Overview of the IDEA detector

OUTLINE

- The detector
- Detector design guidelines
- Ongoing R&D
- Concluding comments
Detector concept IDEA

- Si pixel vertex detector
  - 5 MAPS layers
  - $R = 1.7 - 34$ cm
- Drift chamber (112 layers)
  - 4m long, $r = 35 - 200$ cm
- Si wrapper: strips
- Solenoid: 2 T - 5 m, $r = 2.1-2.4$
  - $0.74 \times X_0$, $0.16 \lambda$ @ 90°
- Pre-shower: μRwell
- Dual Readout calorimetry
  - 2m deep/8 $\lambda$
- Muon chambers
  - μRwell
IDEA details

Small magnet

Small yoke
IDEA details

Small magnet
Small yoke

Yoke/µ chambers
Solenoid
DCH
Calorimeter

vertex region zoom

150 mrad
100 mrad
Design guidelines: Luminosity

- Maximize luminosity $\rightarrow$ Low field detector solenoid
  - Optimized at 2 T
  - Large tracking volume $\rightarrow$ calorimeter outside $\rightarrow$ very thin coil
Design guidelines: Momentum resolution

- Z or H decay muons in ZH events have rather small $p_t$

ZH (Z → $\mu\mu$) Muon pt

ZH (H → $\mu\mu$) Muon pt

FCC Phys. & Det. Workshop, Jan. 2020

F. Bedeschi, INFN-Pisa
Design guidelines: Momentum resolution

- Z or H decay muons in ZH events have rather small $p_t$
  - Transparency more relevant than asymptotic resolution
Design guidelines: Vertex detector

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

![Graph showing resolution vs. threshold](image-url)
Design guidelines: Vertex detector

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

- **Resolution:** Expected vertexing resolutions

---

**Graphs**

- **$D_0$ (µm)**
- **$Z_0$ (µm)**

  - Track angle 90 deg.
  - IDEA
  - CLD

---

FCC Phys. & Det. Workshop, Jan. 2020

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Tracking benchmarks

- Fast simulation with full covariance matrix

Higgs recoil

$HZ \rightarrow H \mu \mu$

No cuts
Tracking benchmarks

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Higgs recoil

$HZ \rightarrow H \, \mu\mu$

$H$ inv. mass

$ZH \rightarrow Z \, \mu\mu$
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IDEA card now in DELPHES

Higgs recoil

$HZ \rightarrow H \mu\mu$

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$ZH \rightarrow Z \mu\mu$
Design guidelines: PID

- Cluster counting in DCH for good dE/dx resolution
  - Excellent K/π separation except 0.75<p<1.05 GeV (blue lines)
Cluster counting in DCH for good dE/dx resolution

- Excellent K/π separation except 0.75<p<1.05 GeV (blue lines)
- Could recover with timing layer

Nσ K/π separation with TOF over 2 meters

3σ

GeV
Design guidelines: calorimeter

- Good, but not extreme EM resolution
  - $\sim 10%/\sqrt{E}$ sufficient for Higgs physics
- Jet resolution $\sim 30-40%/\sqrt{E}$
  - Clearly identify W, Z, H in 2 jet decays
- Transverse granularity $< 1$ cm for $\tau$ physics
- All electronics in the back to simplify cooling and services
- Dual Readout calorimeter satisfies this requirements
Calorimeter simulation

- 4π detector in GEANT4 tuned to RD52 test beam data

Tower segmentation: Δθ = 1.125°, Δφ = 10.0°
Number of towers in barrel: 40 x 2 x 36 = 2880
Number of towers per endcap: 35 x 36 = 1260
Theta coverage up to ~0.100 rad
Calorimeter simulation

- $4\pi$ detector in GEANT4 tuned to RD52 test beam data
- Good EM resolution averaged over $\eta$ and $\phi$

![EM resolution graph with equation $\sigma/E = 11.0\% + 0.8\%$]
Calorimeter simulation

- 4π detector in GEANT4 tuned to RD52 test beam data
- Good EM resolution averaged over η and φ
- DR works well with jets

Jet clustering on:
- True jets
- Cherenkov signal
- Scintillation signal
- DR correction

IDEA Preliminary

$e^+ e^- \rightarrow Z \rightarrow jj$
Calorimeter simulation

- $4\pi$ detector in GEANT4 tuned to RD52 test beam data
- Good EM resolution averaged over $\eta$ and $\phi$
- DR works well with jets
- Adequate separation of W/Z/H

\[
e^+e^- \rightarrow HZ \rightarrow \chi^0\chi^0 jj
\]
\[
e^+e^- \rightarrow WW \rightarrow \nu_\mu\nu_\mu jj
\]
\[
e^+e^- \rightarrow HZ \rightarrow bbv\nu
\]

IDEA Preliminary

No c,b semileptonic decays
Calorimeter simulation

- $4\pi$ detector in RD52 test beam data
- Good EM resolution
- DR works well with jets
- Adequate separation of $W/Z/H$

Effect of 1 X0 Fe

Distance:
- 30 cm barrel
- 10 cm endcap

Z$\rightarrow$ jj
NO material
$\sigma = 2.35$ GeV
Calorimeter simulation

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Z → j j
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Z → j j
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$Z \rightarrow jj$
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Details in talk of L. Pezzotti
Thursday afternoon
Calorimeter separation ($\gamma$)

- Transverse granularity below 1 cm seems adequate

\[ Z \rightarrow \tau^+ \tau^- \]
\[ \tau^+ \rightarrow \rho^+ \nu \rightarrow \pi^+ \pi^0 \nu \]

\[ \Delta \gamma \text{ cm @ 2 m} \]
Calorimeter separation ($\gamma$)

- Transverse granularity below 1 cm seems adequate
- Extreme granularity (~2 mm) achievable with DR
  - At a cost ....

50 GeV electrons

100 GeV $\pi^0$
(Some)
Detector R&D
VTX R&D

❖ Target key issues of pixel detectors:
VTX R&D

*Target key issues of pixel detectors:*

- Extreme spatial resolution (small pixels)
- Time stamping
- Stitching
- Low power
VTX R&D

❖ Target key issues of pixel detectors:
  ➢ Extreme spatial resolution (small pixels)
  ➢ Time stamping
  ➢ Stitching
  ➢ Low power

❖ Funding:
  ➢ ARCADIA project of INFN ~ 1 M€
  ➢ Potential of additional support from AIDA++
VTX R&D

- Target key issues of pixel detectors:

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First Implementation

- Target hit rate: 100MHz/cm²
- Target efficiency: 99.9% (in every regard)
- Pixel size: 20μm x 20 μm
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DAQ based on previous CERN experience
Drift Chamber R&D

 Main issues:
  ➢ Mechanical structure
Drift Chamber R&D

- **Main issues:**
  - Mechanical structure
  - Wire strength

**Soldering of Carbon Materials Using Transition Metal Rich Alloys**

Marek Burda, Agnieszka Lekawa-Raus, Andrzej Gruszczyk, and Krzysztof K. Koziol

1Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, CB3 0FS, Cambridge, U.K. and 2Welding Department, Silesian University of Technology, Konarskiego 18a, 44-100 Gliwice, Poland

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  - Cluster counting electronics for PID
Drift Chamber R&D

**Main issues:**
- Mechanical structure
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**Funding:**
- CREMLIN+
  - Synergy with tau/charm factory
- INFN CSN1
- AIDA++?
**DR calorimeter R&D**

- **Testing new mechanical options**
  - Spaghetti → bucatini – Prototype in progress 10x10x100 cm³
DR calorimeter R&D

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  - Spaghetti → bucatini – Prototype in progress 10x10x100 cm³
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  - 64 ch/board with TDC $\rightarrow$ 4096 ch/controller
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- Interest for SiREAD (timing = longitudinal segmentation)
  - New version: 64 ch with 4 GHz ADC and feature extraction

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F. Bedeschi, INFN-Pisa
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- RBI

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- μRwell:
  - Concept proved/Synergy with LHC
    - Focus on Single resistive layer for high rate
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  - R&D for large area 50x50 cm$^2$
    - Industrialization
    - Cost reduction
    - DLC+Cu sputtering
    - 2D readout

CMS GE2/1 with 2 µRwell 2 m x 1.2 m
Muon chambers R&D

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Funding:

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CMS GE2/1 with 2 µRwell 2 m x 1.2 m

FCC Phys. & Det. Workshop, Jan. 2020
Final comments

- Current design looks very good for FCC-ee/Many R&D’s started
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    - Full simulation → complete integration
    - Detector benchmarking and optimization
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  - Engineering:
    - Overall mechanics and services
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  - Large prototypes: vertex detector, DCH, DR calorimeter
    - Challenging and expensive
- Collaboration on all these R&D’s is growing internationally, but there is still ample space for additional contributions.
Detector requirements

- **Requirements:**
  - **Constraints from physics (similar to LC … more or less)**

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From CDR
## Detector requirements

### Requirements:

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Too tight?
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From CDR

Too tight?

Not enough?
Detector requirements

- Requirements:
  - Constraints from physics (similar to LC … more or less)

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Additional constraints:

- Excellent acceptance and luminosity control
- PID & $\pi^0$ ID for HF/τ physics
- Low B field to avoid emittance blow up
- Power pulsing not allowed

Not present at LC
Transparency

CLD: Material vs. $\cos(\theta)$

- Beam pipe
- Vertex
- Inner tracker
- Outer tracker
Transparency

IDEA: Material vs. $\cos(\theta)$

- Beam pipe
- Vertex silicon
- Drift chamber
- Silicon wrapper

CLD: Material vs. $\cos(\theta)$

- Beam pipe
- Vertex
- Inner tracker
- Outer tracker
Steeper high energy rise of #clusters than ionization E
Calorimeter resolution (jets)

- Separation of $H \rightarrow ZZ^*$ from $H \rightarrow WW^*$
  - $3\text{-}4\% @ 100 \text{ GeV}$ adequate – Can it be worse?
Calorimeter resolution (jets)

- Separation of $H \rightarrow ZZ^*$ from $H \rightarrow WW^*$
  - 3-4% @ 100 GeV adequate – Can it be worse?
- Recoil mass in HZ ($Z \rightarrow qq$)
Calorimeter resolution (jets)

- Separation of $H \rightarrow ZZ^*$ from $H \rightarrow WW^*$
  - 3-4% @ 100 GeV adequate – Can it be worse?
- Recoil mass in $HZ (Z \rightarrow qq)$
- $H \rightarrow qq$
Calorimeter resolution (γ)

- Is 20%/sqrt(E) acceptable? Can we trigger on single γ?
- What about radiative return analysis?
  - Eg. N\nu, and Z→ ν_e ν_e

```
\begin{align*}
\text{Only} \quad \nu_e \text{ interfere}
\end{align*}
```
Calorimeter resolution ($\gamma$)

- Is 20%/sqrt(E) acceptable? Can we trigger on single $\gamma$?
- What about radiative return analysis?

  - Eg. N$\nu$, and $Z \rightarrow \nu_e \nu_e$

Need 5-10%/sqrt(E) for a good measurement

$\sigma(g_{\nu_e})$: 18% $\rightarrow$ 1.4-2.4%

- Worse resolution make separation difficult