HIGHLIGHTS FROM 6TH FCC PHYSICS WORKSHOP

-- MDI PERSPECTIVE --

Manuela Boscolo (INFN-LNF)

MDI meeting #43
zoom, 6 February 2023

https://indico.cern.ch/event/1176398/

6th FCC Physics Workshop Program

23-27 January, Krakow, Poland

https://indico.cern.ch/event/1176398/

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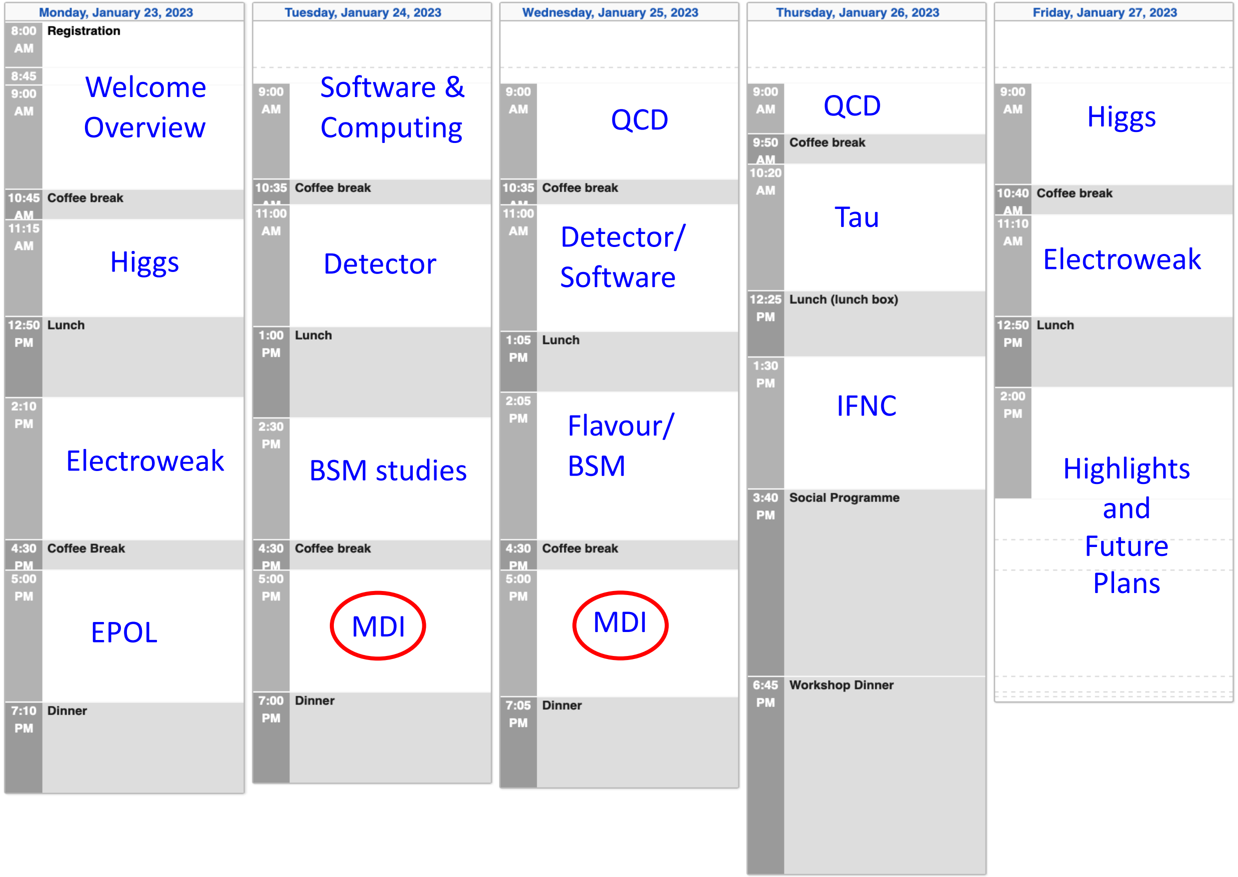

Monday, January 23, 2023
8:00 AM Registration
8:45 9:00 AM Welcome Overview
10:45 AM Coffee break
11:15 AM Higgs
12:50 PM Lunch
2:10 PM Electroweak
4:30 PM Coffee Break
5:00 PM EPOL
7:10 PM Dinner

Tuesday, January 24, 2023
9:00 AM Software & Computing
10:35 AM Coffee break
11:00 AM Detector
1:00 PM Lunch
2:30 PM BSM studies
4:30 PM Coffee break
5:00 PM MDI
7:00 PM Dinner

Wednesday, January 25, 2023
9:00 AM QCD
10:35 AM Coffee break
11:00 AM Detector/ Software
1:05 PM Lunch
2:05 PM Flavour/ BSM
4:30 PM Coffee break
5:00 PM MDI
7:05 PM Dinner

Thursday, January 26, 2023
9:00 AM QCD
9:50 AM Coffee break
10:20 AM Tau
12:25 PM Lunch (lunch box)
1:30 PM IFNC
3:40 PM Social Programme
6:45 PM Workshop Dinner

Friday, January 27, 2023
9:00 AM Higgs
10:40 AM Coffee break
11:10 AM Electroweak
12:50 PM Lunch
2:00 PM Highlights and Future Plans

Agenda MDI sessions

Tuesday 24/1 (MDI/Detector Joint)	
Mechanical model of the FCC-ee MDI	Francesco Fransesini (INFN-LNF)
Detectors integration in the MDI area	Franco Bedeschi (INFN-Pisa)
Status and Perspectives for FCC-ee Detector Backgrounds Studies	Andrea Ciarma (CERN)
FCC-hh detector concept	Anna Zaborowska (CERN)

Wednesday 25/1	
Summary of review for FCC Experimental sites	Mogens Dam (NBI)
Lesson learnt from CMS IR mock-ups	Andrea Gaddi (CERN)
IR beam losses	Andrey Abramov (CERN)
FCC-ee synchrotron radiation collimators and masks	Kevin Andre (CERN)
Detector Stray Magnetic Fields	Nikkie Deelen (CERN)

P. Janot, C. Grojean

Goals of the Workshop

- ❑ Get together in person for the 1st time in three years
  - ◆ 3rd FCC physics workshop: 13-17 Jan 2020
    - In person at CERN
  - ◆ 4th FCC physics workshop : 10-13 Nov 2020
    - Remote only
  - ◆ 5th FCC physics workshop : 7-11 Feb 2022
    - Foreseen to be in person (Liverpool), became remote only
  - ◆ 6th FCC physics workshop: 23-27 Jan 2023
    - In person in Krakow
      - ➔ First in-person physics workshop in the FCC FS era
    - 190 participants – of which 75-80 in person
- ❑ Strengthen the Physics/Experiments/Detector community
  - ◆ Share experience with newcomers
  - ◆ Synergy with Snowmass and ECFA Workshops

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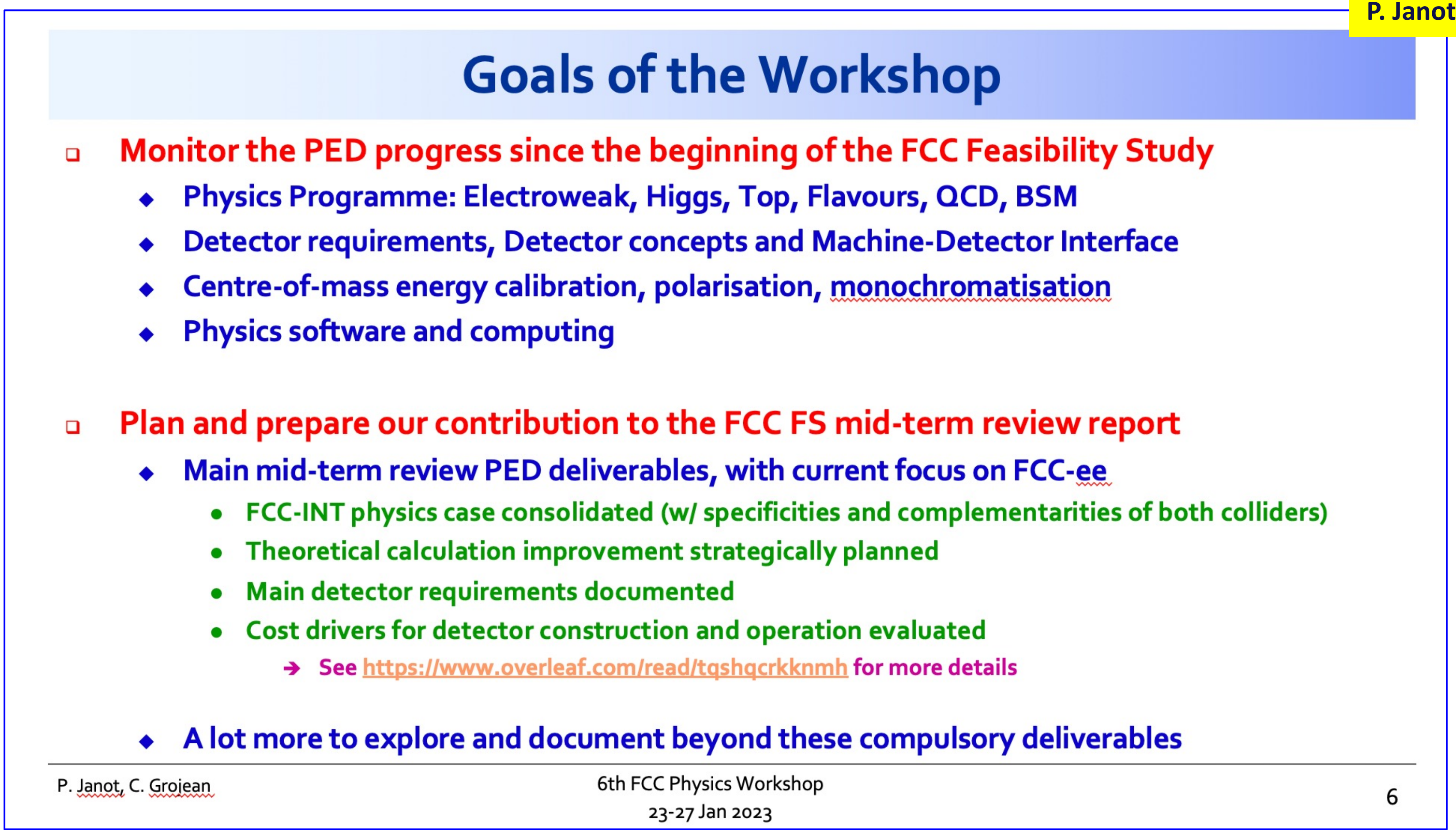

Goals of the Workshop

- **Monitor the PED progress since the beginning of the FCC Feasibility Study**
  - **Physics Programme: Electroweak, Higgs, Top, Flavours, QCD, BSM**
  - **Detector requirements, Detector concepts and Machine-Detector Interface**
  - **Centre-of-mass energy calibration, polarisation, monochromatisation**
  - **Physics software and computing**

- **Plan and prepare our contribution to the FCC FS mid-term review report**
  - **Main mid-term review PED deliverables, with current focus on FCC-ee**
    - **FCC-INT physics case consolidated (w/ specificities and complementarities of both colliders)**
    - **Theoretical calculation improvement strategically planned**
    - **Main detector requirements documented**
    - **Cost drivers for detector construction and operation evaluated**
      - ➔ **See https://www.overleaf.com/read/tqshqcrkknmh for more details**
  - **A lot more to explore and document beyond these compulsory deliverables**

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6th FCC Physics Workshop
23-27 Jan 2023

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P. Janot, C. Grojean

Goals of the Workshop

- A lot more to explore : preliminary to-do list - to be amended and completed
  - Document the (physics) arguments for having 2 or 4 interaction regions
    - Includes carbon footprint, plus all arguments we developed a couple years ago
  - Requirements from detectors on experimental sites
    - e.g, position of the booster, need of a secondary cavern, services, etc.
  - Cost drivers and estimates for detectors
  - Required detector R&D
  - Common software framework and computing infrastructure
    - E.g., plug-and-play, analysis framework, etc.
  - International community building
    - With, in particular, the Informal Forum of National Contacts (IFNC)
  - FCC-hh detector concept
  - Etc.
- To be amended and completed during this and the next workshops

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6th FCC Physics Workshop
23-27 Jan 2023

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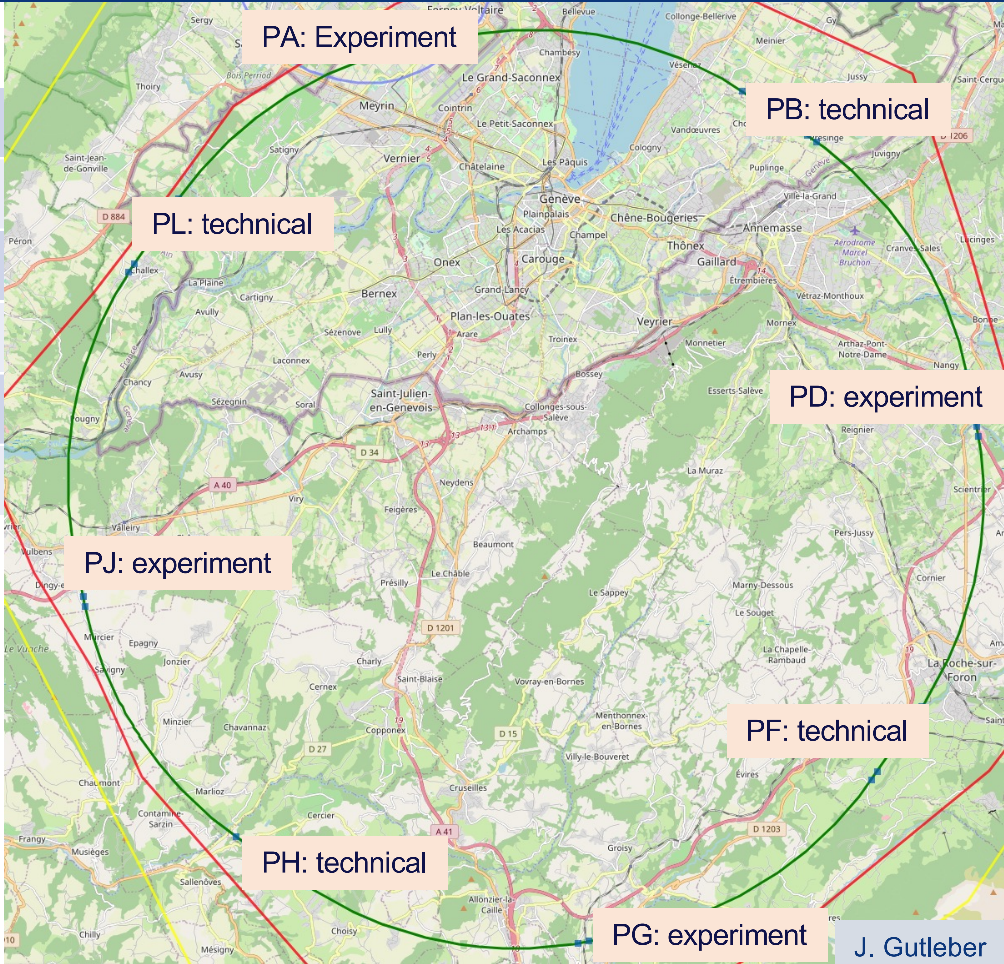
optimized placement and layout

8-site baseline "PA31-3.0"

Number of surface sites	8
LSS@IP (PA, PD, PG, PJ)	1400 m
LSS@TECH (PB, PF, PH, PL)	2032 m
Arc length	9.6 km
Sum of arc lengths	76.9 m
Total length	**90.6 km**

- 8 sites – less use of land, <40 ha instead 62 ha
- Possibility for 4 experiment sites in FCC-ee
- All sites close to road infrastructures (< 5 km of new road constructions for all sites)
- Vicinity of several sites to 400 kV grid lines
- Good road connection of PD, PF, PG, PH suggest operation pole around Annecy/LAPP
- **Exchanges with ~40 local communes in preparation**



J. Gutleber

Review of CE and TI requirements for FCC experimental sites

Reviewers: Austin Ball (STFC), Alain Chabert (SFTRF), Peter Krizan (Jozef Stefan Institute), Rolf Lindner (CERN), Andrew Parker (University of Cambridge – Chairperson), Roberto Tenchini (INFN Sezione di Pisa), Frank Zimmermann (CERN – Secretary)

- endorses the baseline concept for the FCC experiment site underground structures of an experimental cavern with a single experimental shaft for the main detector, linked via a transfer tunnel to the service cavern, with a second shaft (cf. CMS),
- suggests detailed study of implications of the stray field from unshielded FCC-hh detector magnets and to consider alternatives with shielded magnet systems.

Mid-Term Review & Cost Review, autumn '23

M. Benedikt, FCC FS Status

Mid-term review report, supported by additional documentation on each deliverable, will be submitted to review committees and to Council and its subordinate bodies, as input for the review.

Results of both general mid-term review and the cost review should indicate the main directions and areas of attention for the second part of the Feasibility Study

Infrastructure & placement

- Preferred placement and progress with host states (territorial matters, initial states, dialogue, etc.)
- Updated civil engineering design (layout, cost, excavation)
- Preparations for site investigations

Technical Infrastructure

- Requirements on large technical infrastructure systems
- System designs, layouts, resource needs, cost estimates

Accelerator design FCC-ee and FCC-hh

- FCC-ee overall layout with injector
- Impact of operation sequence: Z, W, ZH, $t\bar{t}$ vs start at ZH
- Comparison of the SPS as pre-booster with a 10-20 GeV linac
- Key technologies and status of technology R&D program
- FCC-hh overall layout & injection lines from LHC and SC-SPS

Physics, experiments, detectors:

- Documentation of FCC-ee and FCC-hh physics cases
- Plans for improved theoretical calculations to reduce theoretical uncertainties towards matching FCC-ee statistical precision for the most important measurements.
- First documentation of main detector requirements to fully exploit the FCC-ee physics opportunities

Organisation and financing:

- Overall cost estimate & spending profile for stage 1 project

Environmental impact, socio-economic impact:

- Initial state analysis, carbon footprint, management of excavated materials, etc.
- Socio-economic impact and sustainability studies

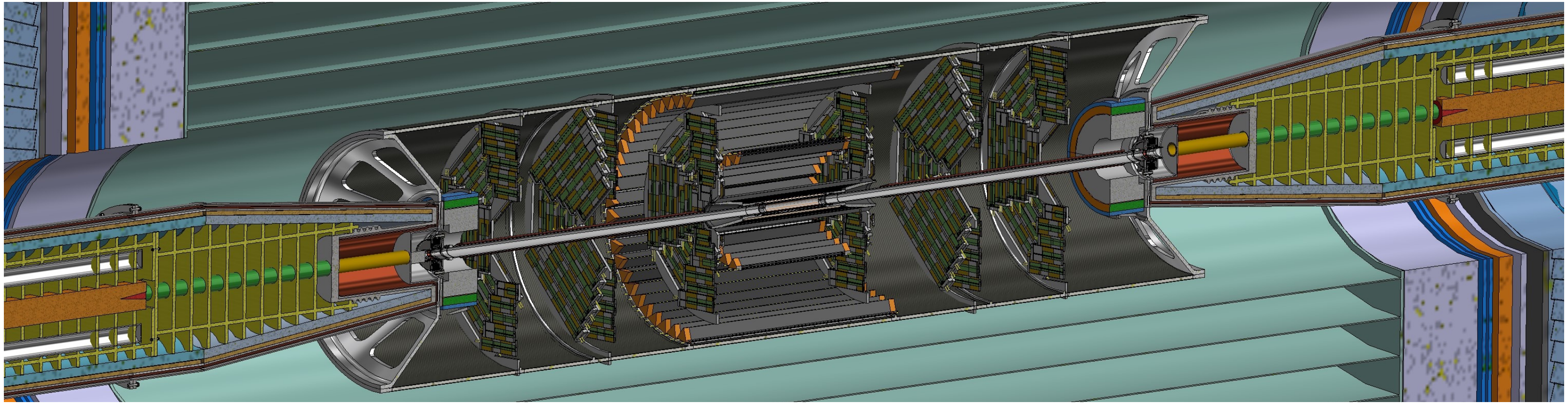
Next Steps - Mechanical model of the FCC-ee MDI

- **Integration of the support tube with the detector**
  Anchoring points with the detector
  Required space for services

- **Design of the Bellows**
  Wakefields calculations
  Engineered design of endcap-bellows & flange-bellows interface

- **Support and alignment of the LumiCal**
- **Cryostat-Support tube interface**
- Refine **FEA calculation with weights and thermal loads**

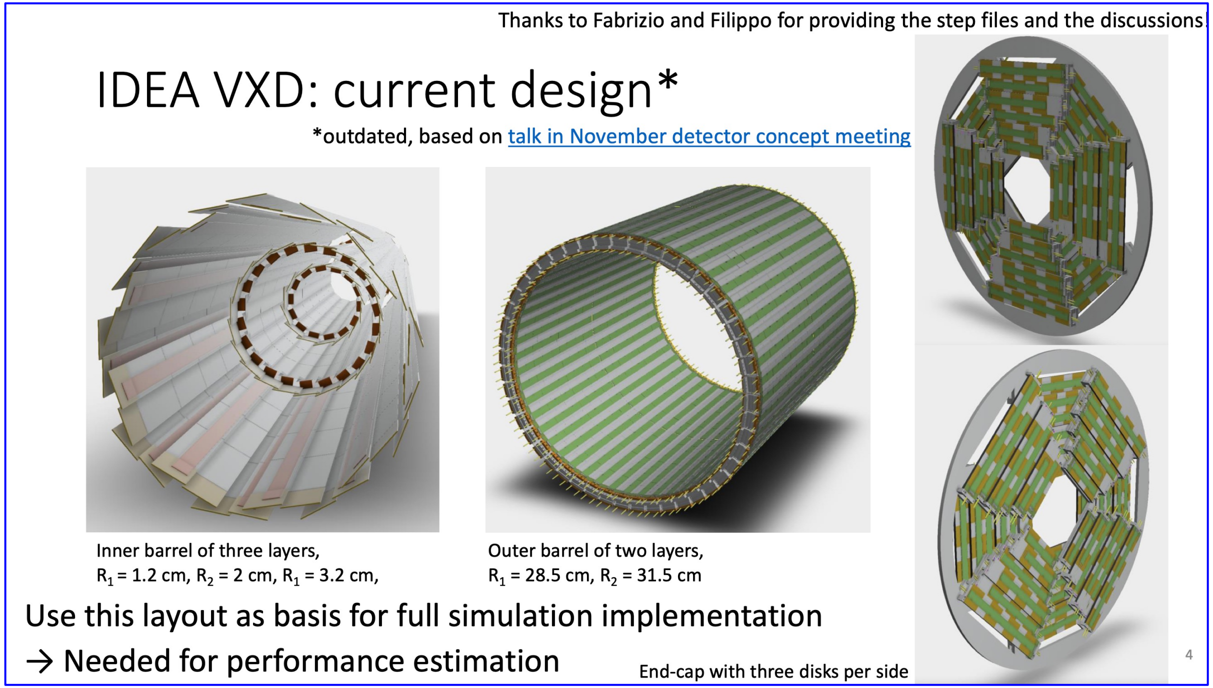
- Refine the **assembly procedure** while the MDI design progresses



IDEA vertex detector in full simulation

Talk: Armin Ilg (Univ. Zurich)

First full sim implementation in DD4hep



Thanks to Fabrizio and Filippo for providing the step files and the discussions!

IDEA VXD: current design*

*outdated, based on talk in November detector concept meeting

Inner barrel of three layers,
R_1 = 1.2 cm, R_2 = 2 cm, R_1 = 3.2 cm,

Outer barrel of two layers,
R_1 = 28.5 cm, R_2 = 31.5 cm

End-cap with three disks per side

Use this layout as basis for full simulation implementation
→ Needed for performance estimation

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Working together to update the software with the evolving design

CLD fullSim vertex endcaps

Future plans: mechanical model of the MDI

The very central region ±1.5 m from the IP is being studied including the integration of the vertex and outer trackers, we will progress outside the very central region and with the overall design, assembly strategy, supports

Also the following topics relevant/critical for the design of the IR

- Remote flange design based on shape-memory-alloy (SMA) will start in the next months
- IR magnets design, key component for the MDI – dedicated slide later
- IP diagnostics, especially for the constraint to the available space, BPMs – need discussion with BI group
- Supports & vibration control
- Alignment system

IR magnet system

- **Progress on the overall IR magnets design including solenoids and correctors is essential to progress with the overall mechanical design, integration and assembly of the MDI.**

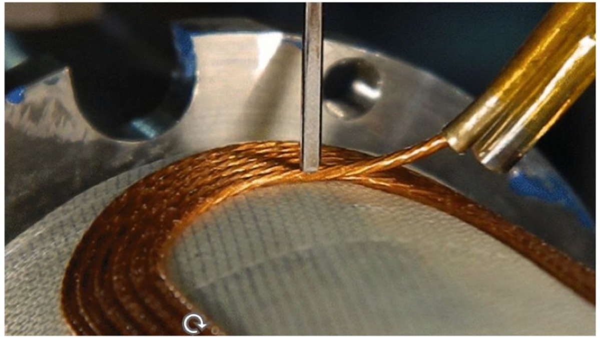
- Review April 2022 on IR magnets design with cryostat, challenges identified - tapering, corrector design, accessibility and serviceability- **we need to move to the next level of the design.** There are pending details on the mechanical support, cryogenics, thermal heat loads, alignment, services which need resourcing to move forward.
- TE Magnet group identified two main work packages as potential collaboration to be discussed with FCC.
  - IR final focus magnets with solenoids, interest of BNL to collaborate, collaboration CERN-BNL under discussion.
  - Crab high field sextupole on FCC-ee are under evaluation for conduction cooled options, optics sensitivity requested and magnetic design. Resourcing subject to pending collaboration with TE.

Marc-André Pleier, BNL contributions to the FCC-ee

Interaction Region magnet design

BNL's Superconducting Magnet Division involved in areas of Interaction Region magnet design and Machine Detector Interface

- BNL Direct Wind magnet production technology suitable for producing the main IR quadrupoles
    - only practical way to introduce FCC-ee IR corrector magnets
    - significant design challenges to resolve for implementing the required anti-solenoid coils for detector field compensation while maintaining the desired experimental acceptance
- Enhance collaboration with the FCC-ee IR design team



BNL Direct Wind in Action Closeup View

Starring:
Brett Parker

Brookhaven National Laboratory

Marc-André Pleier, BNL contributions to the FCC-ee

Conclusion

- BNL has excellent synergies in physics, accelerators and detectors in support of high energy physics
- Excited to deepen BNL's contribution to FCC-ee
- Building FCC-ee community in the US

Brookhaven National Laboratory

Brookhaven National Laboratory

FIRST ANNUAL U.S.

FUTURE CIRCULAR COLLIDER WORKSHOP

BROOKHAVEN NATIONAL LABORATORY

APRIL 24-26, 2023, UPTON, NY

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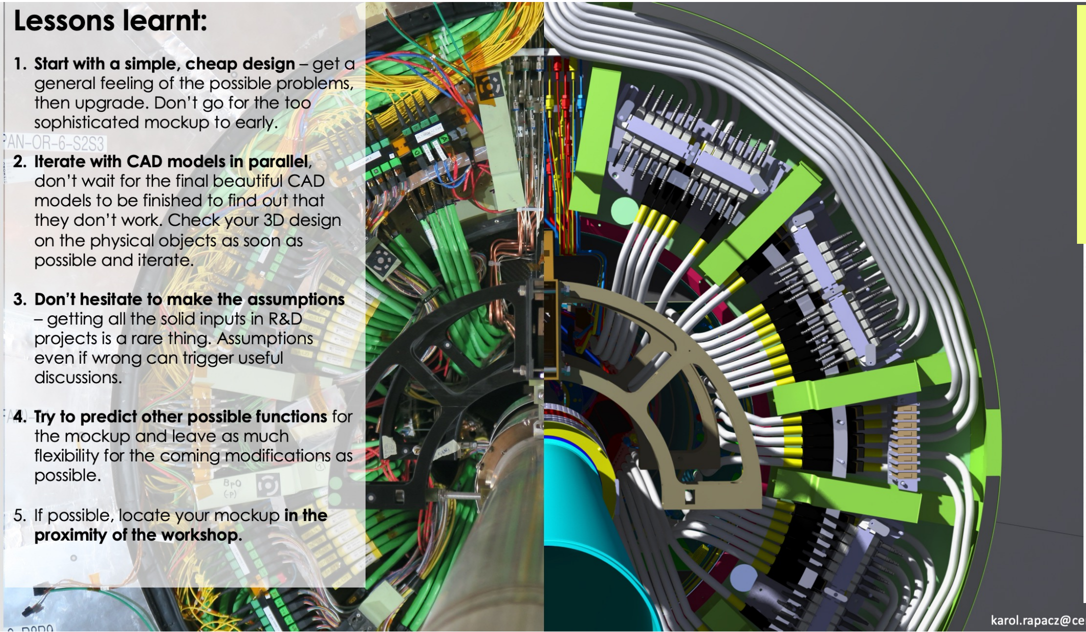
Starring:
The US community
& international partners

FCC-ee IR mock-up at Frascati

Very useful to learn from other experiences of similar R&D activity, e.g. CMS, CLIC.

We propose to add to the CAD model of the MDI a complementary R&D activity consisting in a full-scale IR mock-up to be realised at Frascati.

A project proposal is under evaluation by INFN and details of **scope, cost and timeline** under discussion with CERN. We need to conclude with FCC addendum.



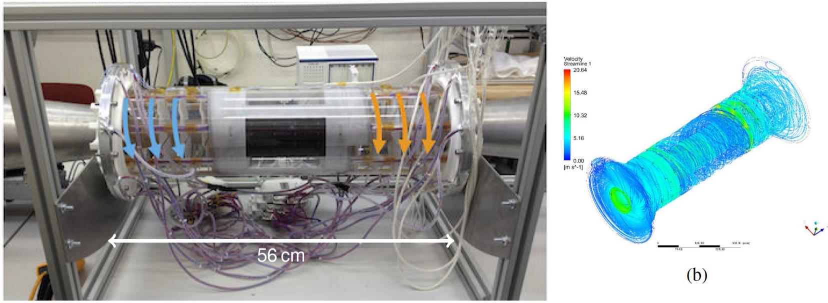
Lessons learnt:

1. **Start with a simple, cheap design** – get a general feeling of the possible problems, then upgrade. Don't go for the too sophisticated mockup to early.
2. **Iterate with CAD models in parallel**, don't wait for the final beautiful CAD models to be finished to find out that they don't work. Check your 3D design on the physical objects as soon as possible and iterate.
3. **Don't hesitate to make the assumptions** – getting all the solid inputs in R&D projects is a rare thing. Assumptions even if wrong can trigger useful discussions.
4. **Try to predict other possible functions** for the mockup and leave as much flexibility for the coming modifications as possible.
5. If possible, locate your mockup **in the proximity of the workshop.**

karol.rapacz@cern.ch

Lessons Learnt from CMS Mock-ups
link talk Andrea Gaddi(CERN)

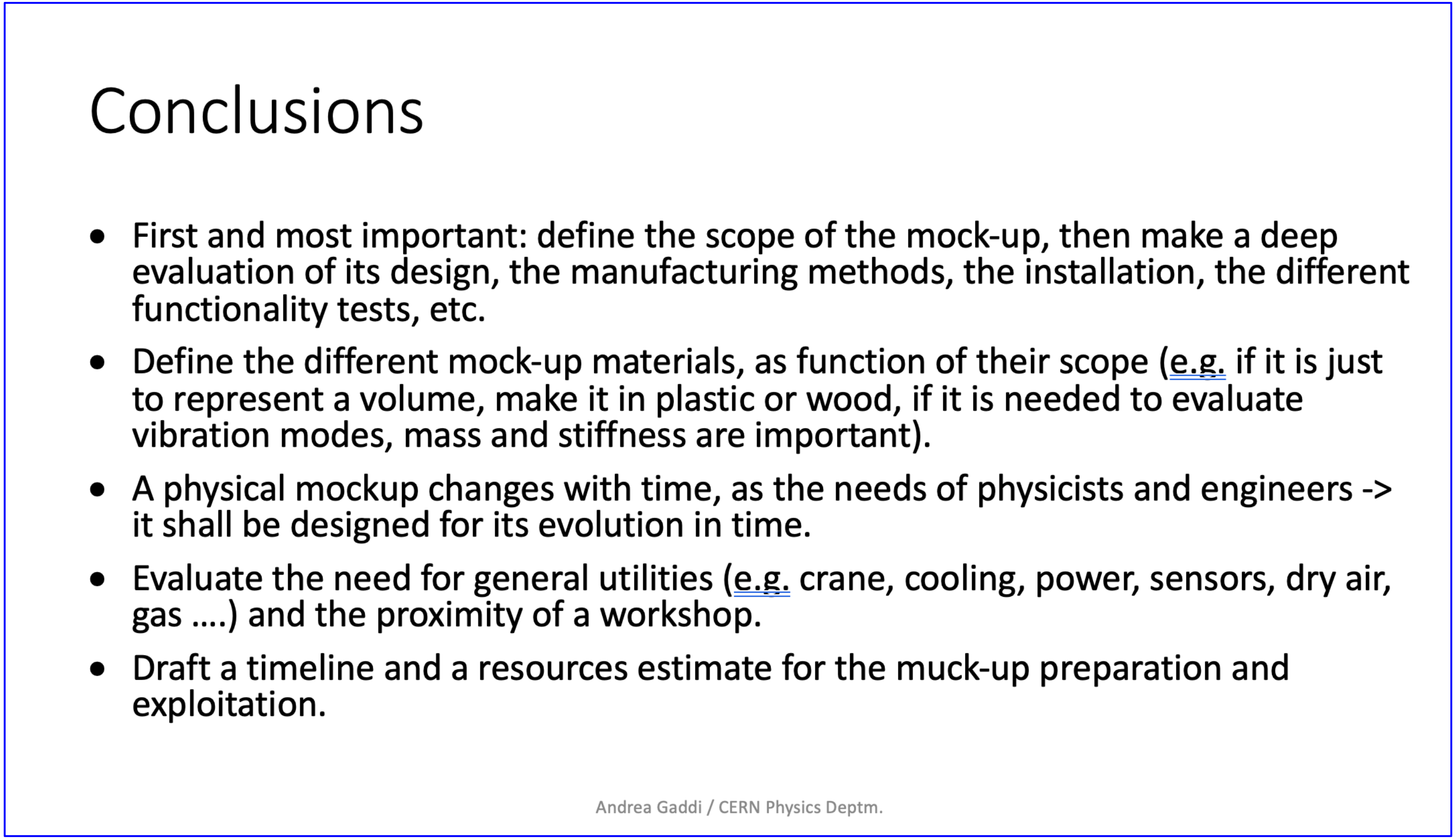
with considerations on
a mock-up for FCC-ee IR



(a)

(b)

courtesy F. Duarte Ramos



Conclusions

- First and most important: define the scope of the mock-up, then make a deep evaluation of its design, the manufacturing methods, the installation, the different functionality tests, etc.
- Define the different mock-up materials, as function of their scope (e.g. if it is just to represent a volume, make it in plastic or wood, if it is needed to evaluate vibration modes, mass and stiffness are important).
- A physical mockup changes with time, as the needs of physicists and engineers -> it shall be designed for its evolution in time.
- Evaluate the need for general utilities (e.g. crane, cooling, power, sensors, dry air, gas ….) and the proximity of a workshop.
- Draft a timeline and a resources estimate for the muck-up preparation and exploitation.

Andrea Gaddi / CERN Physics Deptm.

A side issue for the experimental sites review: Position of the booster ring

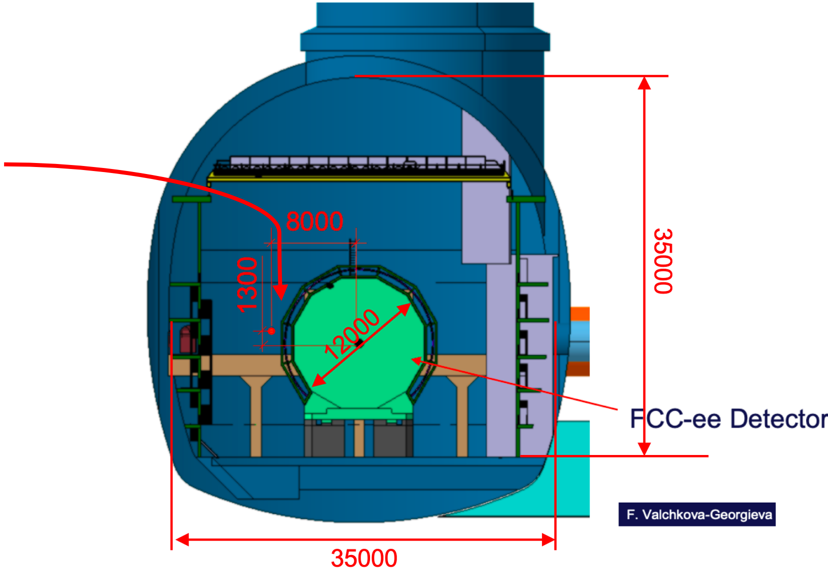
M. Dam

Booster position may have consequences on the tunnel layout around the IP

The booster ring passes through cavern outside detector volume at [x, y]= [8.0, 1.3]m

Request: At the booster position, the magnetic field should not exceed 10 mT

Study performed by Nikkie Deelen (see next slide)



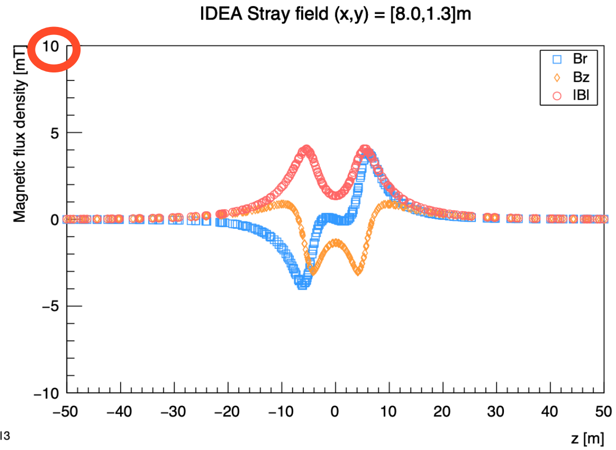
F. Valchkova-Georgieva

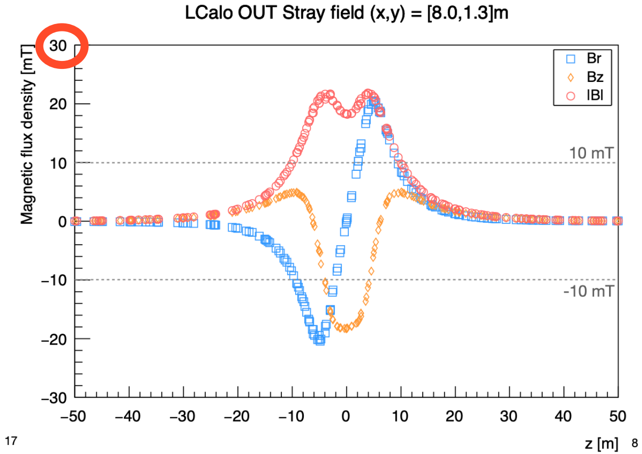
CAVEAT: Compensation solenoids in the interaction region are not included yet, design of those magnets is ongoing by M. Koratzinos.

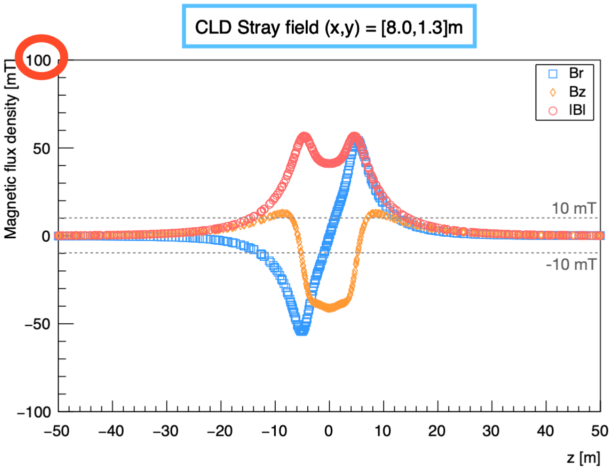
Detector stray magnetic fields

Nikkie Deelen

FCC-ee booster line will pass close to detectors







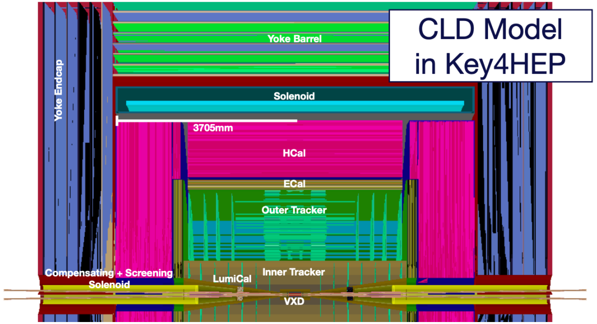
Will be followed-up:

we need to have the tolerable limit value from the booster dipole during injection, and understand if we need shielding or if correctors in the booster can easily recover this value

Detector Backgrounds

- CLD detector and MDI model in Geant4 adapted to 10 mm beampipe
- Solenoid field map imported in key4hep
- Collision products, beam, and photon losses are now studied

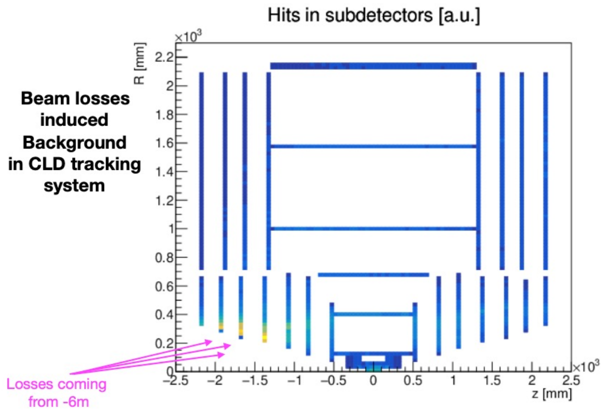
- Occupancy from incoherent pair production tolerable
- Occupancy from beam halo losses only concerning at ttbar, for beam loss scenarios considered until now



CLD Model in Key4HEP

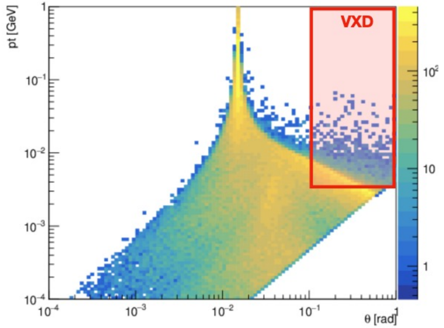
	Z	WW	ZH	Top
Pairs/BX	1300	1800	2700	3300
Max occup. VXDB	70e-6	280e-6	410e-6	1150e-6
Max occup. VXDE	22.5e-6	95e-6	140e-6	220e-6
Max occup. TRKB	9e-6	20e-6	38e-6	40e-6
Max occup. TRKE	110e-6	150e-6	230e-6	290e-6

Beam losses induced Background in CLD tracking system



Beam losses & photon tracks from A. Abramov & K. André

- Preliminary studies show little quench risk for the FF quads due to halo losses.
- Preliminary studies show photon losses absorbed or deflected by mask



Incoherent pair creation

Next Steps on Backgrounds studies

more details at next MDI meeting 20 February
https://indico.cern.ch/event/1251507/

- **Beam losses**
  Study other beam loss scenarios
  Obtain input for the equipment loss tolerances – superconducting magnets, collimators, other
    Energy deposition studies required for magnets, collimators, and masks
    Detailed evaluation of detector backgrounds required – shielding, muon backgrounds
  Study all beam modes
- **Synchrotron Radiation**
  Iteration on the positions and apertures of the synchrotron radiation collimators within the collimation hierarchy
  Study the SR collimation performance with the X-Y tail distribution modeling (charge and width)
  Continue the study of the synchrotron radiation background due to off-axis top-up injection
- **Backgrounds in CLD (& IDEA?) detector**
  Tracking the primary beam particles and the photons hitting the pipe performed in Key4HEP
  Photons at the tip of the SR mask upstream the IP
- **Radiation studies** in the experimental area and in the BS dump area will start with FLUKA in March

Detector Software

Francois Brieuc

The community agreed on using a common software framework for all future collider studies: Key4hep

Detector description with DD4hep, geometry description ongoing:

CLD

- All CLD sub-detectors implements in DD4hep
- Reconstruction well advanced, inherited from ILD/CLICdet

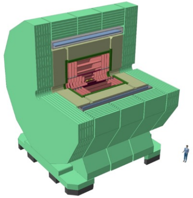
IDEA

- IDEA full sim: standalone (plain Geant4) detector simulatio
- Full reconstruction non available yet
- ongoing effort towards Key4hep integration

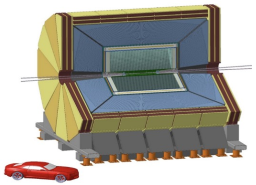
Noble Liquid Based

- Detector concept in its infancy

CLD



IDEA



MDI:

- Improve beam background overlay workflow
- produce field maps with the interplay between magnets and detector magnet fields
- impact on the tracking performance

Outlook

The FCC Physics workshop was a good occasion:

- to get together in person
- strengthen the FCC PED community
- prepare Mid-term report
- sharpen FCC physics case

About MDI:

- We have a FCCIS deliverable on the IR and MDI design, that will be also used as part of the mid-term review report.
- We need a rough cost estimate for the cost review.

Plans for the Mid-Term Review

- **Interaction Region and machine detector interface design**: 3D CAD proof-of-principle engineered mechanical design of the interface between the accelerator and detector components in the interaction region.
- **Detector backgrounds** evaluation, including a first collimation setting and shieldings for various beam loss scenario.
- **Radiation in the IR**: assessment from all sources and handling strategy.
- **Heat load** assessment **from beam losses, synchrotron radiation and wake-fields** on the beam pipe, magnets and components.
- List of **functional and conceptual specification for all the various magnetic fields** including the SC correctors and the cryostat.
- Definition of the **IR magnet system**, studied as an integrated group: **field quality, mechanical constraints, e.m. forces**, supports, accessibility, services.

- Definition of the IR mock-up project