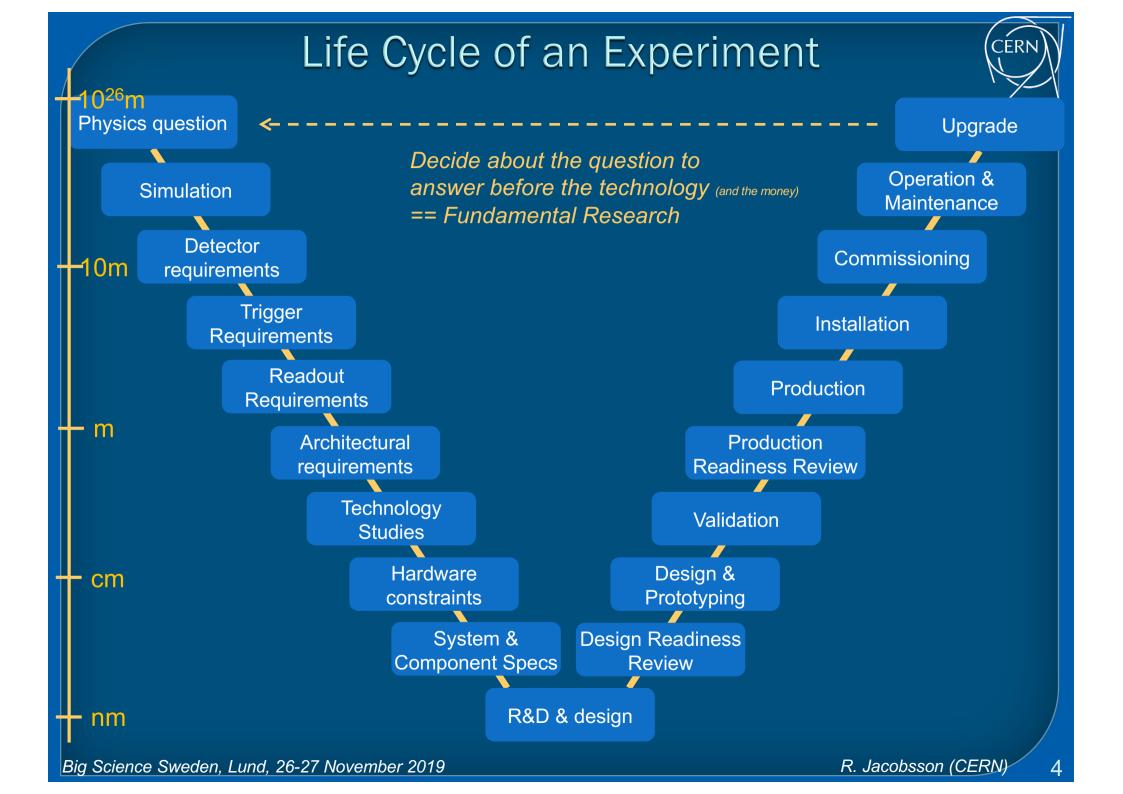


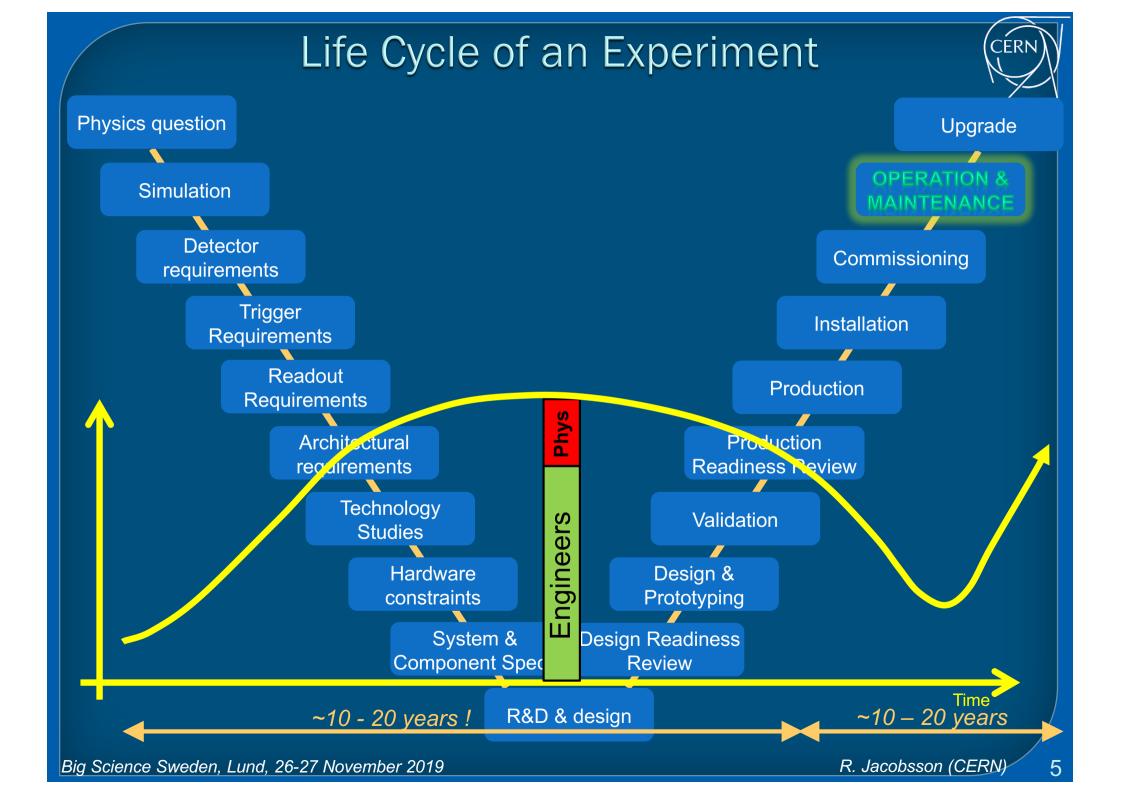


Detector integration!

Design with emphasis on integration, global commissioning, operation, maintenance and evolution





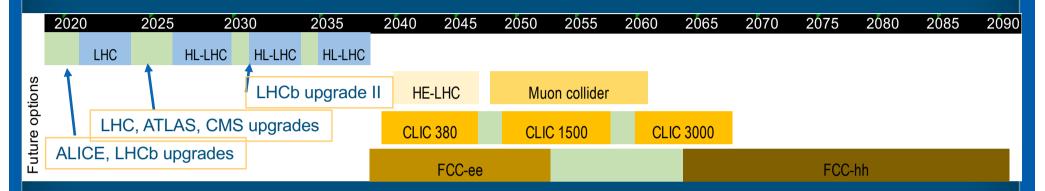


Life Cycle of an Experiment CERN Physics question Upgrade **Operation &** Simulation Maintenance **Detector** Commissioning requirements Industry involvement Trigger Installation Requirements Readout Production Requirements **Architectural** Production requirements Readiness Review **Technology Validation Studies** Hardware Desi n & constraints **Prote typing** System & Design Readiness **Component Specs** Review R&D & design ~10 - 20 years ~10 - 20 years! R. Jacobsson (CERN) Big Science Sweden, Lund, 26-27 November 2019

Future

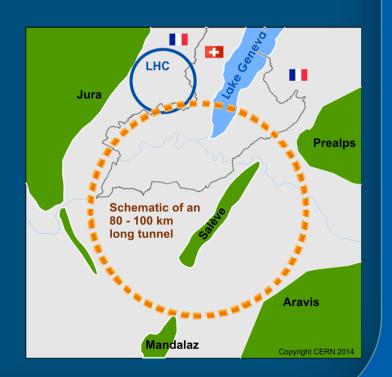


Some possible future scenario (not exhaustive!)



European Strategy for Particle Physics

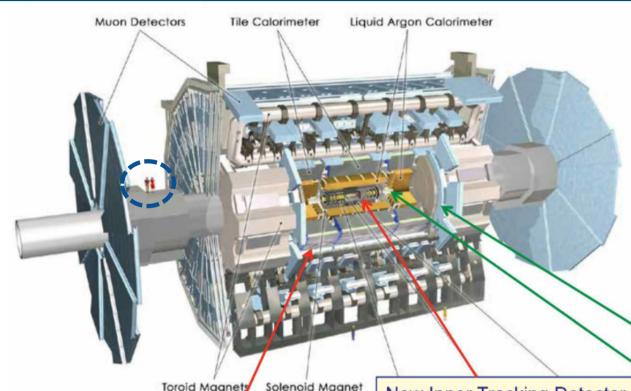
- → European roadmap in the worldwide context of the field
- → Update being prepared 2019 2020



Ex. ATLAS HL-LHC upgrade (2023-2024)



- Upgrade of LHC :meven times higher collision rate than what ATLAS/CMS were designed for
 - → 200 simultaneous proton-proton collisions every 25ns
- New detectors with radiation-hard elements, finer granularity and faster readout.



Upgraded Trigger and Data Acquisition System:

- L0: 1 MHz
- Improved High-Level Trigger

Electronics Upgrade:

- LAr Calorimeter
- Tile Calorimeter
- Muon system

New Inner Tracking Detector (all silicon tracker, up to $|\eta|$ =4)

New muon chambers in the inner barrel region

weiler - Lawrence Berkeley Lab

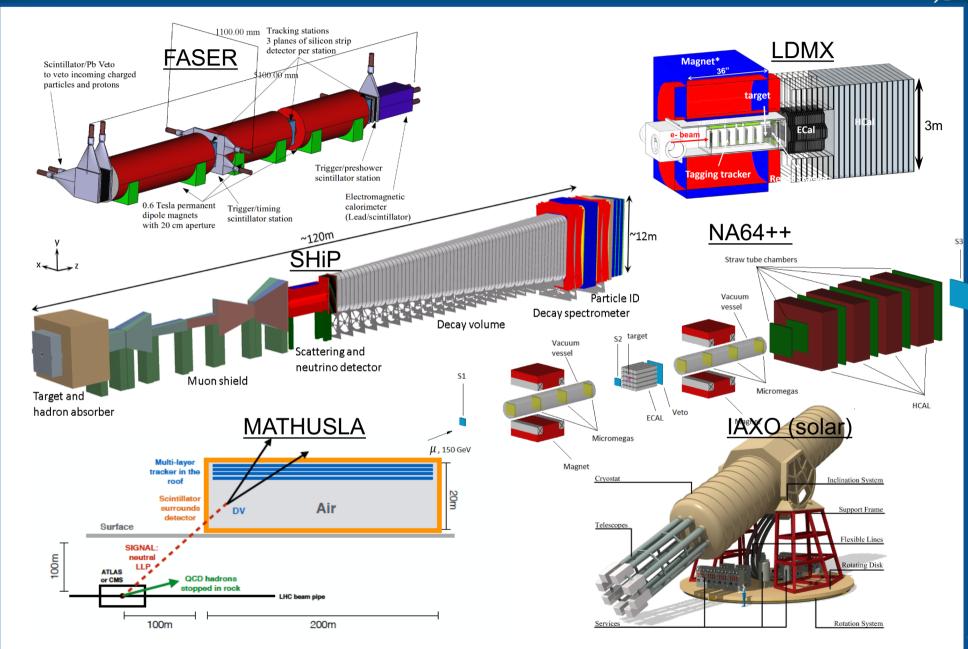
4/23/2018

Options:

- High granularity timing detector (forward region)
- High-η muon tagger
- Forward detectors, incl. luminosity

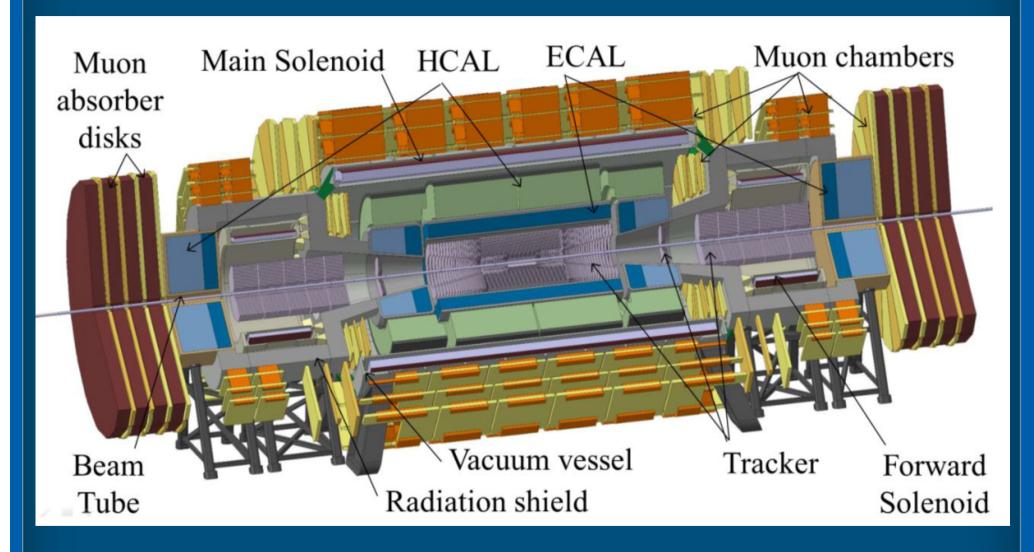
Other experiment proposals on the table





FCC-hh detector (20XX)....





Detector R&D (CERN)



WP1: Silicon Sensors

Novel hybrid pixel detectors Ultimate time/space accuracy and rad hardness Monolithic pixel detectors Cost effective depleted CMOS for ee and hh Simulation and characterization

WP2: Gas Detectors

Solutions for large area gas based detector systems GEMs, µ-megas or µRWELL Industrialisation & performance scaling Tools Novel technologies

Very fast gas

- Gas studies,Simulation and modelling,
- Electronics and instrumentation

WP3: Calorimetry + Light based

LAr Electrodes, σ_{tr} high ionisation rates, feedthroughs

In/organic scint. Tile-cal, hi segm. fibre cal., rad hard

Hi granularity Si

CMS HGCAL + ...

RICH

- Light weight mirrorsLow temp
- Low temp photosensor housing

SciFi

- Fibre light yield
- Fibre production techniques

Advanced scintillators

WP4: Mechanics++

Low mass structures

- Vertex detectors
- Cryostats for calorimetry + magnets

Cooling technologies

- Methods (gas/liquid)
- Coolants (GWP)
- Piping and instrumentation

Interfaces and service architectures

for automated installation and maintenance, in future high radiation environments

WP5: IC Technologies

CMOS

28 nm planar 16 nm FinFET

- Process selection
- Qualification
- Enablers

Assembly Techno

- TSV
- 28 nm on 12" 24/10/20

Design & micro Blocks

- Volt. ref.
- LN amp.
- ADC, DACPLL.DLL.TDC
- ...

Power distribution

- DC-DC POL Conv.
- IP blocks for DC-DC

WP6: High Speed Links

ASICs

- Aggregator /transmitter
- Optoelectronics drivers
- Low-mass electrical cable transmission

Opto-electronics

detectors

production

techniques

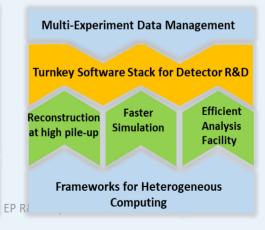
Additive

- Si Phot. system & chip design
- Si Phot. rad hardness
- Next-gen VCSELbased optical link
- Si Phot. packaging

FPGA

FPGA-based system for testing and emulation

WP7: Software



WP8: Exp. Magnets

Reinforced Super Conductors and Cold Masses Ultra-Light Cryostat Studies (with WP4)

Advanced Magnet Powering Magnet Controls, Safety & Instrumentation

Design of a 4 T General Purpose Magnet Facility for Detector Testing

From C. Joram

Detector mechanics

Structure Design
 Ultra lightweight vertex detector structure; large scale composite structures,...

Cooling Design > New system design and coolants, polyimide micro tubes, microchannel 3D print, air cooling, ...

 Carbon materials, carbon nanotube, CVD diamonds, adhesive and composite for high radiation level, ...

> 3D print micro and macro scale, large composite manufacturing and Out of Autoclave curing, ...

High integrated system, low mass CNT power and signal cables, metrology, 3D tomography, ...

Robotic Remote Manipulator System, service Umbilical Mechanism Assembly, alignment and survey, radiation shielding, augmented reality, ...

> High radiation level, vibration and hygro thermo elastic behaviour, monitoring (Fibre Bragg Grating sensors),...

→ Many of which require R&D for development, production and assembly

Key words: Radiation hard, low power, low material, redundant/reliable....

Processes

Materials

- Integration
- Installation and Maintenance

Environment and Stability

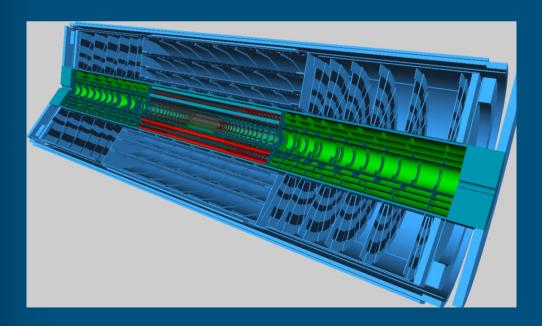
Big Science Sweden, Lund, 26-27 November 2019

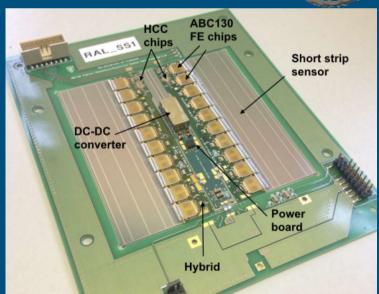
Ex. Silicon sensors and light mechanics



New ATLAS central Tracker: ITk

- More than 100 m² of silicon sensor have to be produced
- ASICs for the detector front-end readout electronics and detector control
- Flex cables, optoelectronics and fibers
- Light and precise mechanical support structure with carbon fibres

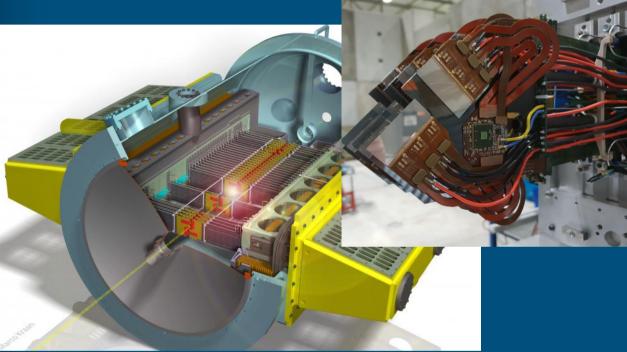




Integrated cooling

Thermal management of detector electronics through ultra-thin micro-structured silicon cooling plates

LHCb Vertex Locator

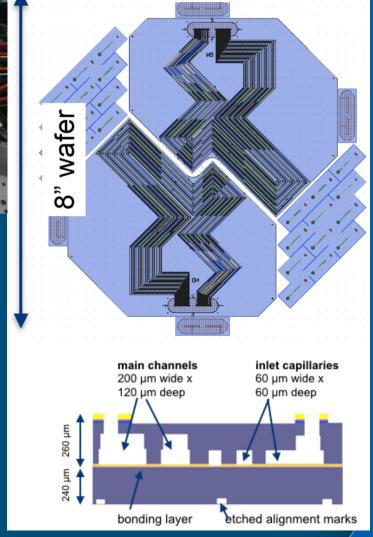


Row of silicon hybrid pixel modules, 5mm from beam Data bandwidth: up to ~15 Gbit/s for central ASICs and 2.9 Tbit/s in total Sensor temperature < -20 $^{\circ}$ C (CO₂ @ -35 $^{\circ}$ C)

400 µm thick silicon substrate 19 parallel micro-channels

- 60 x 60 µm (restrictions)
- 200 x 120 µm (channels)

Pressure up to ~65 bar at room temperature, qualified to 186 bar



Experiment magnets



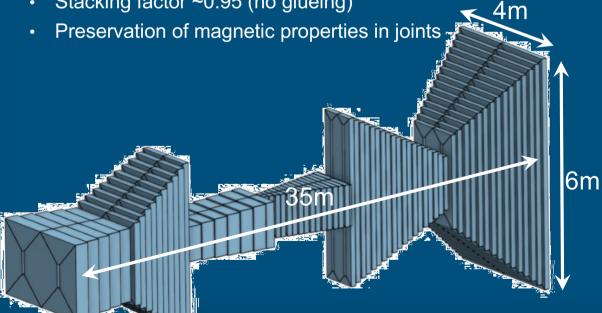
Search for Hidden Particles (SHiP) experiment (Proposal)

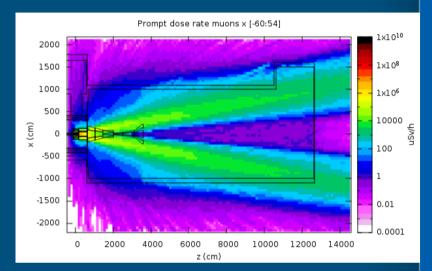
- Construction ~2025 2028
- Magnetic deflector of beam induced muon particles
 - Optimized by Machine Learning
 - → 35m in length and 1500 tonnes of magnetic mass
 - → Complex shapes
 - → Operational assumption: <1.7T>
 - → Use of CRGO steel

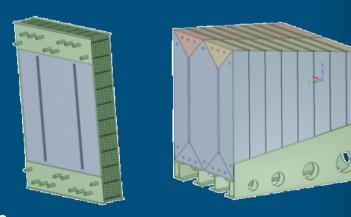
Big Science Sweden, Lund, 20-27 November 2019



Stacking factor ~0.95 (no glueing)







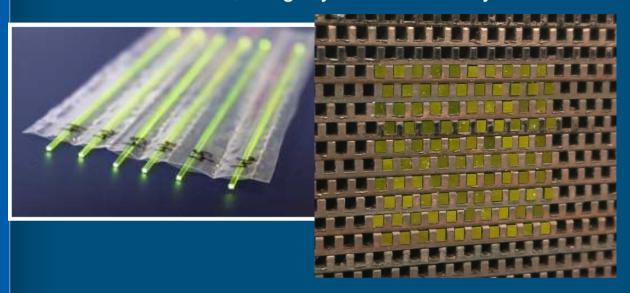
Packs of 50 mm thickness with 150-160 x 0.3mm sheets

Energy measurement detectors

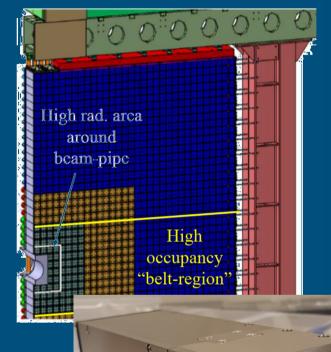


Calorimeter R&D (LHCb, TauFV, future collider experiments):

• Radiation hard, hi-light yield 1x1mm² crystal fibres and tungsten alloy (Pb, Cu) converters



- Up to ~150 modules of 12x12 cm² in 2026
 - → Up to 500 000 fibres ...
 - → 2.5 3 tonnes converter
- Crystal manufacturing (e.g. GAGG)
- → Converter manufacturing from powder metallurgy
- → Photosensors: New: Perovskite structure QD (XIIA2+VIB4+X2-3)
 - E.g. CsPbX₃(X = Cl, Br, I),



Low mass composite cryostats



- Cryostats in HEP are still the purview of metals.
- Need for Ultra Light Weight (ULW) cryostats for both magnets and calorimeters.
- → Organic composite material at low temperatures
 - Carbon Fibre Reinforced Plastic (CFRP)
 - Aluminium-oxide-fibre-reinforced plastics?
 - Ailicon-carbide-fibre-reinforced plastics?
- E.g. Status of CFRP cryo tank for aerospace LH2 and LOX.