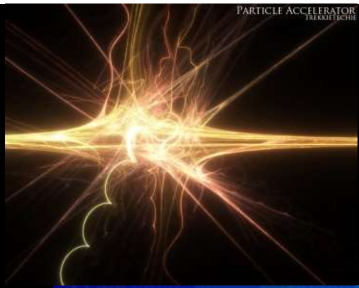

The IDEA detector at the FCC-ee

Franco Bedeschi

Spanish network for future colliders

October 7, 2020

Sommario

- Status and timelines
- Detector requirements
- IDEA design
- Current R&D
- Final remarks

Status and timelines

- ESU approved by CERN council
  - «**An electron-positron Higgs factory is the highest-priority next collider**………. a feasibility study of the colliders and related infrastructure should be …. completed on the timescale of the next Strategy update.»

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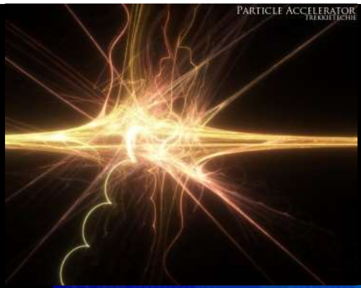

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- Implications on timing for detector R&D:
  - Experiment LoI's by EU strategy 2025/26
    - R&D completed – CDR++
  - FCCee detector TDR 2028
    - Detailed detector design

Status and timelines

FCC project milestones for the next 20 years

- Infrastructure and Machine

Physics, Experiments, Detectors

(exact dates to be discussed in the coming months)

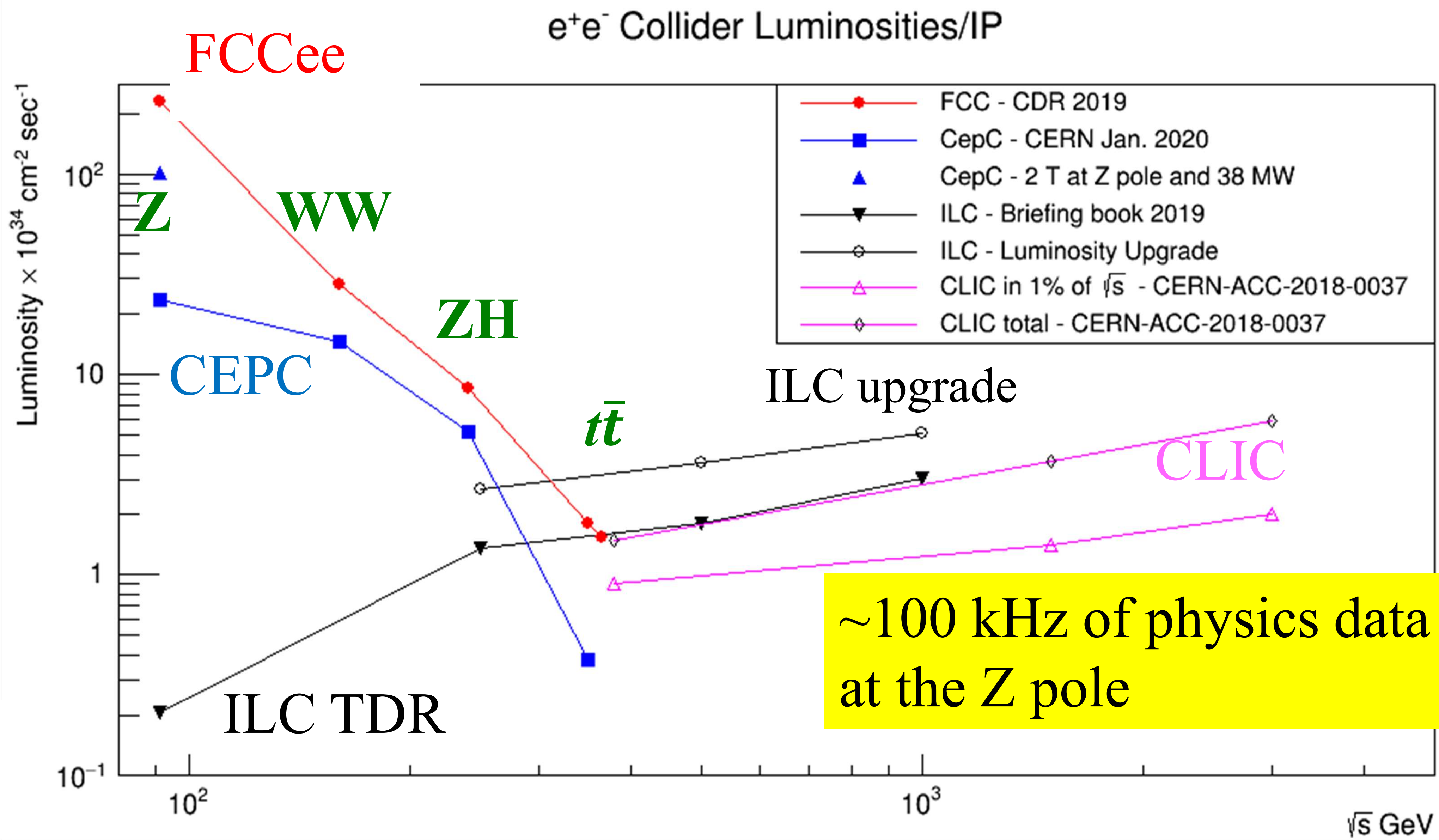
Milestone / activity	Target date	Possible timeline
First e^+e^- collisions in FCC-ee	2040	FCC-ee detector commissioning
Start machine installation	2037	Start FCC-ee detector installation
Tunnel completion	2035/36	
Start tunnel construction	2030	Start FCC-ee detector construction
Project approval	2028	FCC-ee Detector TDR's and approvals
Next ESPPU	2026/27	
Key prototypes (feasibility proof)	2025/26	FCC-ee Proto-collaborations and LoI's
CDR++/TDR (feasibility proof)	End 2025	CDR++ (Common work) Physics, Software, Technologies, R&D

Patrick Janot

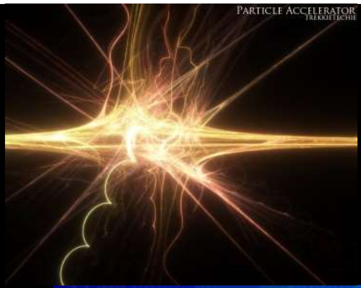
FCC Physics and Experiments General meeting
28 Sep 2020

6

Physics at FCC-ee

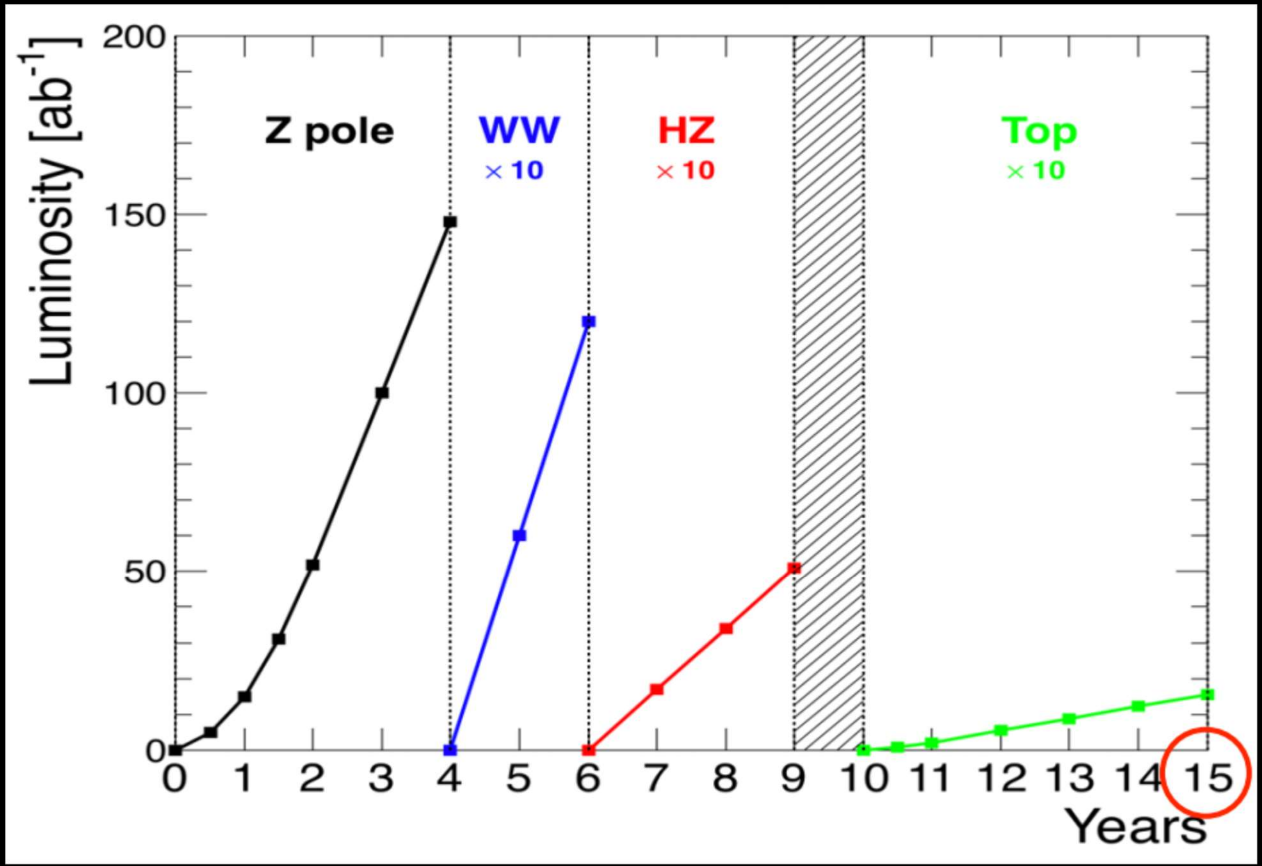


~100 kHz of physics data at the Z pole



Physics at FCC-ee

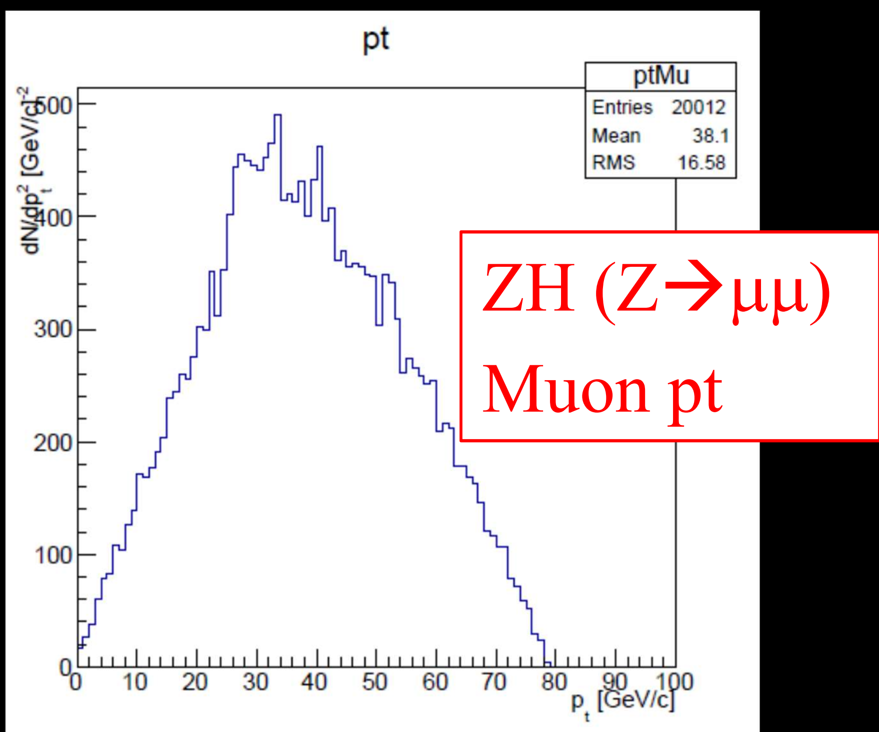
- Higgs factory
  - 10^6 e+e- $\rightarrow$ HZ
- EW & Top factory
  - 3×10^{12} e+e- $\rightarrow$ Z
  - 10^8 e+e- $\rightarrow$ W+W- ;
  - 10^6 e+e- $\rightarrow$ tt
- Flavor factory
  - 5×10^{12} e+e- $\rightarrow$ bb, cc
  - 10^{11} e+e- $\rightarrow$ τ+τ-
- Potential discovery of NP
  - ALPs, RH ν's, …

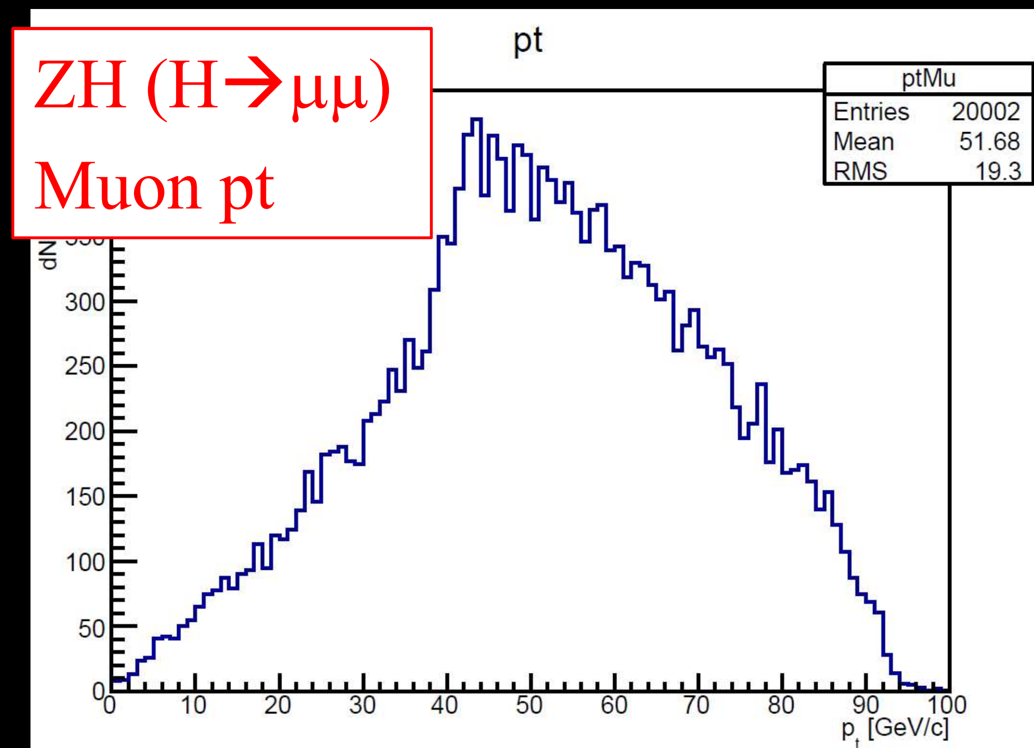


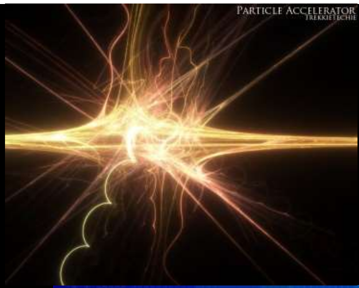
Physics plan still under discussion – Order may change

Requirements for Higgs physics

- Tracking:
  - Momentum resolution for Z recoil (and H→μμ)
    - Comparatively low momenta involved → transparency is important
  - Vertex resolution/transparency to separate g, c, b, τ final states







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  - Vertex resolution/transparency to separate g, c, b, τ final states
- **Calorimetry:**
  - Jet-jet invariant mass resolution to separate W, Z, H in 2 jets
  - Good π^0 ID for τ and HF reconstruction

Requirements for EWK/HF physics

- EWK:
  - Extreme definition of detector acceptance
  - Extreme EM resolution (crystals) under study
    - Improved π^0 reconstruction
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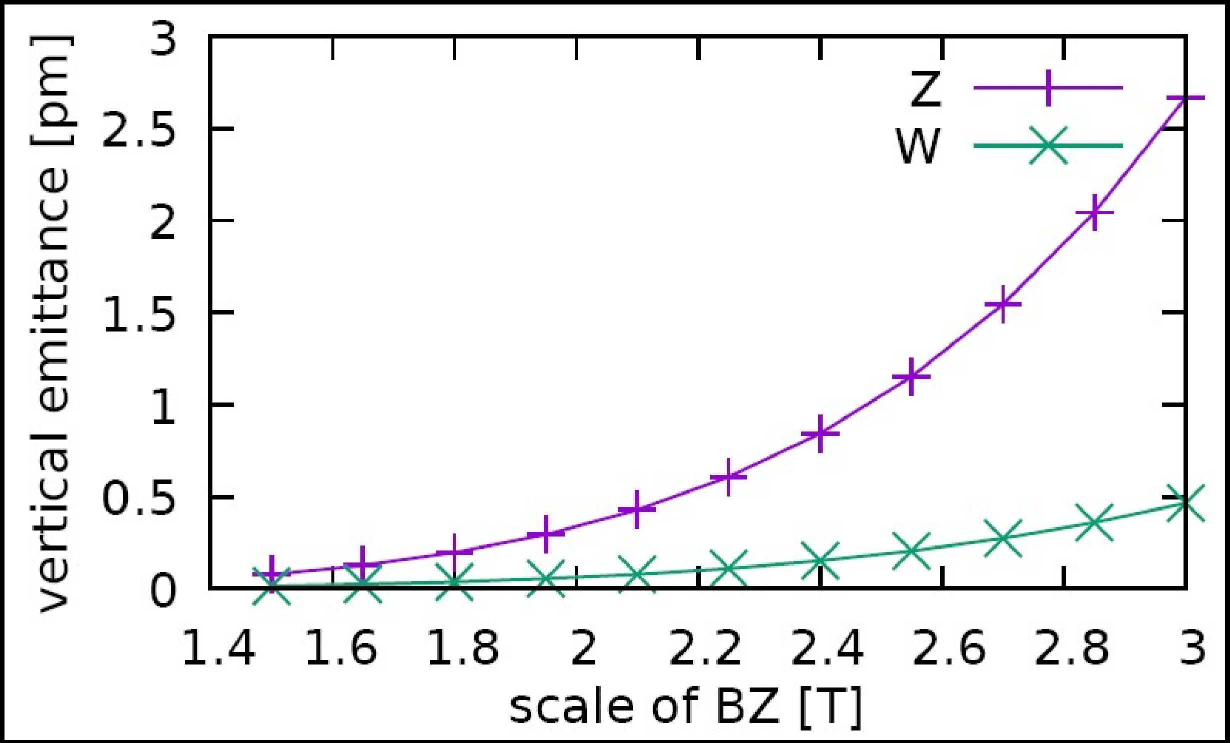
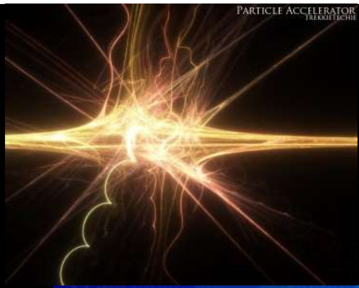
- Other requirements highly overlap with Higgs req.

Circular vs. Linear

- Low field detector solenoid to maximize luminosity
  - Optimized at 2 T
  - Large tracking volume → calorimeter outside → very thin coil





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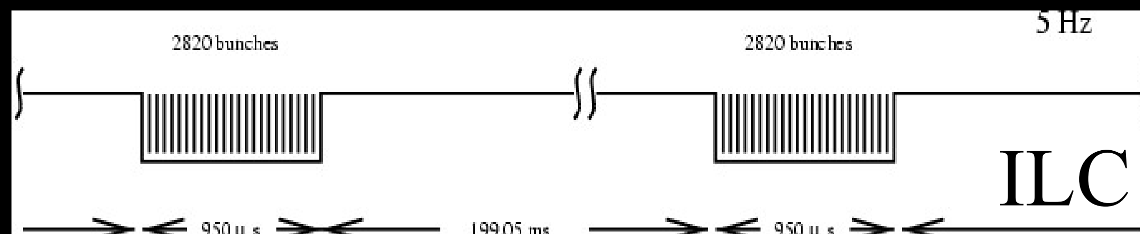
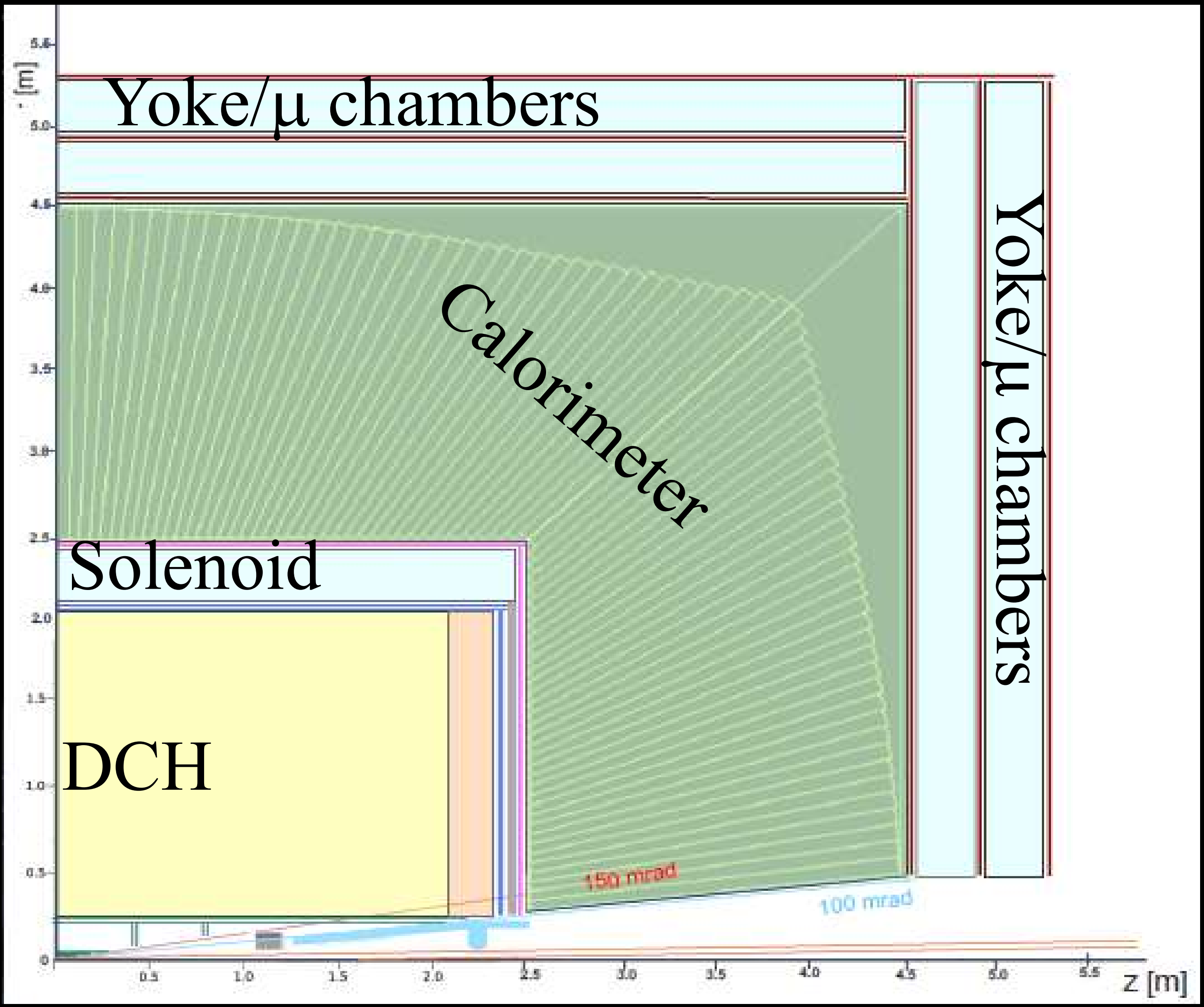


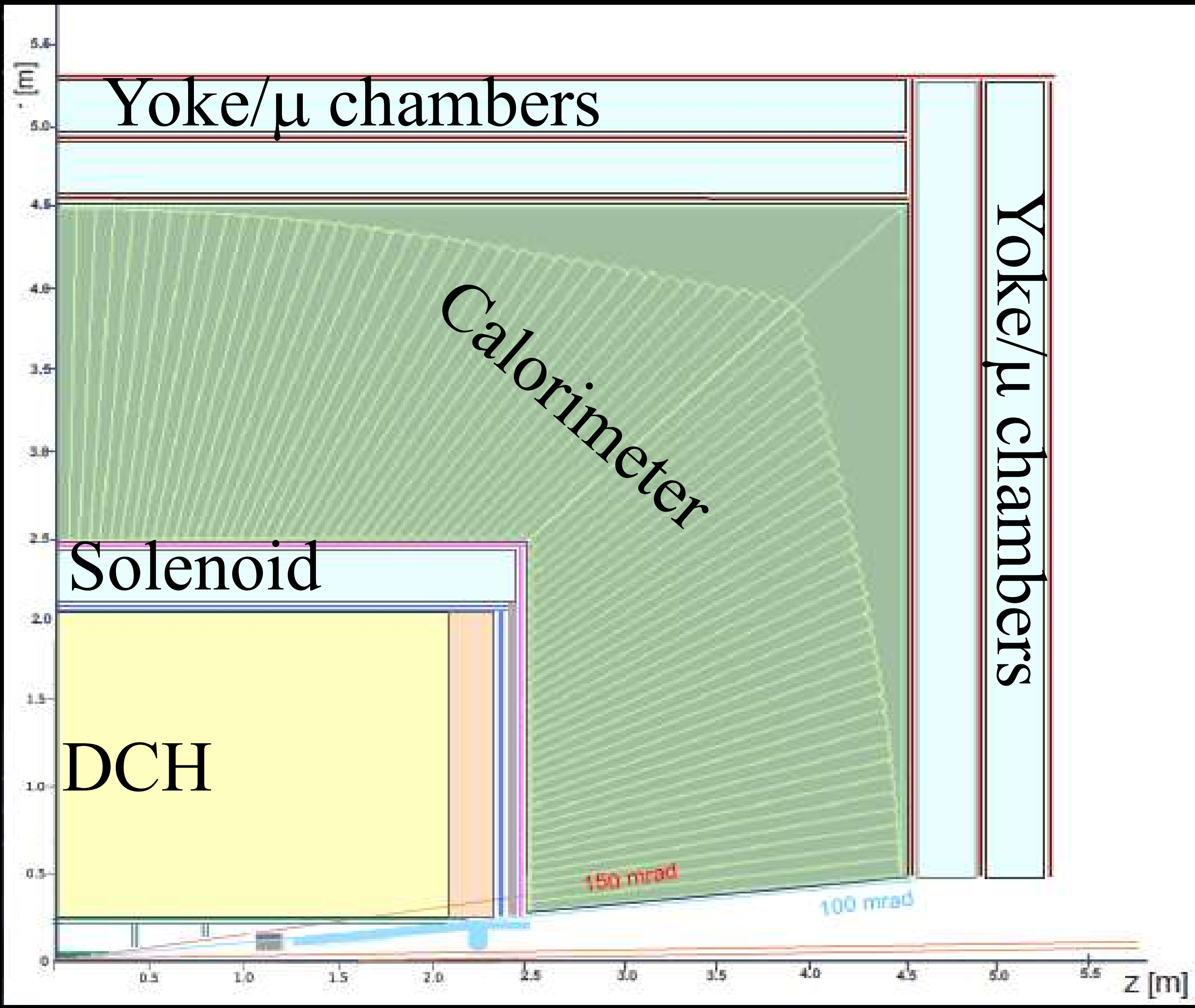
- ❖ Beam time structure:
  - ➢ Short bunch spacing (~ 20-30 ns Z, ~ 1 µs H)
  - ➢ No large time gap
    - Cooling issues for PF calorimeter and vertex detector
    - TPC ion backflow

IDEA layout



Yoke/μ chambers
Calorimeter
Yoke/μ chambers
Solenoid
DCH
150 mrad
100 mrad
z [m]
r [m]

IDEA layout



Small magnet

Small yoke

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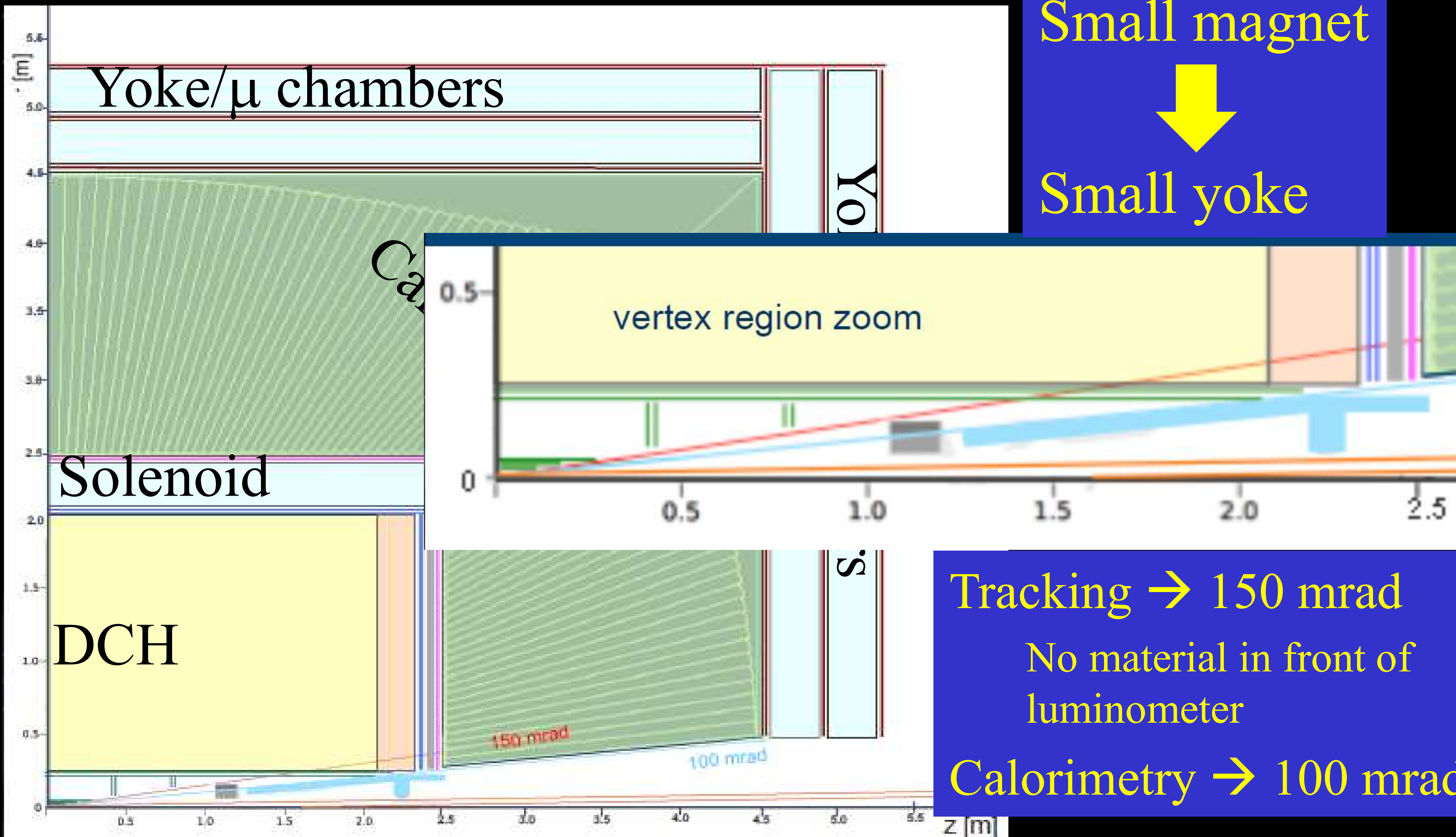
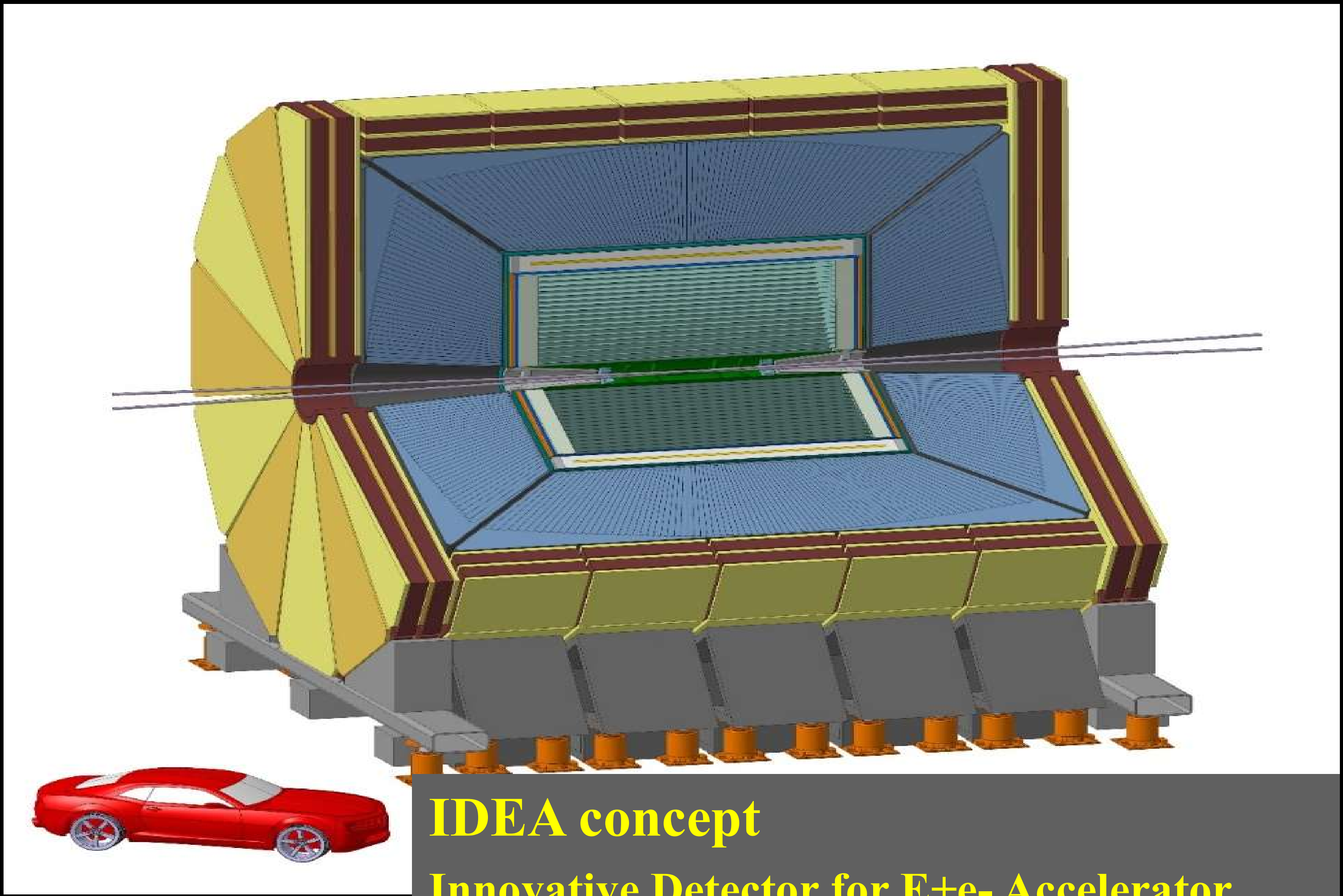


Small magnet
↓
Small yoke

Tracking → 150 mrad
- No material in front of luminometer

Calorimetry → 100 mrad

Detectors & R&D



IDEA concept

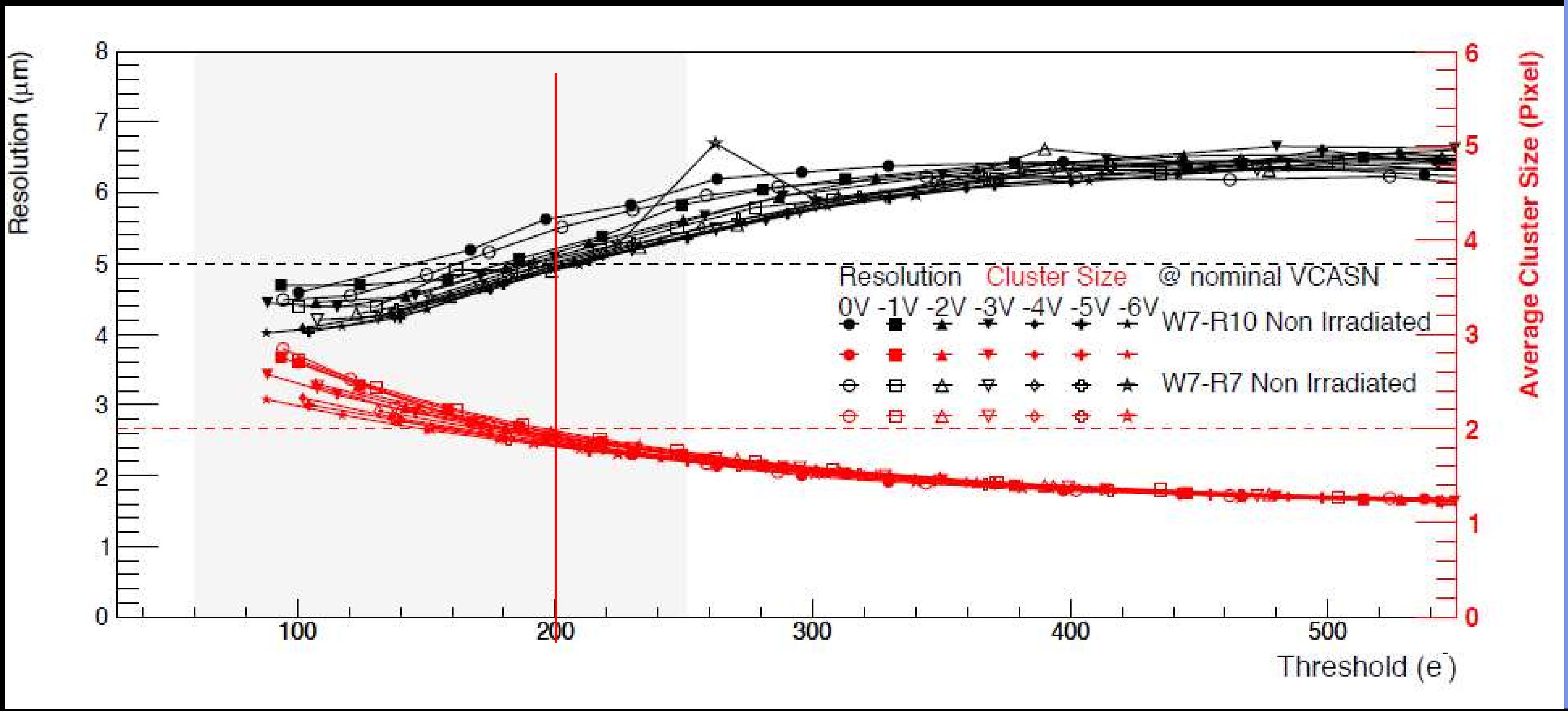
Innovative Detector for E+e- Accelerator

Vertex detector

- Transparency:
  - Low power (< 20 mW/cm^2) to allow air cooling

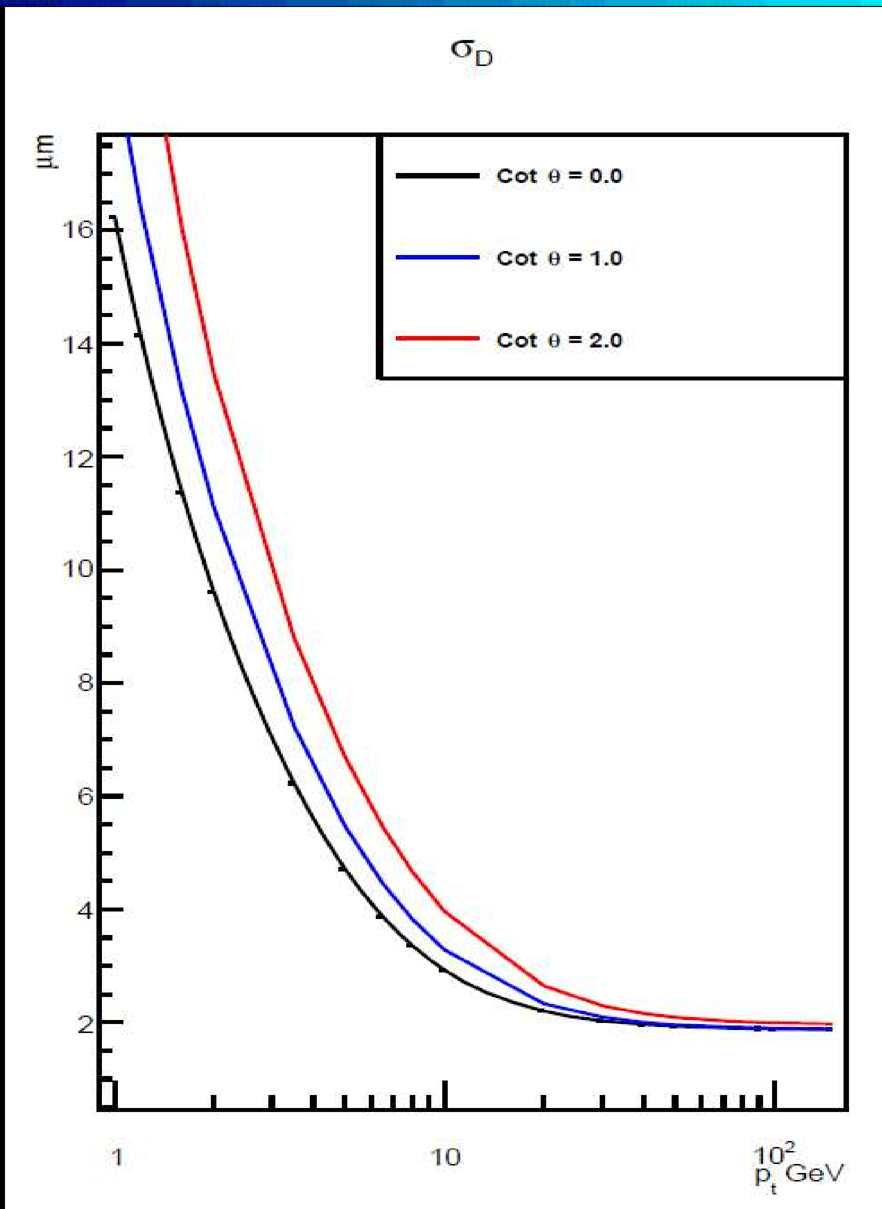
Vertex detector

- Transparency:
  - Low power (< 20 mW/cm^2) to allow air cooling
- Resolution:
  - 5 µm shown by ALICE ITS (30 µm pixels)
  - Aim at ~20 µm pixels for ~ 3 µm point resolution



Courtesy of ALICE J.W. van Hoorne

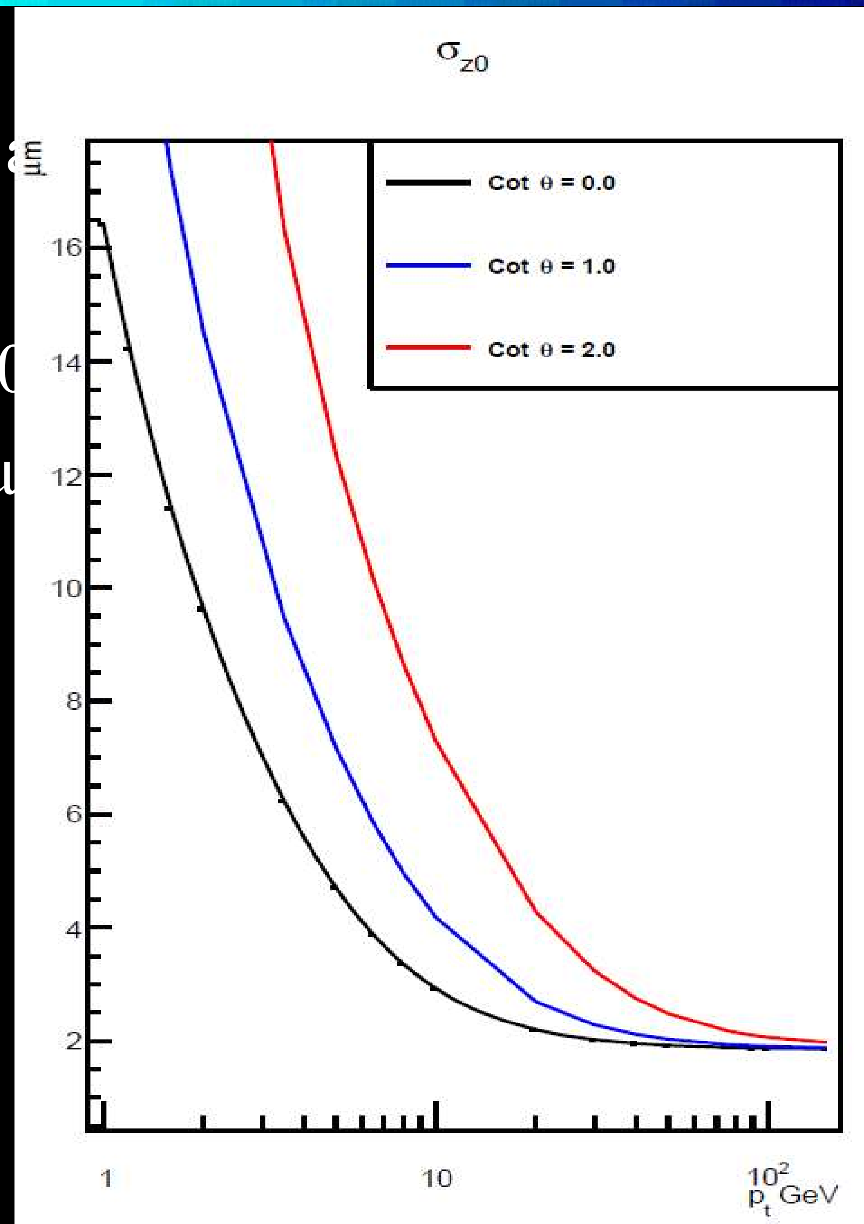
Vertex detector

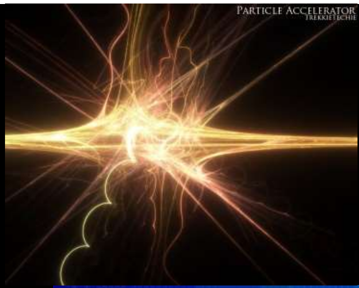


n^2) to a

TS (30

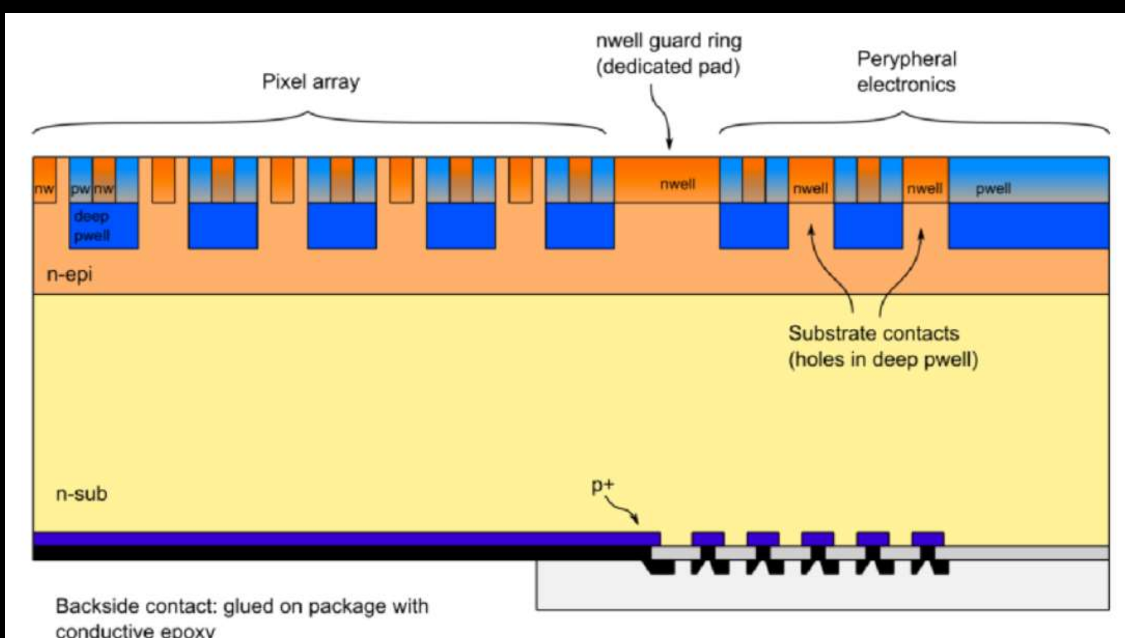
~ 3 μ

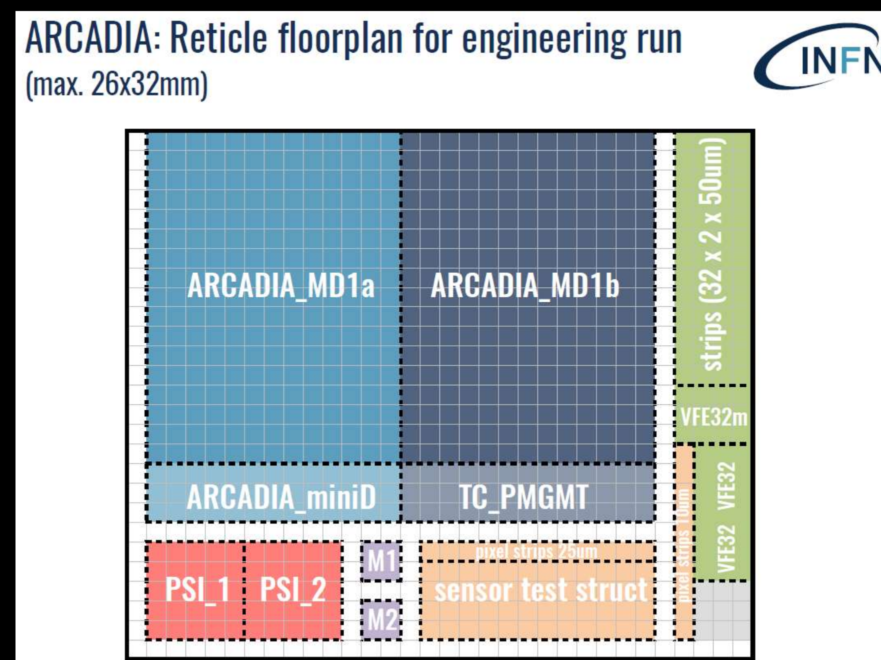


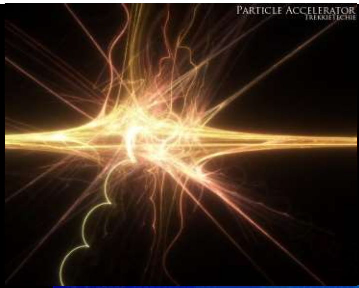


Silicon detector R&D

- Two paths with some overlap:
  - DMAPS pixel detector (ARCADIA/LFoundry)
    - Test beam with staves by ~ 2023
    - INFN-CSN5 call – 2019-2021 (~ 1 M€)
      - Additional funds secured also beyond 2021
    - MoU in progress with industry and other international labs







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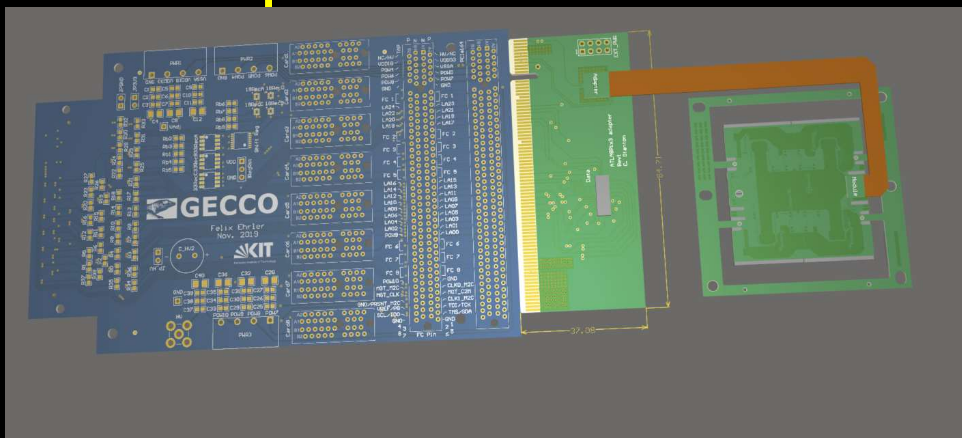
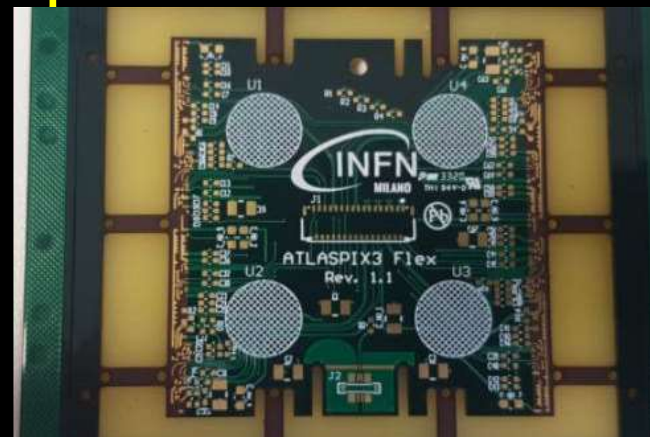
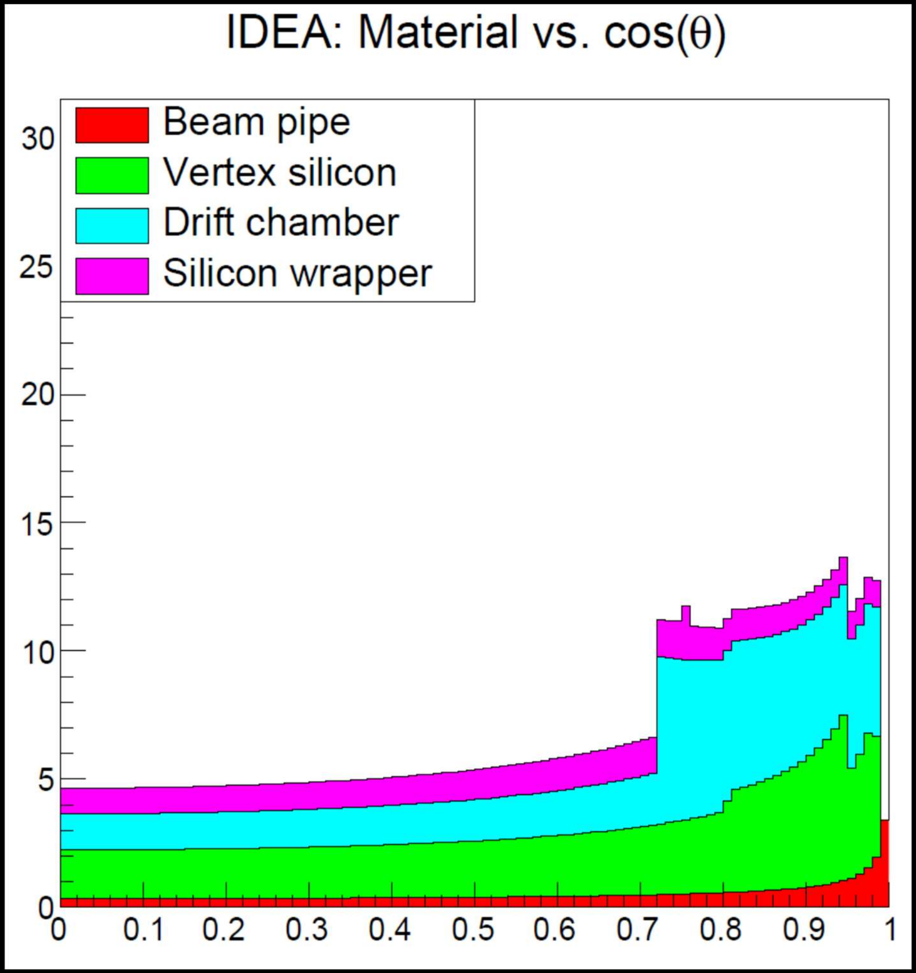


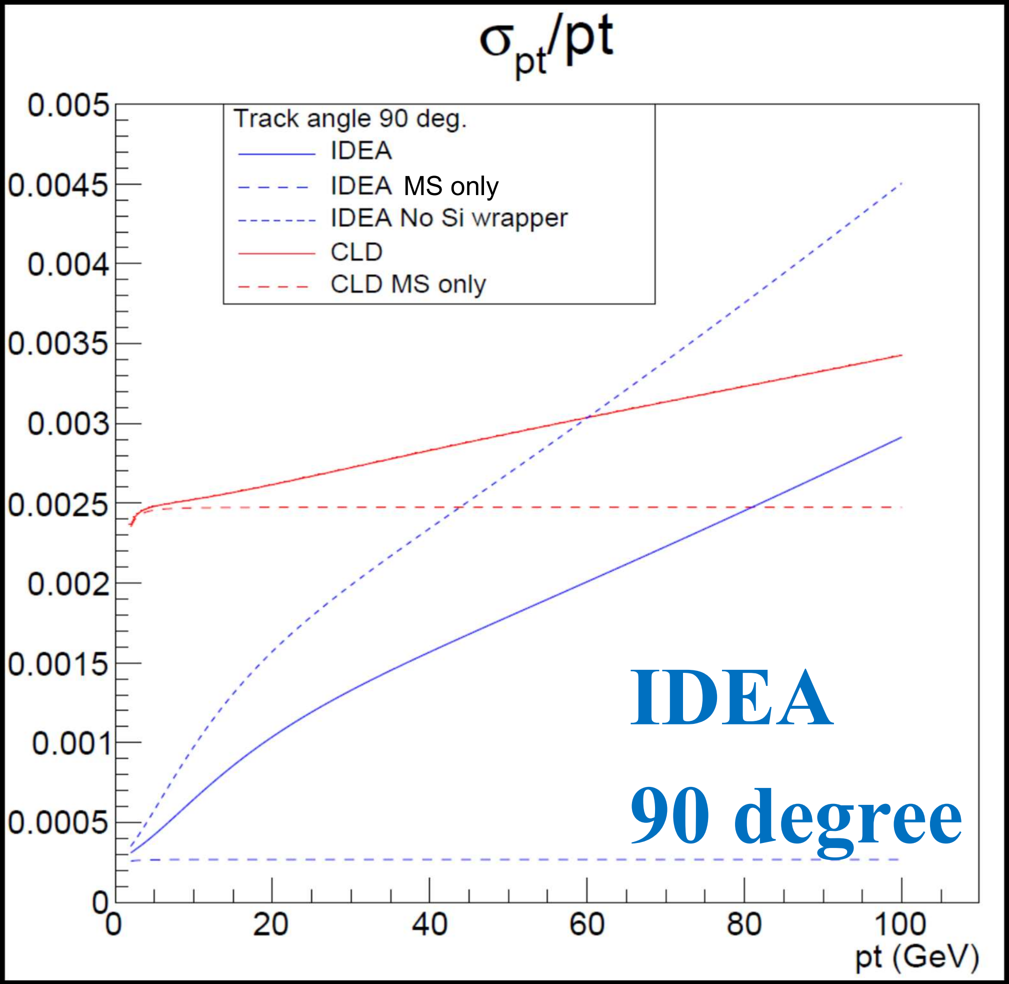


- Large area silicon (Pixels and strips)
  - First demonstrators use AtlasPix3 → modules for mini-staves
  - Full system test beam by 2022/23
  - New pixel development FCEPCPix1 in AMS
  - Passive CMOS micro-strips at Lfoundry
  - Large international collaboration:
    - **China**: Harbin, IHEP, NWPU, Shandong, SJTU, Tsingua, UTSTC; **Germany**: KIT; **Italy**: Milano, Pisa, Torino; **UK**: Bristol, Daresbury, Edinburgh, Lancaster, Liverpool, RAL, Sheffield, Warwick

Drift chamber

- High transparency and fast (max drift ~ 400 nsec)





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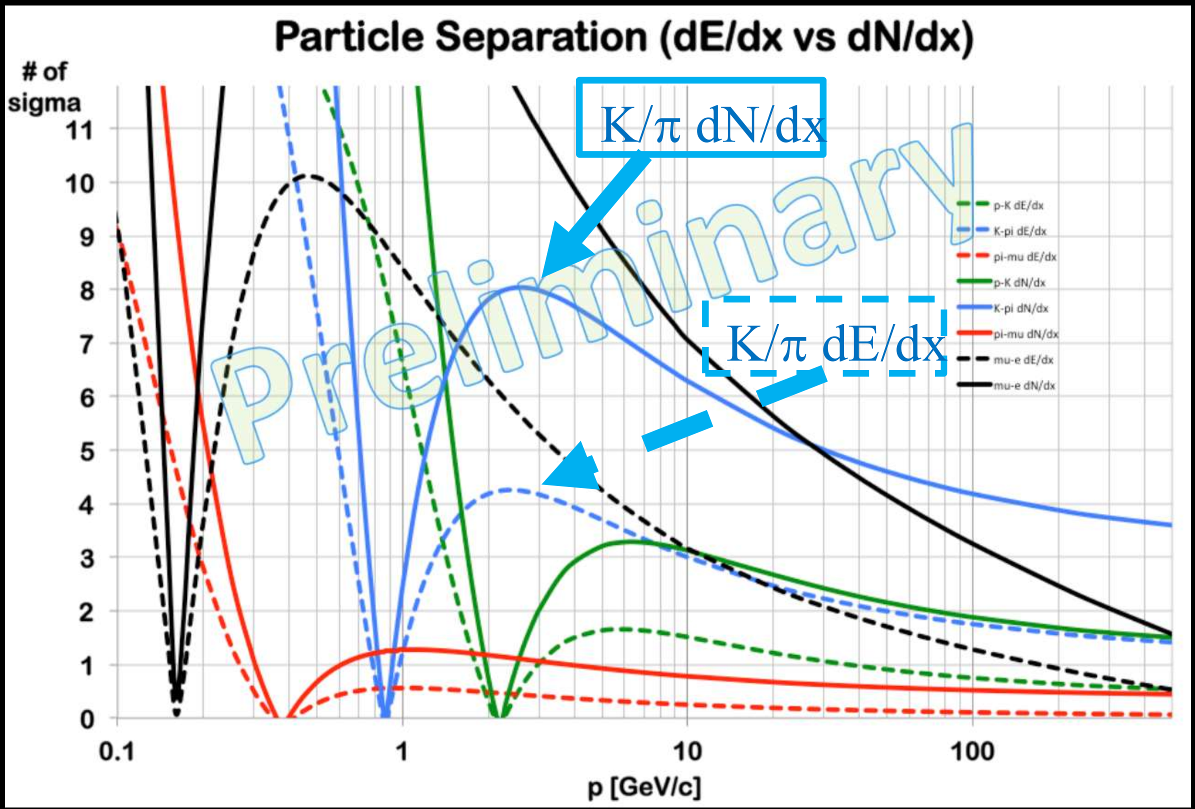
  - Excellent K/π separation except 0.75<p<1.05 GeV (blue lines)



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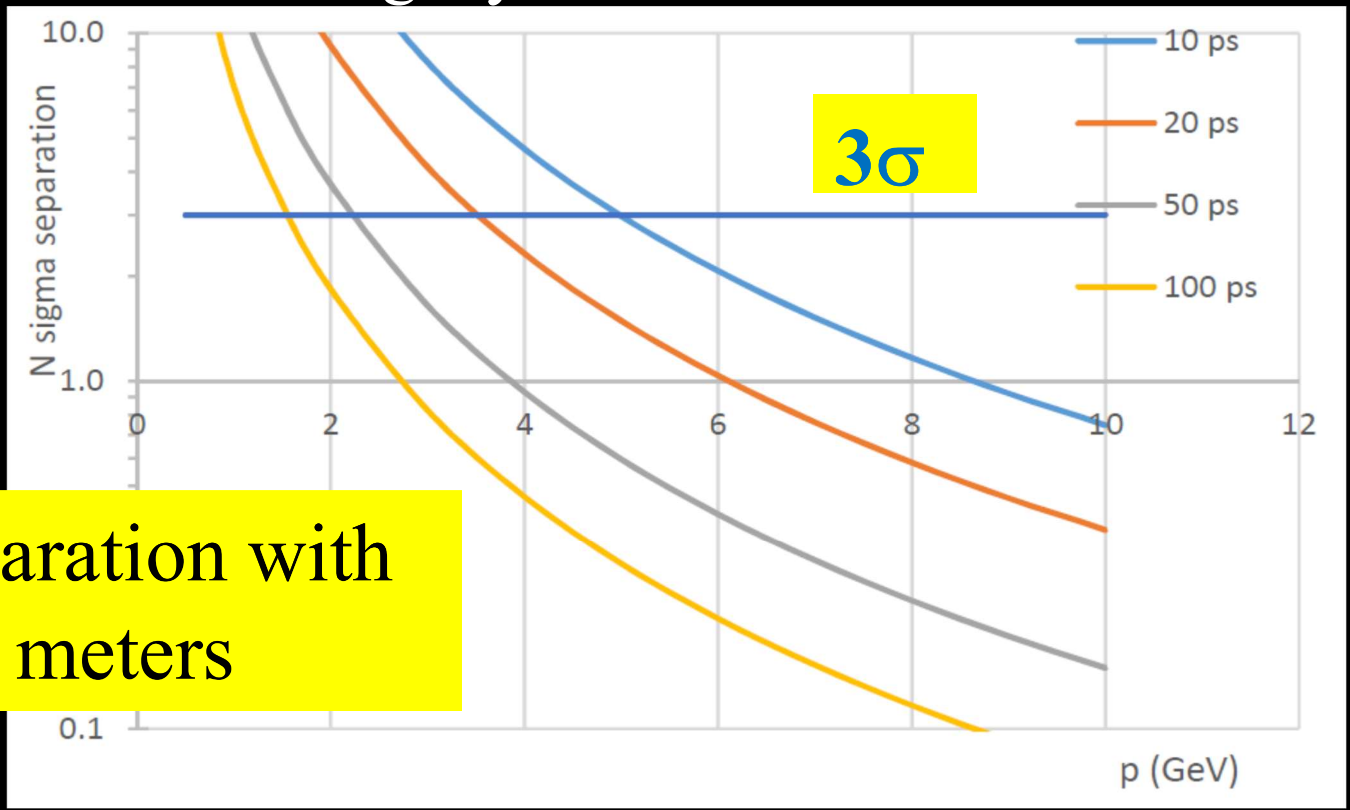
  - Could recover with timing layer



Nσ K/π separation with TOF over 2 meters

Drift Chamber R&D

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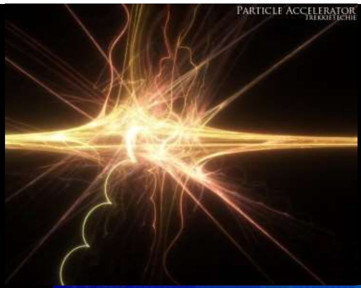

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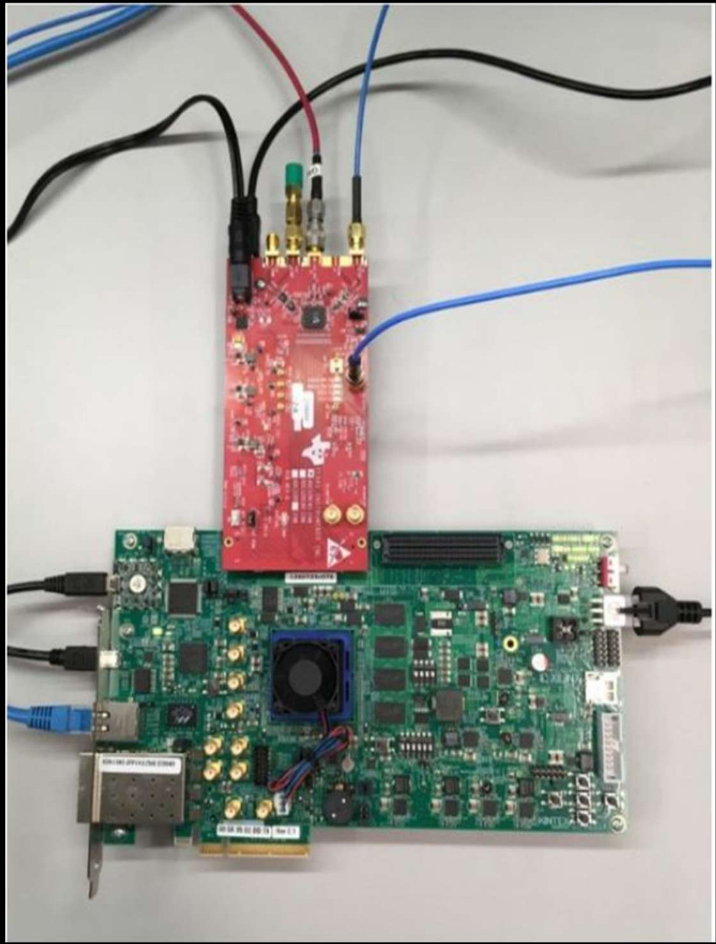

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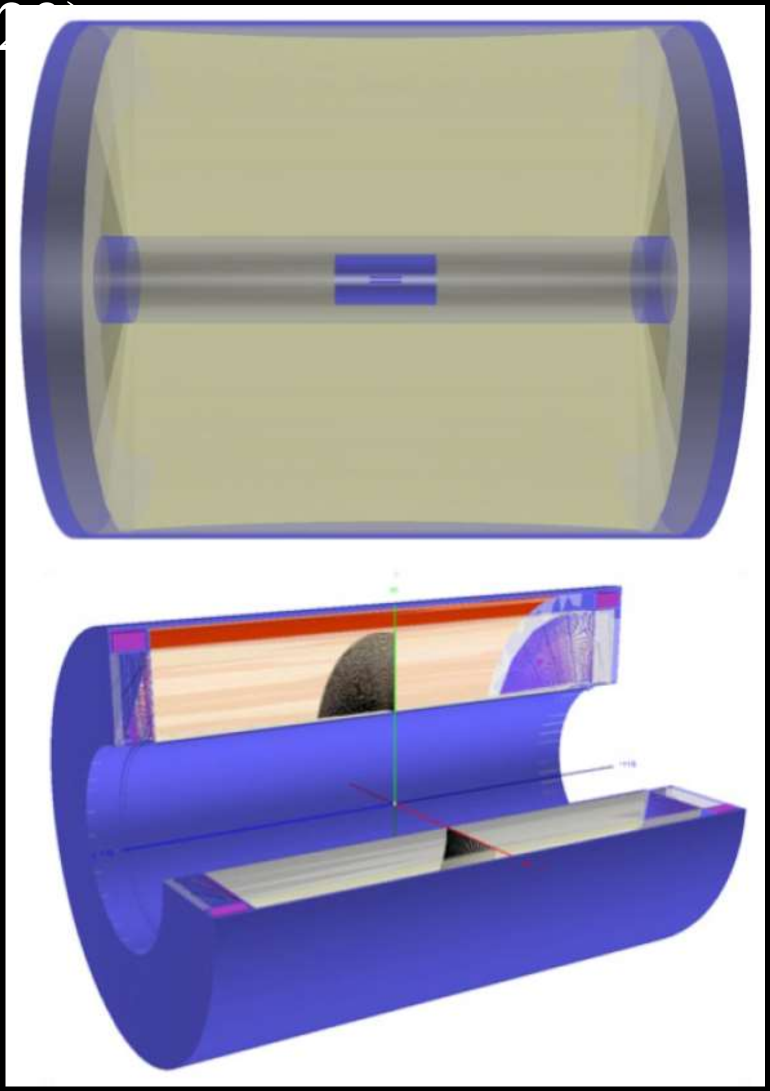
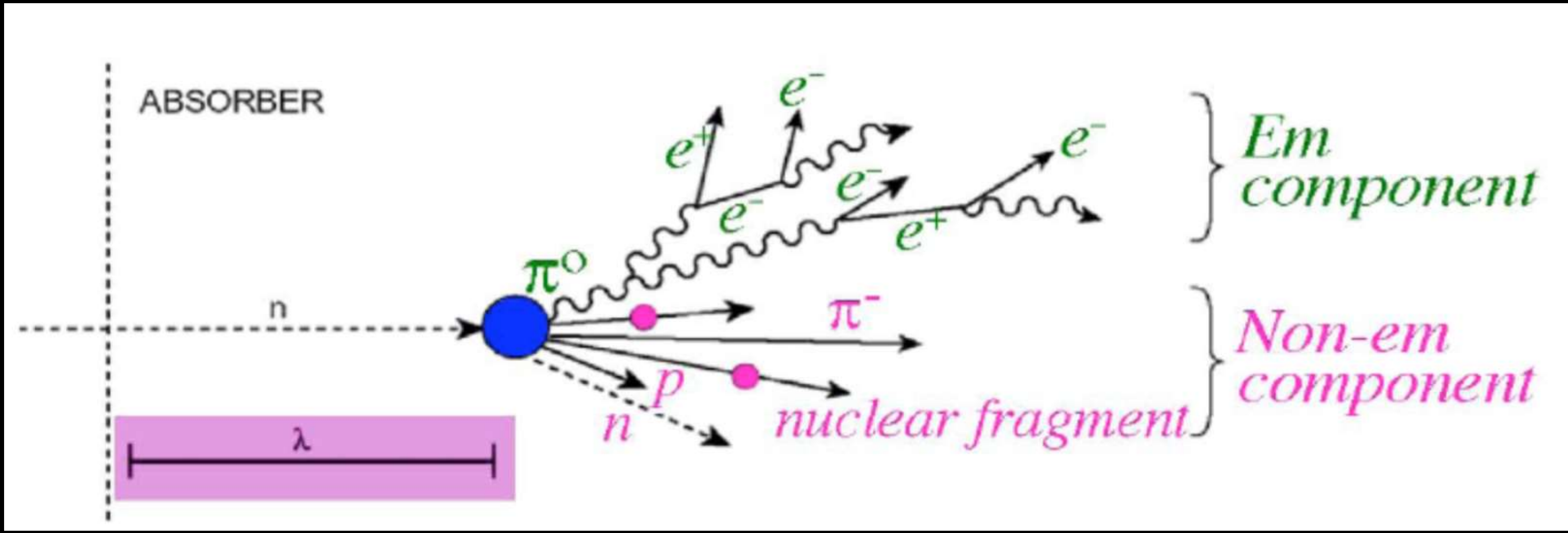


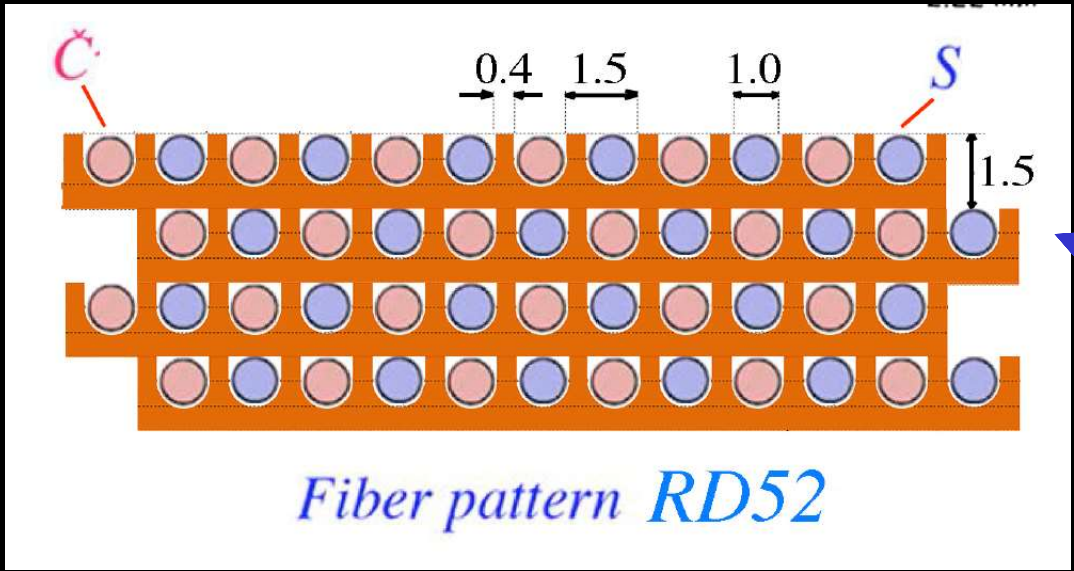
Dual Readout calorimeter

- Event by event correction for EM-had fluctuations
  - Principle demonstrated by DREAM/RD-52



Dual Readout calorimeter

- Event by event correction for EM-had fluctuations
  - Principle demonstrated by DREAM/RD-52
- EM and hadron calorimeter in a single package
  - All electronics in back easy to cool and access
- NEW: mechanics, SiPM readout, readout electronics

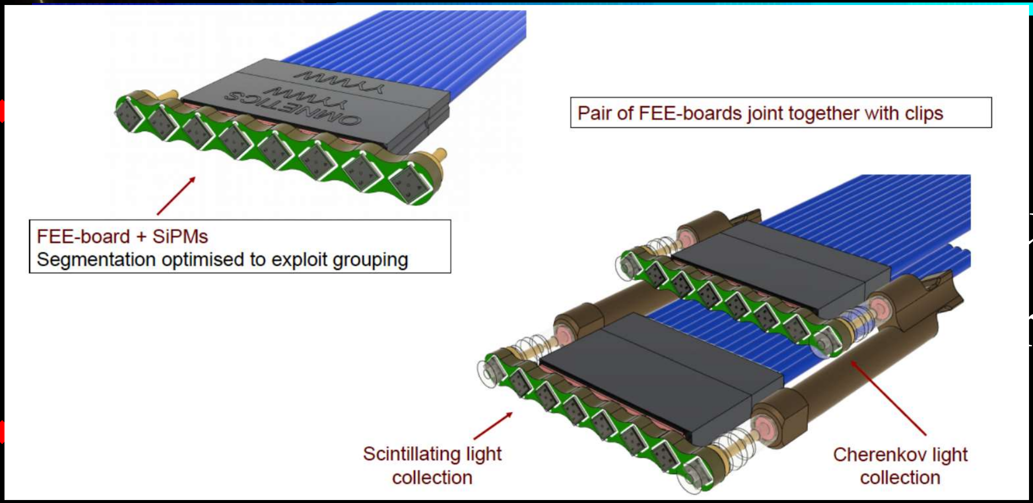


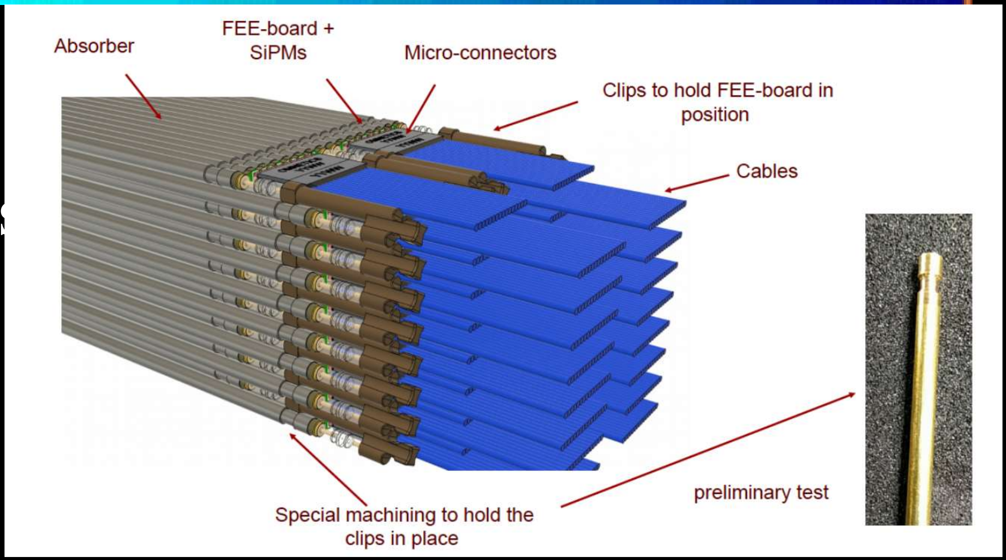
Alternating scintillating and clear fibers in metal matrix

Dual Readout calorimeter R&D

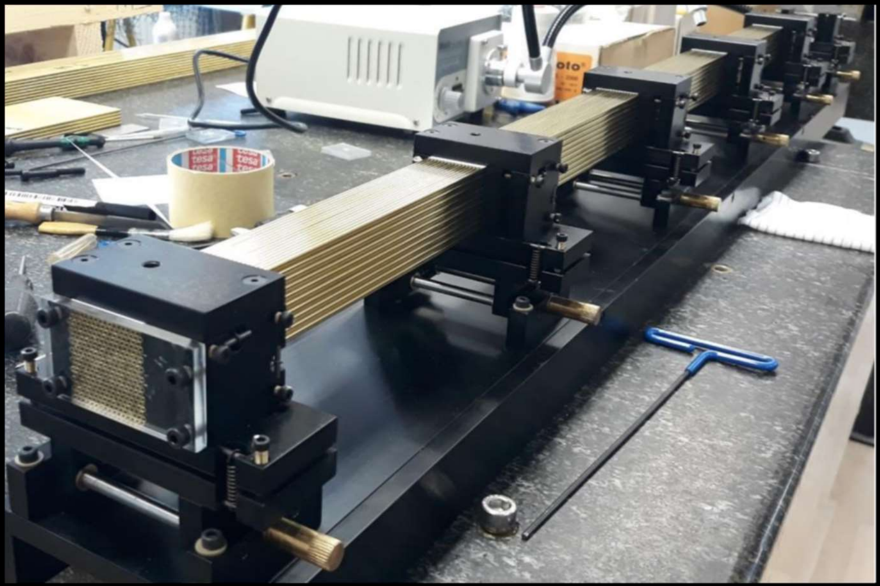
- Collaboration:
  - INFN (Italy), RBI (Croatia), Sussex (UK), Korea – (2 M$/5 yr)
  - Princeton, Maryland (USA) for potential crystal EM addition

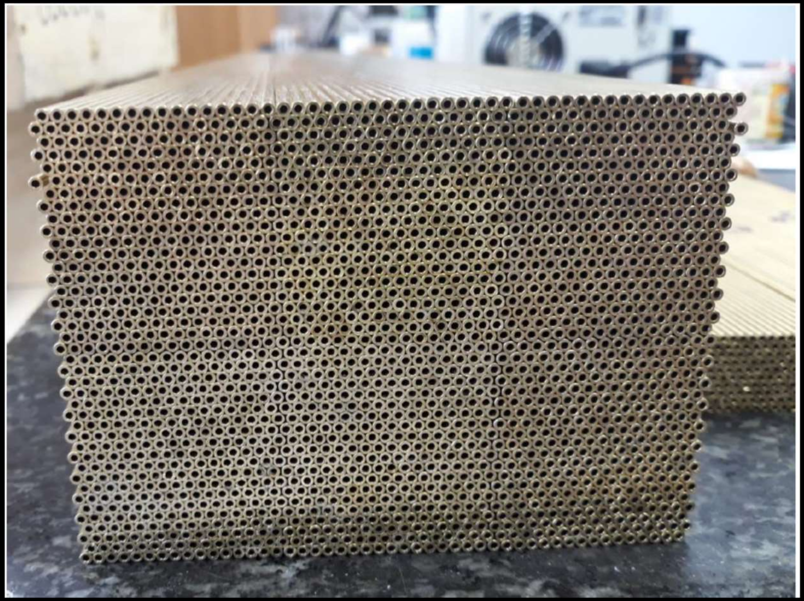
Dual Readout calorimeter R&D

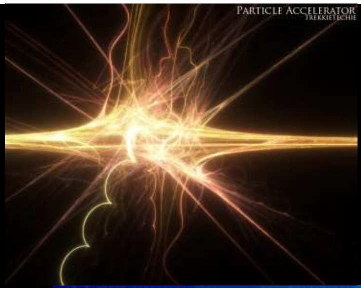




- Scalable mechanics







Dual Readout calorimeter R&D

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  - Princeton, Maryland (USA) f
- Activities:
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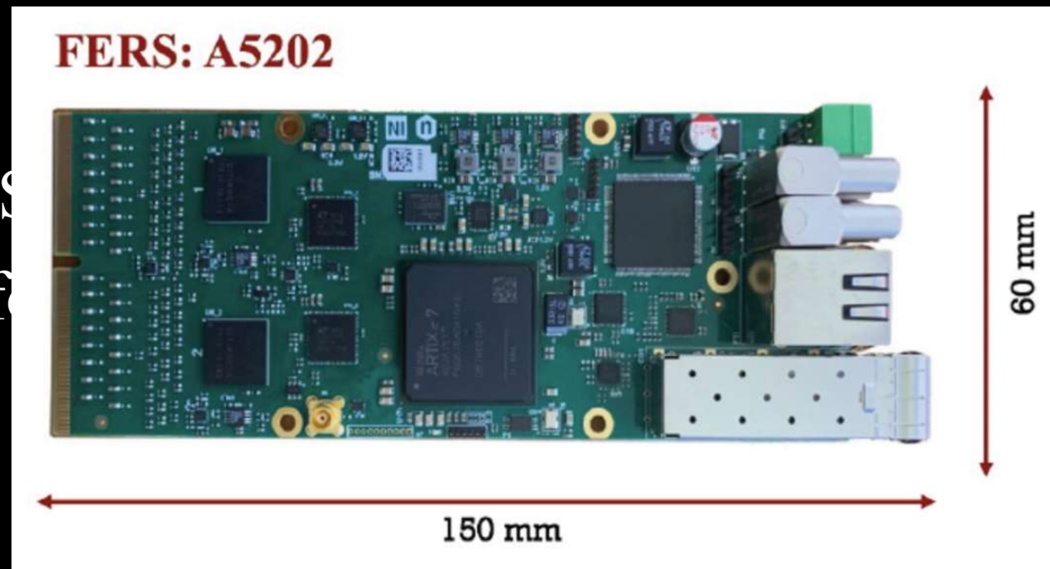
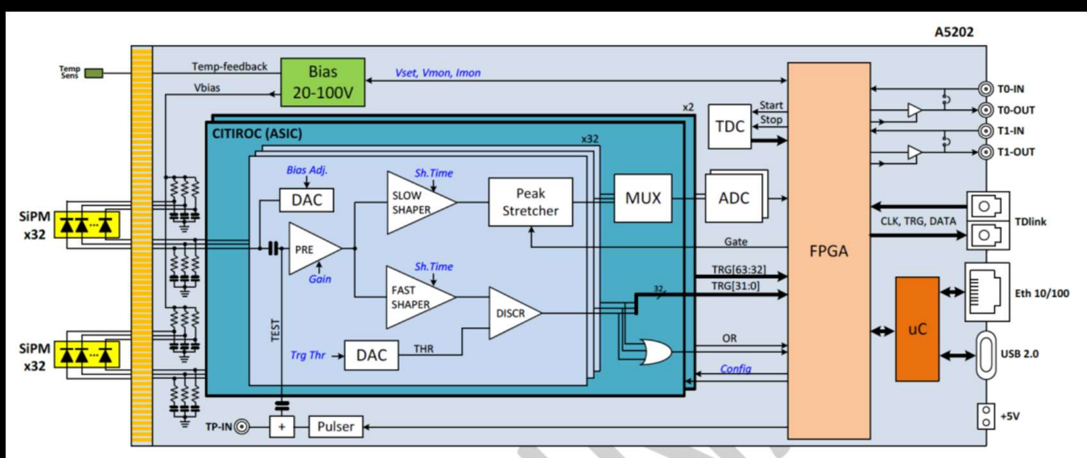
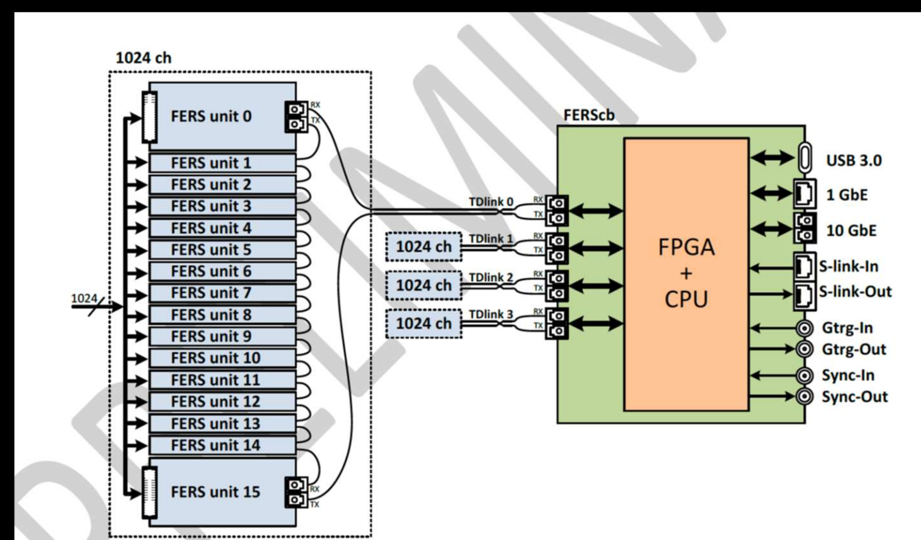
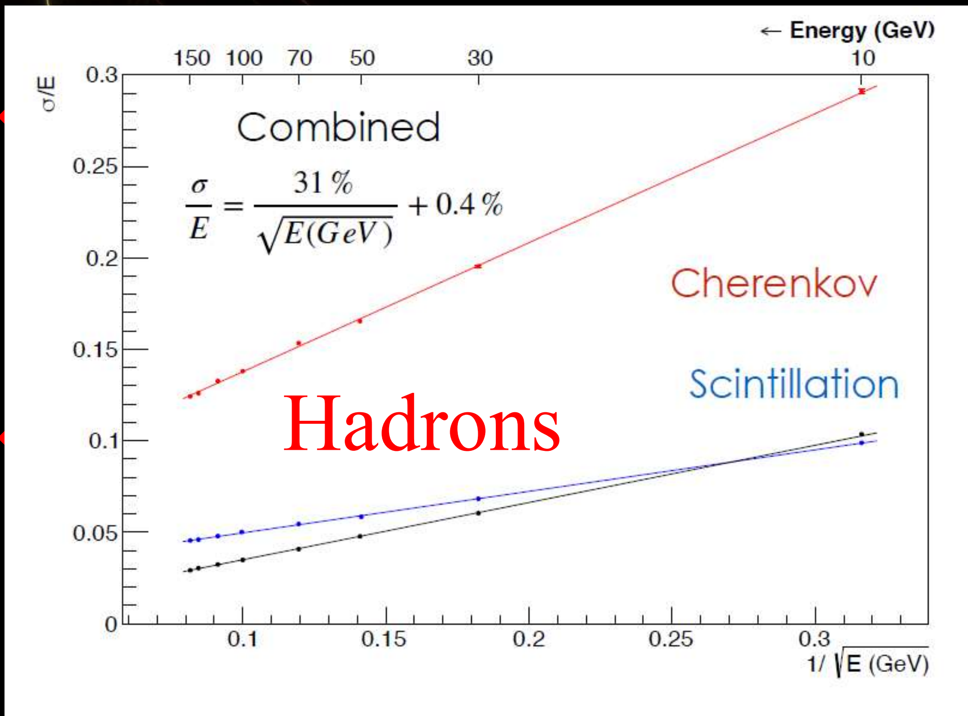
  - Scalable SiPM readout

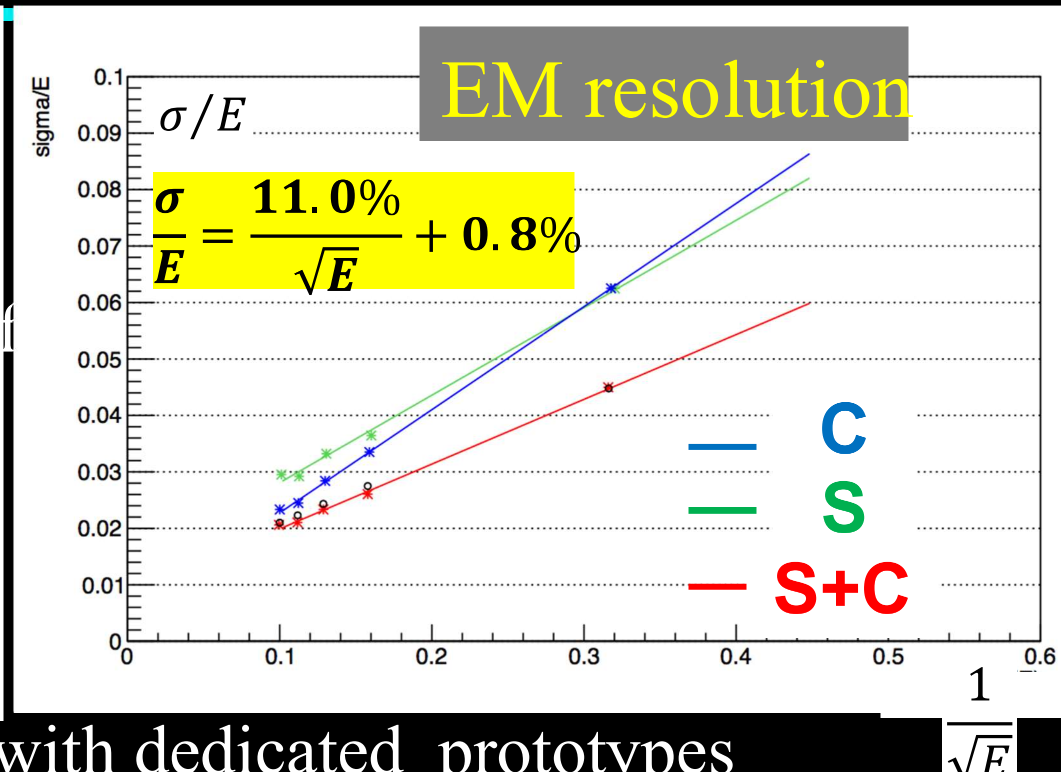






Dual Readout calorimeter R&D





- Performance demonstration with dedicated prototypes
  - EM 2021, HAD ~ 2024

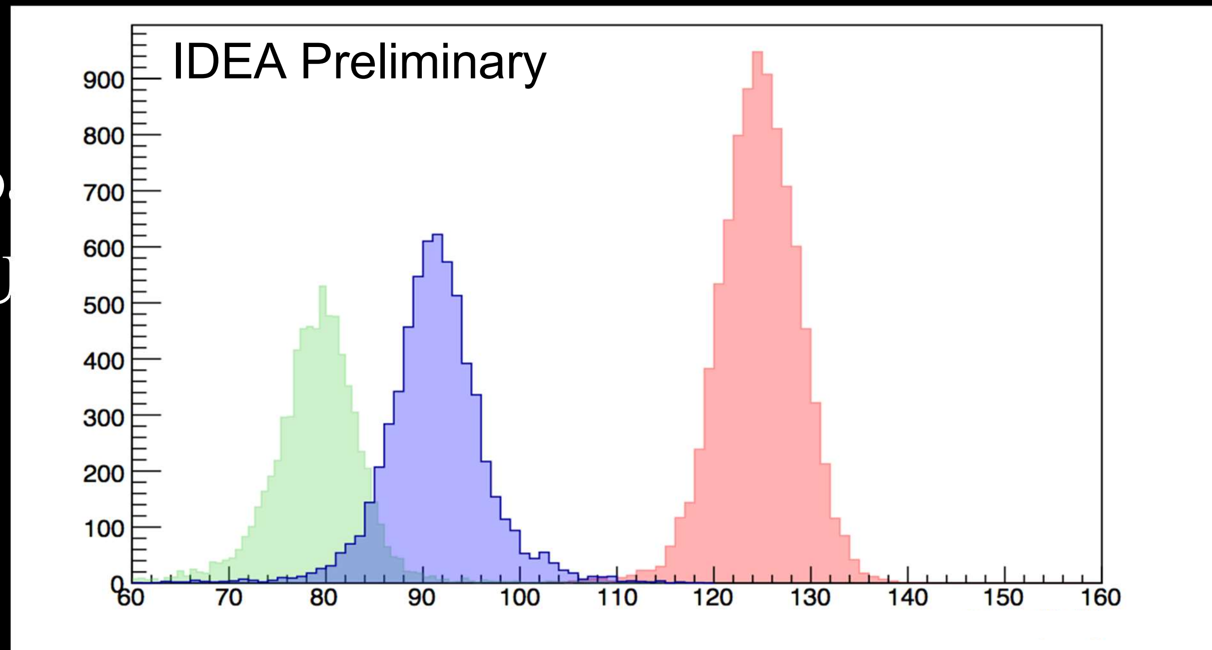
Dual Readout calorimeter R&D

❖ Collaboration:

$e^+e^- \rightarrow HZ \rightarrow \tilde{\chi}^0\tilde{\chi}^0 jj$

$e^+e^- \rightarrow WW \rightarrow \nu_\mu \mu jj$

$e^+e^- \rightarrow HZ \rightarrow bb\nu\nu$



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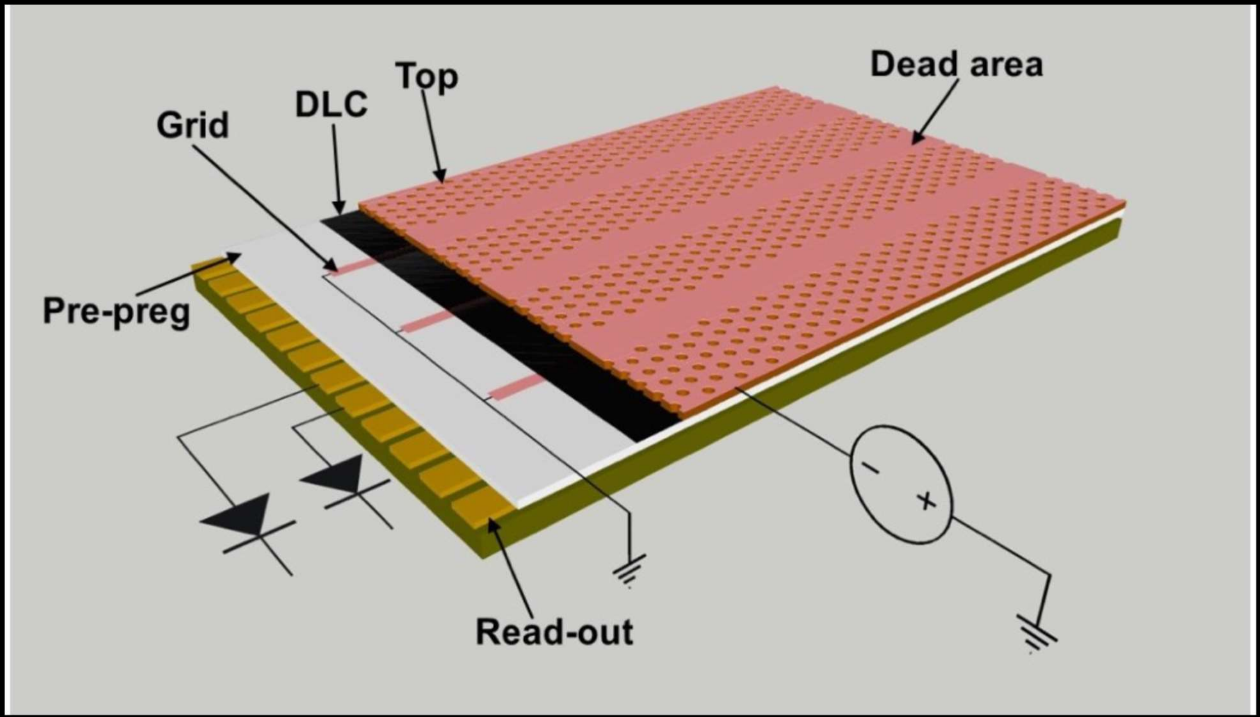

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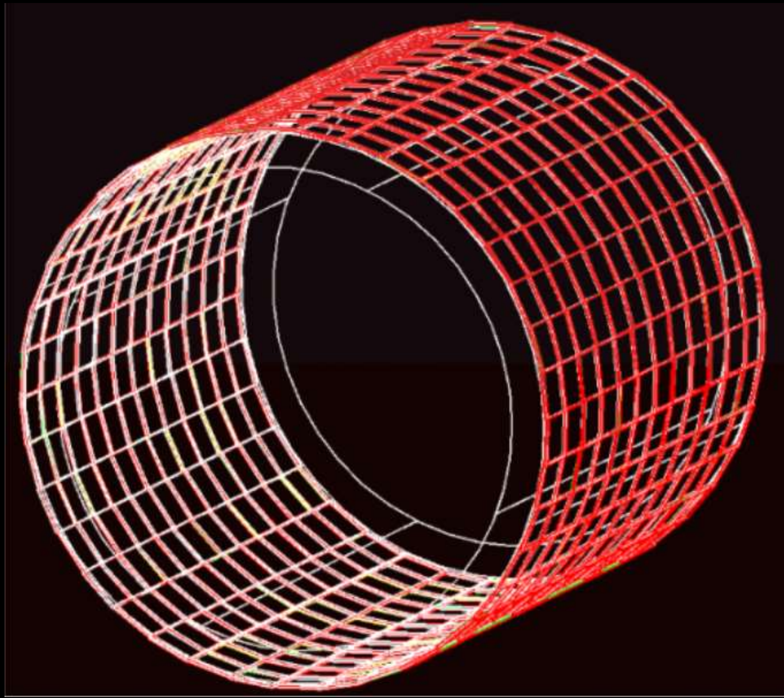
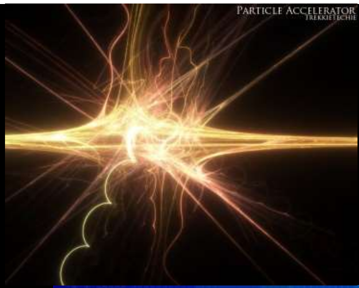


Software

- Significant SW R&D and studies in progress
  - Worldwide development of Key4HEP guided by CERN
    - DD4HEP, EDM4HEP, ….. for the serious SW developer
  - Lot of infrastructure for IDEA:
    - DELPHES card available
    - Full GEANT simulation in progress
  - FCCee physics groups restructured to tackle several “case studies”
    - Physics Performance Coordinators recently appointed
      - P. Azzi (INFN), E. Perez (CERN)

Final comments

- Summary of main features:
  - High precision vertex detector
  - High transparency and momentum resolution
    - Good integrated PID with cluster counting → even better with timing layer
  - Excellent calorimetry → FANTASTIC with crystals
  - Light solenoid and minimal yoke
  - Tracking muon system
  - Excellent performance at all energies: Z, WW, ZH, tt



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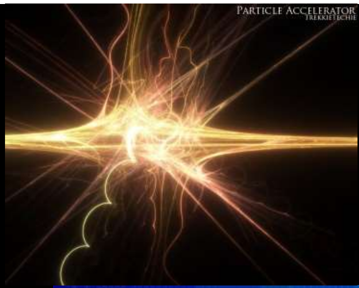

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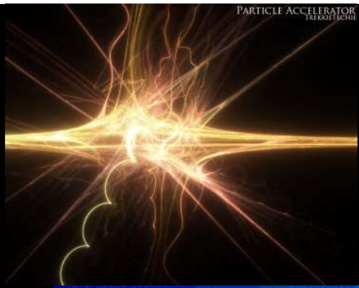
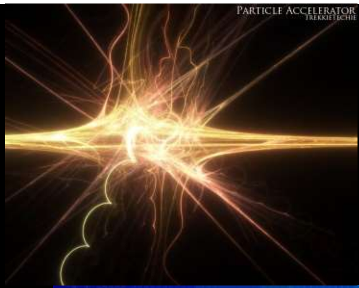
- Collaboration on all these R&D's is growing internationally, but there is still ample space for additional contributions



Additional material

Special funding (1)

- Programs active in 2021:
  - ARCADIA (CSN5) - Pixel DMAPS
  - Cremlin + (EU) - Drift Chamber/cylindrical μRwell
  - FEST (EU) - CEPC: Software/Physics
  - FCC-IS - FCC accelerator R&D



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  - FCC-IS - FCC accelerator R&D

- Programs seeking approval in 2021:
  - HiDRa (CSN5) - Dual Readout calorimetry
  - ITN SPIRAL-NET - e+e- collider performance studies

Special funding (2)

- Programs seeking approval in 2021
  - AIDAinnova (EU)
    - WP 5 – Pixel MAPS – tasks: 5.2.1/ 5.2.2
      - ARCADIA/Belle2
    - WP 7 – Gas Detectors – tasks: 7.3.2/ 7.4.1
      - μRwell chambers/drift chamber readout
    - WP 8 – Calorimetria – tasks: 8.4.2
      - Dual readout calorimeter
    - WP 10 – Cooling per VTX – tasks: 10.2
      - Cooling substrates/microcooling
    - WP 11 – Microelettronica – tasks: 11.3
      - ASICS per μRwell
    - WP 12 – Software – tasks: 12.2.1 /12.4.2/ 12.5.2
      - Key4HEP/MPGD simulation/Particle flow for Dual readout cal.

FCC-IS Design Study – just approved by EU-H2020 NEW!

- **FCC-IS** (Innovation Study) is a **design study** project: **3M€ for 4 years**
- Kick-off: 9-10 November 2020

Goal of the FCC-IS study: Carry out the technical design study for a 100 km long luminosity frontier circular collider infrastructure at CERN that will extend Europe's leadership in the domain of fundamental physics research until the end of the 21st century.

The study **focuses on the high priority topics to prepare the ground for a construction project by 2026.**

First priority: optimisation of the particle collider design.

It includes both design and prototyping.

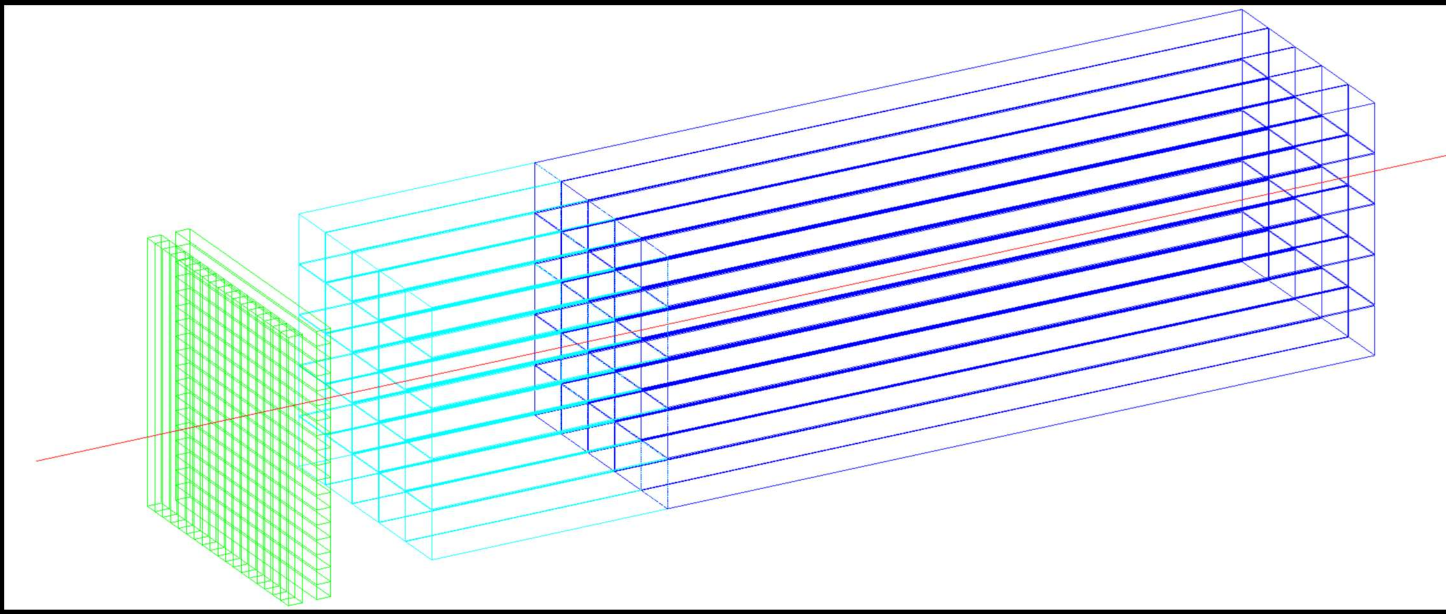
- INFN-LNF participates to FCCIS *(Scientific Responsible for INFN: M. Boscolo)*
- MDI is included in the proposal as well as instabilities and impedance studies

- There is usually **strong competition** for Design Studies. Proposals come from every field of science, including social sciences and humanities. At the last call (November 2019) the success rate was only **18%** (10 project approved out of 60 submitted, only 1 for physics selected: FCC-IS).
- **Examples**: at the moment, for accelerators 2 DS have just completed (EuPraxia for a compact plasma-based FEL and EuroCirCol for FCC), ESSnuSB for a neutrino superbeam at ESS is ongoing, FCC-IS, for FCC-ee, has been just approved.

Back

Crystal option

- ~20 cm $PbWO_4$
- $3\%/\sqrt{E}$
- DR w. filters
- Timing layer
  - Lyso 20-30 ps



1x1x5cm^3 PbWO

1x1x15cm^3 PbWO

- **ECAL layer:**
  - PbWO crystals
  - front segment 5 cm (~5.4X_0)
  - rear segment for core shower
  - (15 cm ~16.3X_0)
  - 10x10x200 mm³ of crystal
  - 5x5 mm² SiPMs (10-15 um)