2ND "FCC ITALY & FRANCE WORKSHOP" HIGHLIGHTS – MDI FOCUSED

Fabrizio Palla

INFN Pisa and CERN

MDI meeting #60

11 November 2024

- Venue: Palazzo Franchetti on the Grand-Canal

- 110 participants with good attendance of young people

- Agenda https://indico.cern.ch/event/1457081/timetable/?view=fcc

INFN
Istituto Nazionale di Fisica Nucleare

- 1^{st} and 3^{rd} day with plenary sessions.
  - IT and FR Funding agencies reprs.
  - Focus on common and complementary R&D
  - MDI session on 1^{st} day's plenary
- 2^{nd} day with parallel sessions
  - accelerator, detector R&D, SW and physics

Plenary 1: Overview of FCC Project — Sala del Portego (Palazzo Fra...

Convener: Claudia Cecchi (Universita e INFN, Perugia (IT))

11:00 **Welcome from the Director of the Padova INFN Section: Prof. R. Carlin** — 10m
Speaker: Roberto Carlin (Universita e INFN, Padova (IT))

11:10 **Overview and Status of the FCC Project** — 30m
Speaker: Michael Benedikt (CERN)
241104_FCC-genera... | 241104_FCC-genera...

11:40 **Overview of the FCC Project in Italy** — 20m
Speaker: Paolo Giacomelli (Universita e INFN, Bologna (IT))
FCC-project-Italy-20...

12:00 **Overview of the FCC Project in France** — 20m
Speaker: Gregorio Bernardi (APC Paris CNRS/IN2P3)
Overview-FCC-Franc...

12:20 **Overview of FCC accelerator activities in Italy and France** — 20m
Speaker: Manuela Boscolo (INFN e Laboratori Nazionali di Frascati (IT))
241104_FCC_Accel...

12:40 **INFN initiatives for European Strategy Update** — 20m
Speaker: Aleandro Nisati (Sapienza Universita e INFN, Roma I (IT))
INFN ESPPU prepar...

13:00 **French Initiatives for the European Strategy Update** — 20m
Speaker: Laurent Vacavant (IN2P3 (FR))
FCC_ITFR_Venise_2...

14:30 → 15:45 **Plenary 2: Discussion around Detector Concepts** — Sala del Portego (Palazzo Fra...

Conveners: Gregorio Bernardi (APC Paris CNRS/IN2P3), Paolo Giacomelli (Universita e INFN, Bologna (IT))

14:30 **Discussion about detector concepts** — 1h
A guided discussion about present detector concepts proposals, their possible evolution and new ideas
Speakers: Gregorio Bernardi (APC Paris CNRS/IN2P3), Paolo Giacomelli (Universita e INFN, Bologna (IT))
FCC-detector-conce...

15:30 **Presentation of plans for IDEA paper** — 15m
Speaker: Franco Bedeschi (Universita & INFN Pisa (IT))
Venice_Nov2024.pdf | Venice_Nov2024.pptx

15:45 → 16:15 **Coffee break** — 30m — Sala della Biblioteca (Istituto ...

16:15 → 18:15 **Plenary 3: MDI** — Sala del Portego (Palazzo Fra...

Convener: Manuela Boscolo (INFN e Laboratori Nazionali di Frascati (IT))

16:15 **MDI Design & solenoid compensation scheme** — 40m
Speaker: Andrea Ciarma (INFN e Laboratori Nazionali di Frascati (IT))
2024-11-04_FCCee...

16:55 **Vertex Layout and detector integration** — 20m
Speaker: Fabrizio Palla (Universita & INFN Pisa (IT))
2nd FR-IT Venice 20... | 2nd FR-IT Venice 20...

17:15 **Preliminary parameters of a 3T HTS Solenoid for the IDEA Detector** — 20m
Speakers: Samuele Mariotto, Samuele Mariotto
2024_10_30_Fcc-ee... | 2024_10_30_Fcc-ee...

17:35 **Plans for backgrounds studies** — 20m
Speaker: Giulia Nigrelli (Sapienza Universita e INFN, Roma I (IT))

10:00 **Discussion on next steps for Simulation and Reconstruction** — 30m
Speaker: Brieuc Francois (CERN)
20241106_Discussi...

10:30 → 11:00 **GROUP PHOTO IN PALAZZO FRANCHETTI -before- Coffee break** — 30m — Sala della Biblioteca (Istituto ...

11:00 → 12:40 **Plenary 1: Overview and Discussion of Common R&D** — Sala del Portego (Palazzo Fra...

Convener: Roberto Tenchini (Universita & INFN Pisa (IT))

11:00 **Vertex Detector and ToF PID layers** — 25m
Speaker: Didier Claude Contardo (Centre National de la Recherche Scientifique (FR))
FranceItaly_VDPID_... | FranceItaly_VDPID_...

11:25 **Drift Chambers** — 25m
Speaker: Nicola De Filippis (Politecnico/INFN Bari (IT))
DeFilippis_DriftCha...

11:50 **MPGDs** — 25m
Speaker: Paul Colas (CEA/Irfu)
20241106-FCCTPC_...

12:15 **Calorimeters** — 25m
Speaker: Giovanni Marchiori (APC, CNRS/IN2P3 and Université Paris Cité)
2024:11:06 - Summ...

M. Benedikt

Feasibility Study Report for March 2025

Structure: Three Volumes

- ***Vol. 1:*** *Physics, Experiments and Detectors (~200 pages)*
- ***Vol. 2:*** *Accelerators, Technical Infrastructures, Safety Concepts (~400 pages)*
- ***Vol. 3:*** *Civil Engineering, Implementation & Sustainability (~200 pages)*
- **Executive Summary of the FCC Feasibility Study: ~40 pages**

Input for Update of European Strategy for Particle Physics

to be prepared with Overleaf & published by EPJ (Springer-Nature) – FCCIS members

Overleaf · FUTURE CIRCULAR COLLIDER Innovation Study · EPJ.org your physics journal · SPRINGER NATURE

In addition:

a. Documentation on Cost Estimate – Funding Models

b. Environmental Report

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FCC Main Goals for Coming Years

- **Upcoming milestone for FCC is the completion of the Feasibility Study by March 2025 as input for the Update of the ESPP.**
- **The following pre-TDR phase should prepare for a possible project approval by 2027-2028 and enable the subsequent start of CE design contract:**
  - Updated cost and schedule studies
  - specifications to enable CE tender design by mid 2027
  - refined input for environmental evaluation and project authorisation process
  - requires overall integration study and designs based on technical pre-design of accelerators, technical infrastructure and detectors
- **Possible start of CE construction would then be 2032-33:**
  - CE groundbreaking
  - TDR to enable prototyping, industrialization towards component production
- **Strong international collaboration is essential for success!**

P. Giacomelli

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FCC activities in Italy

- Italy has been involved from the very beginning on FCC
  - The main goals for FCC (and PED) will be described by Gregorio
  - Italian Accelerator activities will be covered by Manuela
  - I will concentrate on PED activities
    - I will focus mostly on the IDEA detector concept and its sub-detectors
    - We are also very active on physics studies and these will be discussed in several talks at this workshop
    - We are actively seeking to develop synergies and collaborate with many International colleagues
    - At this workshop we hope to initiate and foster many collaborations with French colleagues on several activities

FCC Expression of Interests

- IDEA plans to prepare an EoI for each sub-detector:
  - Vertex tracker
  - Drift chamber
  - Outer wrapper
  - DR crystal ecal
  - Superconducting Solenoid
  - DR fibre calorimeter
  - Muon detection system
- An EoI of the IDEA detector concept
  - Strongly encourage international collaborators to participate and sign the EoI(s) of their interest

G. Bernardi

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French Institute Interests per DRD topic, for FCC-ee Subdetectors

- **Tracking**
  - TPC — IRFU;
  - MCMOS — CPPM, IPHC, IP2I, LPNHE;
  - DCH — IJCLab, Ganil, LPSC
- **Timing Layers**
  - MicroMegas — IRFU,
  - MCMOS — IPHC, IP2I, CPPM,
  - Optical — CPPM, IP2I
- **Liquid Argon calorimetry**
  - ECAL — APC, CPPM, IJCLAB, LPNHE, LAPP
  - electronics — Omega
- **Sampling calorimetry with fully embedded electronics**
  - ECAL/SiW (calice) — IJCLab, LLR, LPNHE;
  - HCAL — IP2I,
  - electronics — Omega
- **Optical calorimetry**
  - ECAL GRAiNita — IJCLAB, LPC-CF,
  - Crystals — IP2I
- **Muon hodoscope/tagger**
  - Micromegas — IRFU,
  - (RPC — experience at IP2I but no specific project)

APC	Paris
CPPM	Marseille
IJC Lab	Orsay
IPHC	Strasbourg
IP2I	Lyon
LAPP	Annecy
LLR	Polytechnique
LPC	Clermont-Ferrand
LPNHE	Paris
LPSC	Grenoble
IRFU	Saclay

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EoI's signed by several French Institutes

- Calorimetry:
- ALLEGRO
- SiW-ECAL / - T-SDHCAL & T-MRPC
- GRAINITA
- Tracking and vertex detectors:
- EoI for a Vertex Detector at FCC-ee (FCC-SEED)
- EoI for Time of Flight layers for PID (Precision timing in a Monolithic CMOS technology)
- Detector Concepts:
- ALLEGRO
- ILD-CC
- IDEA ? Other subdetectors EoI's ? Up for discussion during this workshop

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M. Boscolo

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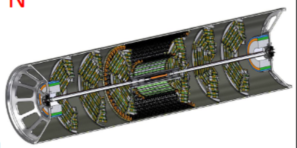
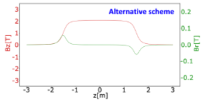
FCC-ee Machine detector interface (MDI) – INFN

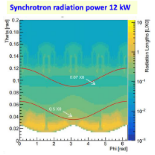
- **Engineered design of the interaction region and its components**
  Light and cooled beam pipes, vertex detector, luminosity calorimeter, bellows, services and routings. LNF, Pisa, Perugia



- **Optimisation of the final focus optics and solenoid compensation scheme** LNF
  Aim at reducing the synchrotron radiation produced in the IR, improving the vertical emittance growth, and optimising space in the crowded area.



- **Detector backgrounds** evaluation, material budget optimisation.
- **Beamstrahlung** radiation dump and induced backgrounds.
- **Collimation scheme** with beam losses from halo beam, beam-gas, thermal photons.
LNF
- **3T solenoid design** - ***NEW*** *talk by S. Mariotto, MDI session* Milano



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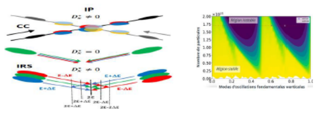
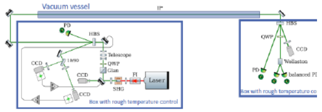
Collider design

IN2P3

- Monochromatization optics
  - IR Optics with horizontal/vertical dispersion at IP ($D^*_{x,y}$)
  - Possible experimental tests at DAFNE/SuperKEKB/BEPCII
- Beam-Beam studies
  - including more precise wakefield model and possible experimental studies.
- Compton polarimetry
  - Laser system and pixelized detectors
- Stabilisation, vibration and positioning & uniform waves analysis
- R&D on HTS IR quadrupole and its cooled beam pipe (emerging new studies)

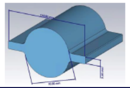
(see talk M. Merchand (LAPP) , Acc-1 session)





INFN-Roma1, LNF

- Collective effects, single bunch and multibunch instabilities
- Beam-beam and coupling impedance



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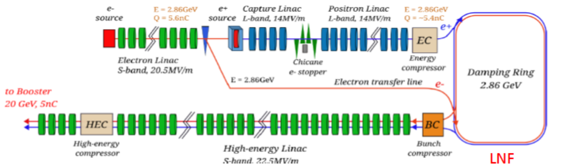
Positron source and capture system – IJCLAB / INFN

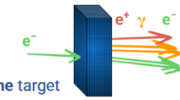
→ positron flux of ~1.35×10[13] e+/s. *Demonstrated at SLC (a world record for existing accelerators):* ~6 ×10[12] *e+/s*



5.4 nC e+/bunch at the DR* → **13.5 nC e+/bunch at the exit of the Positron Linac**, considering **60% of losses** due to transport, collimation and injection in the DR (**safety margin of 2.5**).

- Capture System and Positron Linac
  - HTS solenoid or flux concentrator IJCLab
  - AI techniques for beamline optimization INFN-Milano
- Crystal-based positron source INFN-Ferrara/IJCLab
- Use of AI for global optimization IJCLab

HTS solenoid
18.2 T @15K@2kA reached for stack of 4 coils



Crystalline target

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High-field magnets for FCC-hh

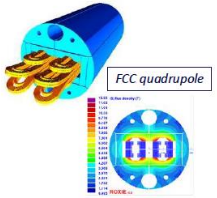
Ultimate goal: 16 T – 20 T

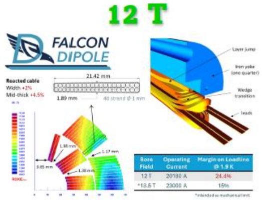
12 T Nb_3Sn Dipole Magnet

- Robust concepts using a **partnership with industry** INFN-Mi, INFN-Ge
- Technology developments in the lab CEA

R&D activities:

- Thermomechanical behaviour of Nb_3Sn conductors during heat treatment
- Mechanical tests of Nb_3Sn cables





High Temperature Superconducting Magnets

- **INFN** strategy: PNNR_IRIS: development of a HTS (REBCO) dipole in the range 8-10 T
- **CEA** strategy : MI (Metal-Insulated) HTS tapes for very high current densities
  Relying on fast turn-over / reduced-risk subscales

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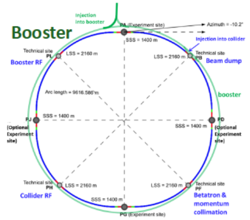
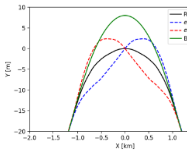
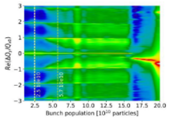
Booster Design – CEA

- Optics design
- Dynamic aperture
  - also with AI techniques
- Parameter table
- Tuning strategy





- Collective effects INFN-Roma1, LNF



Bunch population scan at injection energy

Mid-term parameter tabl

Running mode		Z	W	ZH	tt̄
Injection option		LINAC/SPS			
Circumference	[km]	91.174			
Injection energy	[GeV]	20/16			
Extraction energy	[GeV]	45.6	80	120	182.5
Number bunches / ring		11200	1780	440	60
Maximum particle number / bunch Nmax	[10[10]]	≥ 2.5 (4 nC)			
Particles / bunch in top-up	[10[10]]	2.14	0.87	0.69	0.93
RF frequency	[MHZ]	800			
Arc optics FODO		60°/60°		90°/90°	
Momentum compaction		14.9×10^{-6}		7.34×10^{-6}	
Coupling		2×10^{-3}			
Injection horizontal emittance (norm.)	[μm]	10/190			
Injection vertical emittance (norm.)	[μm]	10/4			
Extraction horizontal equilibrium emittance (RMS)	[nm]	0.26	0.81	0.63	1.45
Extraction vertical equilibrium emittance (RMS)	[pm]	0.53	1.62	1.25	2.90

Extraction horizontal equilibrium emittance (RMS)	[nm]	0.26	0.81		
Extraction vertical equilibrium emittance (RMS)	[pm]	0.53	1.62	1.25	2.90
Injection Energy loss / turn	[MeV]	1.514/0.6203			
Extraction Energy loss / turn	[MeV]	40.93	387.7	1963	10500
Injection bunch length	[mm]	4/5.5			
Extraction bunch length	[mm]	4.38	3.55	3.34	1.94
Injection RMS energy spread	$[10^{-3}]$	1/4			
Extraction RMS energy spread	$[10^{-3}]$	0.38	0.67	1.01	1.53
Injection Maximum relative energy acceptance	[%]	3			
Extraction Maximum relative energy acceptance	[%]	0.36	0.76	0.49	2.39
Injection RF voltage	[MV]	104.9/82.97		52.85/41.36	
Extraction RF voltage	[MV]	49.48	458.6	2018	11533
Filling time	[s]	28/31.5	8.9/9.6	4.4/4.75	0.6/0.95
Ramp time	[s]	0.32/0.37	0.75/0.8	1.25/1.3	2.03/2.08
Flat top	[s]	1.9	0	0	0
Total cycling time	[s]	30.54/ 34.14	10.4/11.2	6.9/7.35	4.66/5.11

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Superconducting radio-frequency (SRF) cavities INFN/IN2P3

RF system R&D is key for increasing energy efficiency of FCC-ee

- Nb on Cu 400 MHz cavities
- Bulk Nb 800 MHz cavities, surface treatment techniques, cryomodule design
- RF power source R&D in synergy with HL-LHC

INFN-LNL R&D on surface polishing and SC film coating

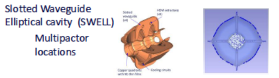
Nb_3Sn coating by Physical Vapor Deposition (PVD)
on a Quadrupole Resonator @20 mT @400 MHz @4.5K

INFN-Milano R&D on Nb bulk cavities:

- 1-cells 1.3 GHz: **surface and thermal treatments** development & qualification
- 9-cells 1.3 GHz: **industrialization** (9-cells) of the developed process
- **New cryostat dedicated to R&D** (Design specifically for TESLA type single- and multi-cell cavities)

IN2P3

- **Multipacting** modeling on the SRF SWELL cavities
- SRF High-Q & Thermoelectrical (800 MHz & bimetal structures)



FCC-JLAB prototype
800 MHz at IJCLab

A. Nisati

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INFN future accelerator R&D

- **High-Q High-G Superconducting RF R&D**
- **Development of thin film SRF relevant for FCC-ee**
- **High-Field Magnets and High Temperature Superconductors**
  - **Discussion on financial support is on-going**
- **FCC-ee Machine Detector Interface**
  - project already supported also by an INFN & CERN agreement
- **FCC-ee Injector and Damping Ring**
  - project already supported by an INFN & CERN agreement
- **Muon Collider R&D**

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Main INFN events dedicated to discuss the ESPPU

Istituto Nazionale di Fisica Nucleare

- **3 July 2024: First ECFA-INFN Early Career Researchers Meeting https://agenda.infn.it/event/42205/**
- **30 September 2024: 2° meeting ECR community** https://agenda.infn.it/event/42691/
- **1 October 2024**: **Workshop on High Luminosity LHC and Hadron Colliders** (LNF) https://agenda.infn.it/event/42594/timetable/
- **22-24 January 2025: Workshop on Lepton Colliders** (LNF)
- **4 February 2025 Workshop to review the INFN Input to the ESPPU** (Milano Bicocca)
- Meeting(s) after the Symposium in Lido di Venezia are possible

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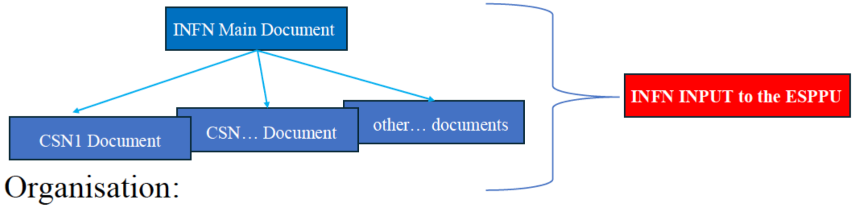
INFN Input for the European Strategy



- Organisation:
  - **Steering Group** **(C. Borca, M. Ciuchini, S. Malvezzi, A. Nisati, R. Tenchini)**
  - **Gruppo di Lavoro**, composed by:
    - Presidenti delle cinque Commissioni Scientifiche
    - Direttori dei Laboratori Nazionali
    - Chair del Machine Advisory Committee dell' INFN (MAC)
    - Rappresentante attività Calcolo (CNC)
    - Rappresentanti dell' Ufficio Comunicazione dell' INFN

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INFN Input per la European Strategy

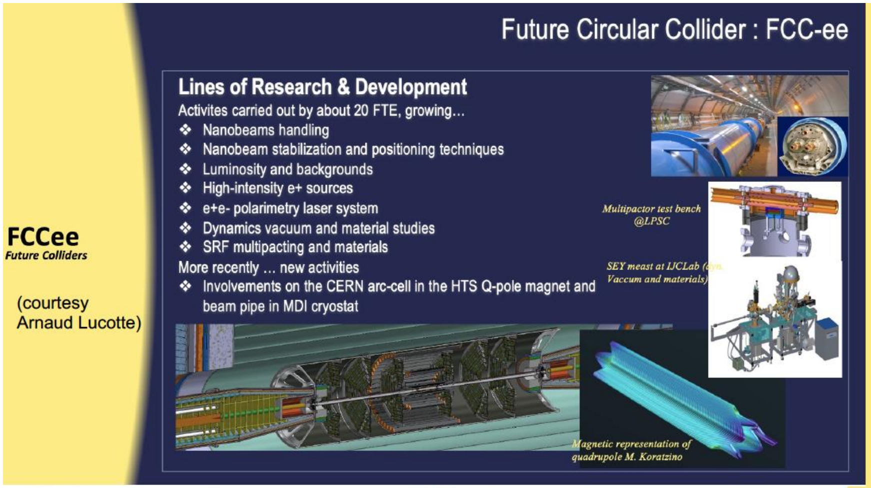
- The INFN has started work on the preparation of the Update of the European Strategy for Particle Physics (ESPPU) with the workshop on May 6th and 7th in Rome.
  - During the discussions that took place at this meeting, the basic recommendation emerged with which INFN will contribute to the work of the *Strategy*.
- The next step is to promote discussions within the Laboratories and Sections of the Institute, and to coordinate the preparation of documents that will be submitted as *Input* for the next *Strategy*.
- This approach is inspired by the model adopted by INFN during the last *European Strategy* from December 2018 to January 2020 (symposium in Granada in 2019).

L. Vacavant

Key points for the organization in France

- Process defined jointly by CEA/IRFU & CNRS/IN2P3
- As institutes we are only providing the skeleton of the organization
- In the current phase of the exercice, this is really a bottom-up approach, dealt with by the community itself – *this is new*

- The process aims at organizing the « particle physics national input »
- Based on the remit given by CERN Council to ESG
- The goal is to submit a unique (but not exclusive) contribution by March 31 (the « national input »)
- 4 thematic working groups were created, building on existing and strong community scientific networks at the French or European levels (CNRS tools: Groupement de Recherche GDR, or International Research Network IRN): recurrent scientific animation with workshops, gathering theorists and experimentalists – same as last exercice
- In addition a specific WG is in charge of the explicit question in the remit regarding machine scenarii



(courtesy Arnaud Lucotte)

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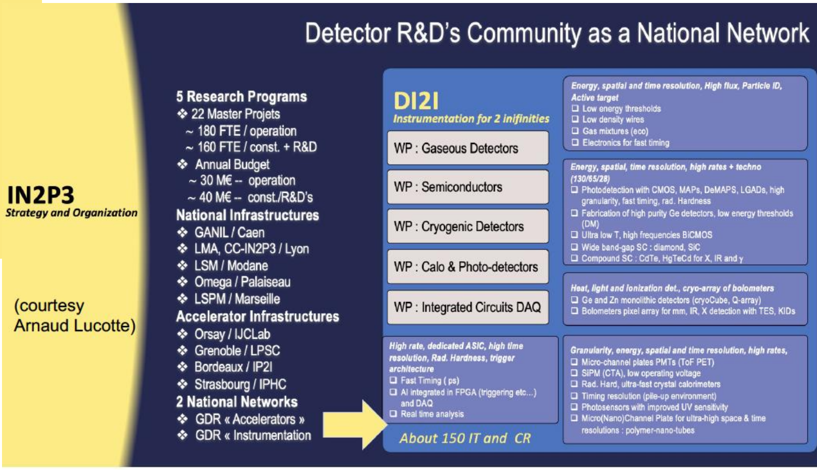

(courtesy Arnaud Lucotte)

Main events organized by Working Groups

- GT3 (Neutrinos): Sept 9-10, https://indico.in2p3.fr/event/33652/
- GT4 (QCD): Sept 19, https://indico.in2p3.fr/event/33460/
- GT1 (SM & BSM): Oct 4, https://indico.in2p3.fr/event/33970/
- GT2 (Flavour): Nov 6, https://indico.in2p3.fr/event/33443/
- GT1 (SM & BSM): Nov 13-14-15, https://indico.in2p3.fr/event/33701/overview
- GTS (Scenarios): Dec 18, https://indico.in2p3.fr/event/34334/

Symposium for French community

- January 20-21, 2025
- Campus Pierre & Marie Curie, Jussieu, Paris – auditorium T44-55 – 500 seats
- Ahead of that symposium:
  - Collection of contributions of all sorts
  - Work in the various WG (dedicated meetings, zoom sessions, etc)
- Restitution of the work of all the working groups
- Discussion/exchanges, building of a consensus
- Preparatory work towards the drafting of the national input
- At this point, no plan to use the slot for additional national input (May 26): if needed, likely to have a virtual symposium ahead of that deadline
- *We could also take advantage of that time for another discussion with INFN*

- NB: a few critical points yet to be settled/decided
  - how to organize the discussion & the consensus building
  - at which point exactly and to which degree the directorates of RFU & IN2P3 should play a role

A. Ciarma

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FCC-ee MDI activities

IR Mechanical Model
- engineered design of beam pipe, cooling system and support
- heat load distribution from wakefield and SR
- integration in the MDI region and assembly strategy of LumiCal and vertex detector

Background Simulations
- estimation of beam losses in the MDI region and halo collimation scheme
- development of SR maskings
- tracking of unwanted particles in the detector for occupancy calculation

Beamstrahlung Photon Dump
- characterization of beamstrahlung radiation and first FLUKA studies on dump
- integration of extraction line with civil engineering of downstream tunnel and magnet aperture design

Non-local Solenoid Compensation Scheme
- first studies on alternative solenoid compensation scheme without the -5T compensating solenoid in IR

Summary

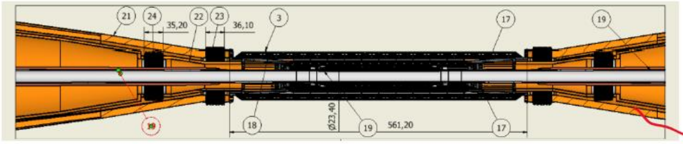
Significant progress on all key aspects of the FCC-ee MDI design:

- Engineered model of the low impedance **IR beam pipe**
- **Cylindrical support tube** for assembly and vertex detector and LumiCal integration
  ➡ **IR mockup** to be built in INFN-LNF
- **Collimators** and **SR masks**
- **Detector background** estimation
- **Beamstrahlung** photon dump
- Alternative **solenoid compensation** scheme

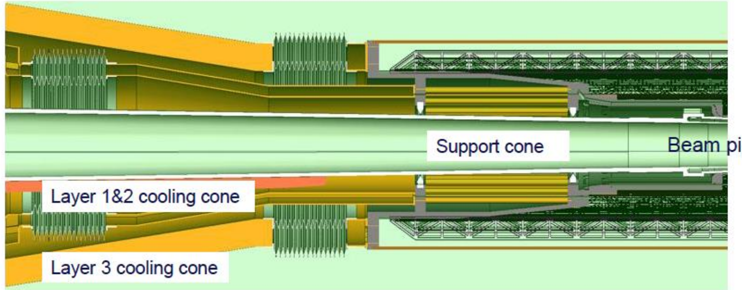
Credits for the many topics shown in this overview:
K. André, M. Boscolo, F. Bosi, G. Broggi, R. Bruce, H. Burkhardt, A. Ciarma, M. Dam, E. Di Pasquale, B. Francois, F. Fransesini, A. Frasca, A. Gaddi, A. Ilg, M. Koratzinos, S. Lauciani, A. Lechner, G. Lerner, G. Nigrelli, A. Novokhatski, K. Oide, F. Palla, B. Parker, A. Perrillo Marcone, P. Raimondi, G. Roy, J. Seeman, G. Sensolini, F. Valchiova, F. Zimmermann

F. Palla

Inner vertex – beam pipe integration



Air-cooling cones

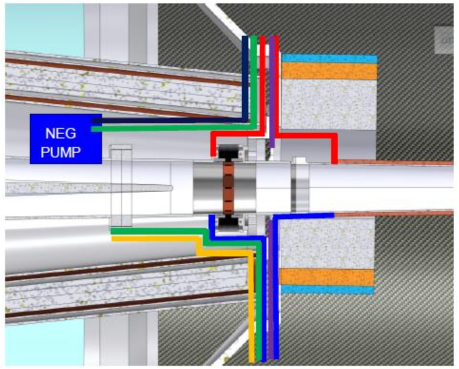


Courtesy F. Bosi

Integration with cryo-magnet system

- Luminosity calorimeter needs to be integrated in a very congested area
  - Service routings
  - Tight construction tolerances
  - Alignment system
  - Accelerator components

LumiCal



Courtesy F. Fransesini

1.2 m to the IP

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Detector opening scenarios

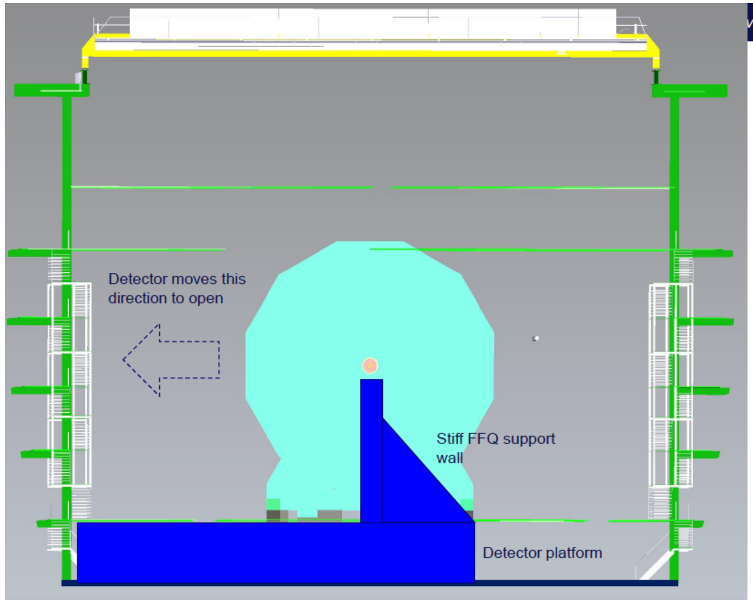
Detector vs machine requirements:

Detector side:

- Detector acceptance and hermeticity
- Simple opening sequence – minimal services disconnection & handling
- Accessibility to detector inner parts in reasonable time during shut-downs

Machine side:

- Stability of the FFQ supports
- Quick and reliable alignment procedure
- Beampipe vacuum preserved



Scenario #3

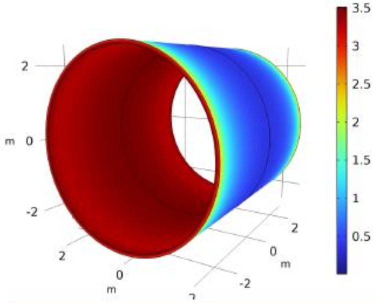
In the large experimental sites A & G there is enough clearance to envisage the scenario to move the detector aside the beamline and get full access to the detector's inner parts.
The FFQ can either be removed before the translation or move with the detector and be removed from the garage position.

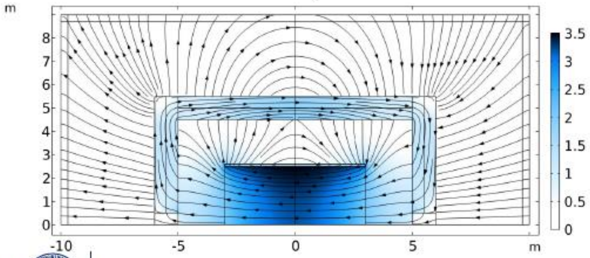
S. Mariotto (3T solenoid)

First Considerations: Magnet

From analytical evaluations:
- B= 3 T, R_i=2.5 m e L=6 m → **18.65 MA-turns**

Peak field on the conductor equal to **3.5 T** at solenoid edges
- 2D Rotational Symmetry Simulation in COMSOL
  - Iron Yoke BH Curve still to be defined
  - Internal radius increased to allow for EM Calorimeter
    - Still to be discussed coil transparency requirements
  - Coil thickness limited by the equivalent stress on conductor (100 MPa)

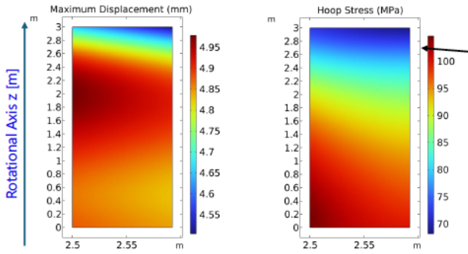




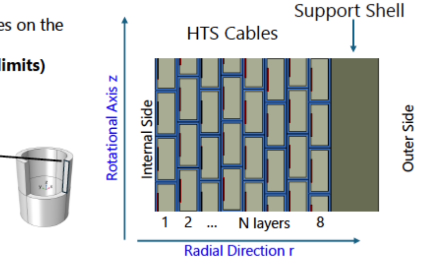
Parameter	Value
Bore Field	3 [T]
I_{nom}	9323 [A]
Coil Thickness	92.3 [mm]
Turns	250x8
Inductance	17 [H]
Stored Energy	556 [MJ] - 28.2 [kJ/kg]
Operating Temperature	20 [K]

Preliminary Mechanical Performances

Coil simulated as an **ortotropic material** with averaged properties on the material fraction and cable geometry
- Maximum stress (only Lorentz Forces): **105 MPa (well under limits)**
- Longitudinal Strain on the cable: 0.19% (no HTS degradation)



Aluminum alloy 5083 (25 mm) shell as support for the coil
- Maximum hoop stress of 120 [MPa] (Tensile Strength 400 [MPa])

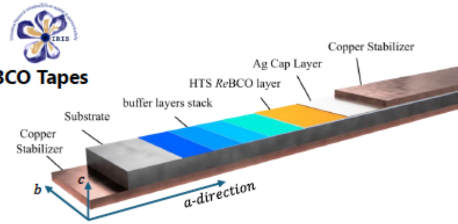


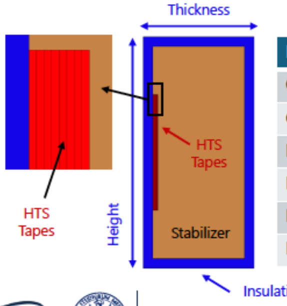
Parameter	Value
HTS Tape E_r, E_ϕ, E_z	[70,180,180] $[GPa]$
Cable E_r, E_ϕ, E_z	[51,61,54] $[GPa]$
Poisson Ratio	0.33

First Considerations: Cable

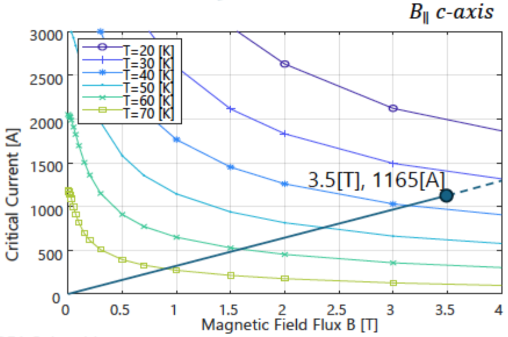
Cable concept: **U Shape channel cable** with **8 Faraday Factory HTS REBCO Tapes**
- Critical current depending on cable orientation along field lines
- 12 mm width tape: 256 km (32 km of cable x 8 Tape/cable)

Stabilizer: Pure Aluminum (99.999%) Al2.0%wtNi
(RRR=170, Yield Strength=170 Mpa @ 4.2 K)





Parameter	Value
Cable Thickness	11.5 $[mm]$
Cable Height	24.0 $[mm]$
N Tape	8
F_HTS	2.32%
F_Stabilizer	73.45 %
F_Ins	24.23 %



Conclusions and Next Steps

Preliminary design evaluations did not identified any showstopper for the feasibility of an HTS design @ 3T - 20K
However.....Concepts to be further investigated:

1. **Shielding of Solenoidal field @ 3T on collider elements**
   - IR region magnetic elements and beam pipe
   - Fringe field on Booster accelerator beamline
2. **Magnetic Design and Quench Protection**
   - Field quality enhancement
   - Margin optimization with coil grading
   - Detailed quench analysis and failure estimation
3. **Detailed Mechanical Assembly and Cool-down**/energization stresses on conductor
   - Optimization of coil and cryostat thermal and mechanical supports
   - Cryostat losses and cooling technologies evaluation
4. **Cable manufacturing and characterization**
   - Properties of HTS aluminum stabilized cables at cryogenic temperatures
   - Joints: LASA facility equipped with necessary infrastructure for cable testing (ATLAS Cable joints)

G. Nigrelli

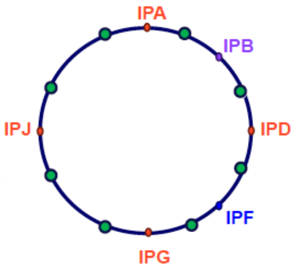
Table of contents

Simulation setup

- Performed with **Xsuite-BDSIM** simulation tool.
- Building on the **state-of-the-art FCC-ee optics**.
- Fast instability introduced as **8 exciter placed along the ring** (one per arc, shown as green points).
- Kicks (H/V) are **equally distributed in phase advances across 90° and 180°** (smooth change in amplitude within 1 turn).
- The exciter **strengths change with time** as:

$$k = \frac{A_0}{\beta_{x,y}} \cos(2\,\pi\, Q_{x,y}\, t)\, e^{\frac{t}{\tau}}$$, where τ is the **rise time**.

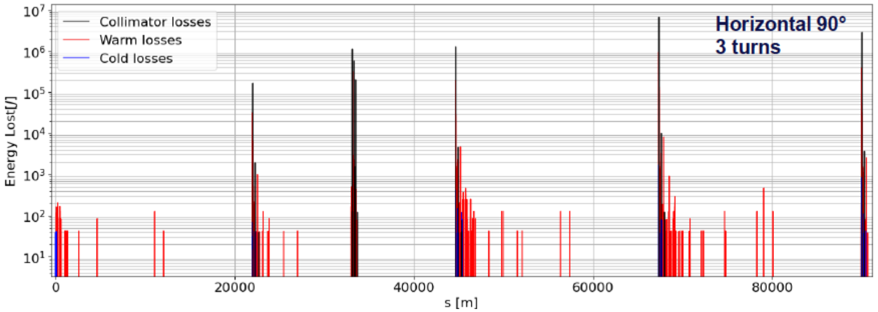
- Resulting in **betatron oscillations exponentially growing with time**.



Simulation parameters:
- **5×10^5 45.6 GeV electrons**.
- **SR** (mean model), **RF** cavities, magnet **tapering.**
- detailed **aperture model**, **halo and tertiary collimators**, **SR collimator**, wiggler...

Preliminary results

Lossmaps at each turn have been generated to study the **time distribution of the losses**:
- Entire beam is lost within 22(15) turns for $\tau = 6(3)$ turns.
- Losses start to be observed during the last ~ 5 turns for H and ~ 10 turns for V.
- Most of the configuration presents a **turn where up to $\sim 50\%$ of the beam is lost**.
- **Order of MJ lost across collimators and apertures in one turn!**
- The energy lost in first turns might be detected to damp the beam before damages.



Conclusions

Collimation system for FCC-ee is being developed.

- **Beam losses scenarios must be investigated** to further improve the design where needed.

The **fast instability could be dangerous** if the feedback system fails.

- This instability can cause damage both at the machine and detectors, as well as increasing backgrounds.
- **Chances of damaging collimators/detectors**. The beam is lost within few turns, almost 50% of beam energy lost in one turn.
- The effect depends also on the phase advance.
- High losses nearby experiments, shower calculation in the detector region is needed.

Full session on Magnets and SRF

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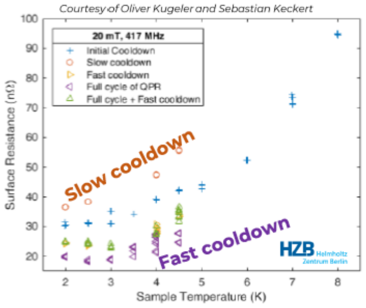
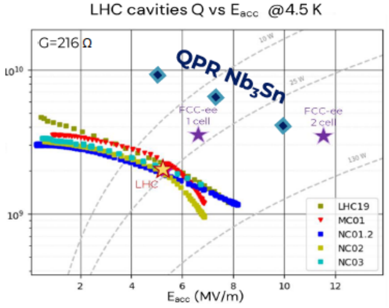
08:45 → 10:45 **Parallel 3: Accelerator 1**

Convener: Stefania Farinon (INFN e Universita Genova (IT))

- **08:45** **SRF - R&D**
  Speaker: Cristian Pira
  Pira - SRF ReD - FCC... | Pira - SRF ReD - FCC...
- **09:05** **HFM FCC Program - Italian activities**
  Speaker: Stefania Farinon (INFN e Universita Genova (IT))
  farinon-Venezia-202...
- **09:20** **HFM FCC Program - French Activities (R)** — 15m
  Speaker: Dr Etienne Rochepault (Université Paris-Saclay (FR))
  2024-11-05 Nb3Sn ... | 2024-11-05 Nb3Sn ...
- **09:35** **HTS IR Quadrupol and Beampipe: R&D proposal** — 20m
  Speaker: Matthieu Marchand (Centre National de la Recherche Scientifique (FR))
  2024-11-05_R&D act... | 2024-11-05_R&D act...
- **09:55** **A new conceptual layout of a HTS Superferric combined function quad/Sext corrector magnet** — 20m
  Speaker: Simone Busatto (INFN-LASA)
  2024_05_11_FCCee... | 2024_05_11_FCCee...
- **10:15** **AI applications for Dynamical Aperture calculations (R)** — 20m
  Speakers: Quentin BRUANT, Quentin Bruant (CEA/IRFU)
  ESNforDA_FCC_FR_...

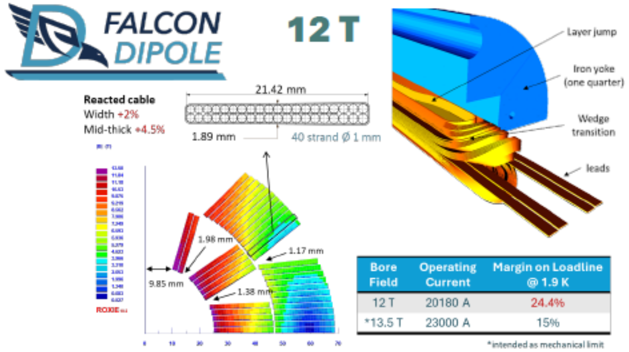


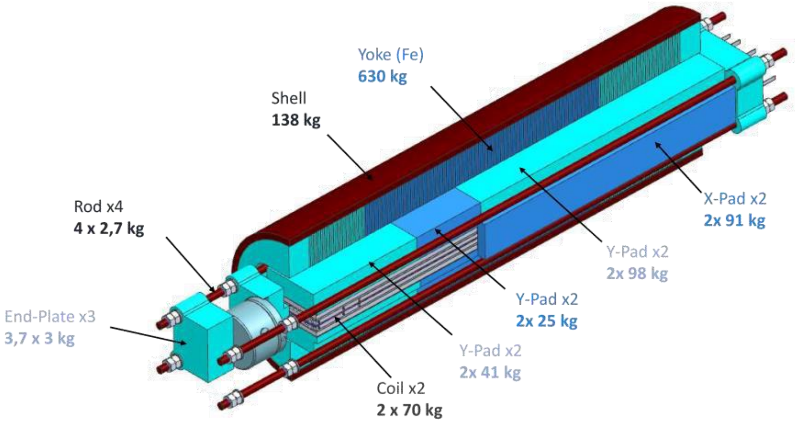


Equivalent to a Q of $9{\cdot}10^9$ @5 MV/m @4.5 K

5 times better than LHC → FCC-ee compatible

Room for improvement





Full session on Booster/e$^+$ source

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Speaker: Ines Combes
higgs_width_combe...

16:30 → 18:30 **Parallel 3: Accelerator 2**
Convener: Laura Bandiera (Universita e INFN, Ferrara (IT))

- 16:30 **FCC booster design (R)**
  Speaker: Antoine Chance (CEA Irfu)
  2024_11_05_high_e... 2024_11_05_high_e...
- 16:50 **A crystal-based positron source for FCC-ee**
  Speaker: Alexei Sytov (Universita e INFN, Ferrara (IT))
  Sytov_Positron_Sou...
- 17:10 **Beam dynamics positron beamline**
  Speaker: Alberto Luigi Bacci (infn)
  FCC_I_F-WS-Venice...
- 17:30 **Performances of the pre-injector with a crystal-based positron source**
  Speaker: Gianfranco Paterno (Universita e INFN, Ferrara (IT))
  FCC-IT-FRworkshop...
- 17:50 **Experiments on crystal radiators at CERN PS and DESY TB** 20m
  Speaker: Nicola Canale
  NC_FCC_IT_FR_202... NC_FCC_IT_FR_202...

Parameter summary (1): layout + filling

https://gitlab.cern.ch/acc-models/fcc/fcc-ee-heb (access with a CERN account).

Parameter	Unit	Z	W	ZH	ttbar
Layout					
Version		PA31-3.0			
Number of Ips		4			
Circumference	km	90.65871376			
Revolution period	ms	0.302404918			
Offset IP	m	8			
Hor. Arc offset booster-collider	m	-0.165			
General parameters					
Injector		LINAC			
Number of booster cyclings to have a full collider ramp		10	2	1	1
Number bunches/collider		11200	1852	300	64
Number bunches/booster		1120	926	300	64
Collider particles/bunch	1.00E+10	21.6	13.8	16.9	14.8
Allowable charge balance	%	5	3	3	3
Particle number / bunch (filling)	1.00E+10	2.5	2.5	1	1
Bunch charge (filling)	nC	4.005441585	4.00544159	1.60217663	1.602176634
Mean beam current (filling)	mA	14.83472756	12.2651408	1.5894351	0.339079487
Maximum bootstrap particle number / bunch (top-up)	1.00E+10	2.16	0.828	1.014	0.888
Maximum bootstrap bunch charge (top-up)	nC	3.46E+00	1.33E+00	1.62E+00	1.42E+00
Mean beam current (top-up)	mA	1.28E+01	4.06E+00	1.61E+00	3.01E-01
Collider beam life time at collisions	s	868.1	492.4	376.2	348.2
Collider top-up interval (between e+ and e-)	s	43.405	14.772	11.286	10.446

Same circumference as the collider.

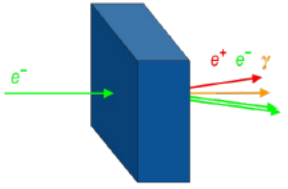
Updated transverse offset between booster/collider to keep the same circumference.

Several booster cyclings in top-up to fill the collider → Less stored bunches in the booster.

Reduced max bunch charge for the filling at tt and ZH operation modes

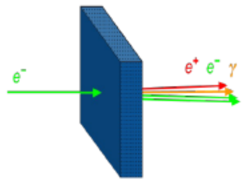
In top-up injection the charge bunch-to-bunch can vary from 0 to 100% of the bootstrap bunch charge

Conventional target



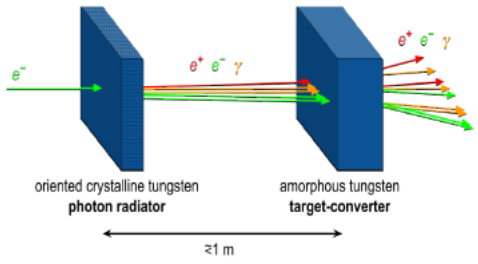
amorphous tungsten

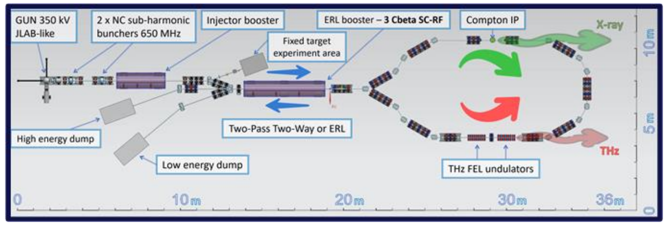
Crystal target



oriented crystalline tungsten

Hybrid scheme





B. François

Background studies

- Beam induced background (BIB) simulation made great progress recently
- Ready to feed detector simulation with BIB particles
  - Incoherent pair production (IPC), synchrotron radiation (SR), beam gas interaction (WIP)
- Detector occupancy studies have started (WIP)
  - IPC: IDEA vertex detector and drift chamber, ALLEGRO ECAL
  - SR: drift chamber (technical demonstration)
- We have to cover the full matrix: **BIB X sub-detector** → need people!
  - **Technical machinery is in place → light w.r.t. software development**
    - **Can be a side project**
  - 'Only' need to know how the sub-detector readout would look like
- NB: we also have the possibility to **overlay background particles on top of physics events** (different than 'just' occupancies) → also possible to evaluate impact on performance (if digitizer detailed enough)
- How to get more people engaged in these studies? (esp. detector experts)

Vertex Detector Digitization

- Already available: simple **gaussian smearing** with user defined resolution, 100% efficiency, no pixel separation
  - Not suited for proper background studies
- Refined version, ongoing effort
  - Define the pixel spatial extend, emulate charge sharing, clustering → resolution 'from first principles'
    - See Gaelle Boudoul's talk
  - Another US group interested in implementing detailed digitization for LGAD's
- Looks good, but can still be discussed

Drift Chamber Digitization

- The drift chamber geometry is available in DD4hep together with a simple digitizer
  - Smearing of the simHit position in the wire local coordinate system
  - Not enough to evaluate the impact of beam background on performance
- Implementing a **detailed digitizer in Key4hep is urgent**
- Do we have a candidate to work on this (ideally starting now)?
  - Drift chamber (digitization) expertise and good software skills
- How shall we implement the detailed digitizer?