HFCC Computing/Sim for Calorimetry R&D Projects

Bob Hirosky
Michael Begel
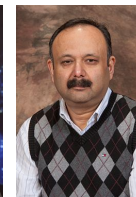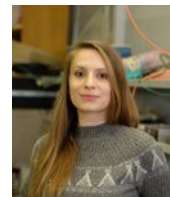
19-Dec-2024

L3 coordination (Calorimetry)

Calorimeter (us-hfcc-calorimetry@cern.ch)

- Dual Readout: Grace Cummings
- Nobel Liquid: Erich Varnes
- Si-W: Jim Brau
- Tile-Scint: Vishnu Zutshi

US HEP has demonstrated expertise and leadership across multiple calorimeter technologies, e.g.

- **DR Calorimetry**
  - Calvision, DREAM/RD52
- **Noble Liquid**
  - ATLAS ECAL, D0
- **Silicon-Tungsten**
  - CMS HGCAL, CALICE
- **Tile-Scint**
  - ATLAS Tile CAL, CMS HCAL/HGCAL

CalVision - DR for e+e- colliders

Single crystal + matrix studies

PbF₂

UMich, Y. Guo - image

Single Crystal MC M. Paranjpe

G. Cummings

Full detector sim

2020 JINST 15 P11005

SCEPCal

Particle Flow Algos

Heavy Glasses for Homogenous HCAL

Aluminoborosilicate Glass

AS-2 AS-3
AS-1
AS-4 AS-5

R. Zhu CPAD 2023

DR Fiber HCAL

TTU S. Kunori

Mechanics

Andy Jung   Andy Jung

W. Chung

Brandeis

🔷 Fermilab Caltech Argonne NATIONAL LABORATORY UNIVERSITY OF MARYLAND M TTU

Stony Brook University R UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA MIT OAK RIDGE National Laboratory Purdue UNIVERSITY of VIRGINIA BU

Scintillator-SiPM Hadron Calorimetry

Large community working in this area, esp for CMs HGcal
- **NIU, FSU, UMD, Notre Dame, Minnesota, …**

- **SLAC/Oregon**
  Caterina Vernieri, Lorenzo Rota, Martin Breidenbach, Jim Brau, David Strom
- **CMS HGCAL group**
  Lindsey Gray, Murtaza Safdari, Zoltan Gecse
- **Graham Wilson (Luminosity monitor and forward calorimetry)**
- **Larger community including CMS HGCal groups…**

Noble Liquid Calorimetry
US groups expressing interest:

- **Arizona, Brookhaven, Irvine, Columbia, SMU, StonyBrook, Austin**
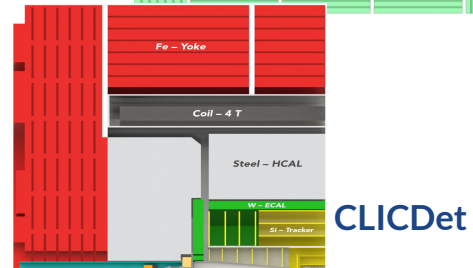
3

Proto detector concepts

ECAL: Si/W - HCAL: Sci Tile

SiD (MAPs)

ILD

CLD

CLICDet
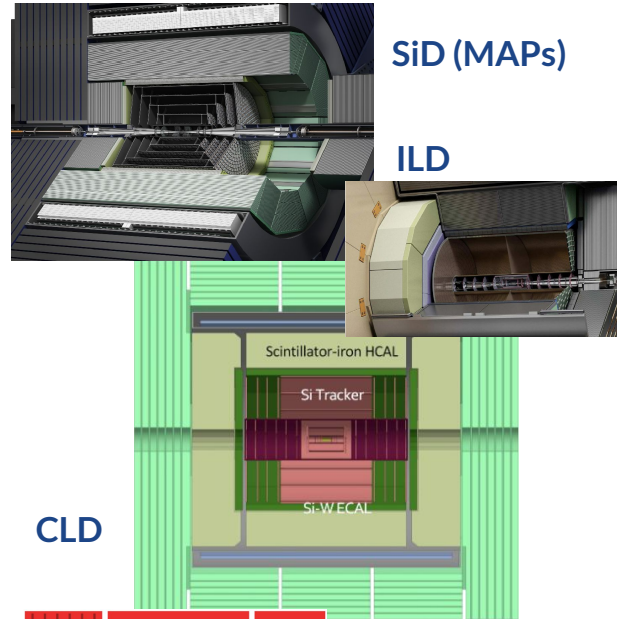
ECAL: LAr/LKr with Pb/W absorber
HCAL: CALICE- or TileCal-like

IDEA

Allegro
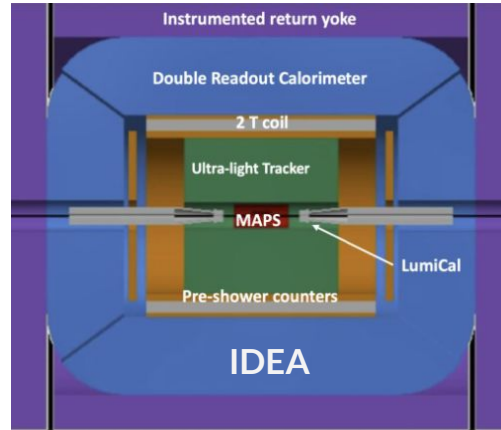
ECAL: dual-readout crystal
HCAL: Copper with S/C fiber
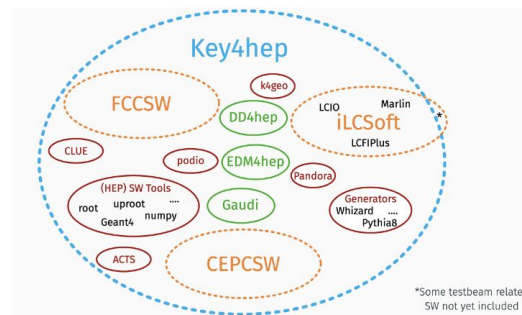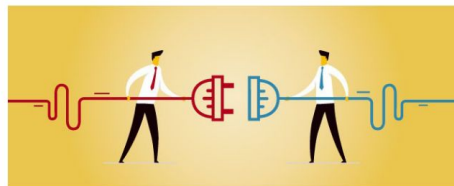
Calorimetry Simulation for HF Detectors

View from DRD6

Overall direction in DRD6 community is Key4Hep with DD4HEP for geometry definition

Key4hep Philosophy

➢ Key4hep is a **software framework** serving (and developed by) the **future collider community**

➢ **Key4hep** guiding principles

  ➢ **Interoperability:** what is developed by some should be useable by others (with minimal modifications)

  ➢ **Versatility:** covers a large spectrum of needs (serves diverse facilities and detectors)

  ➢ **Flexibility:** still under active development (nothing is frozen), targets "the future" → has to adapt to evolving needs, detector configurations, etc

View from DRD6

Overall direction in DRD6 community is Key4Hep with DD4HEP for geometry definition

Key4hep Building Blocks

> Key4hep building blocks: state of the art software with active user community

>> Algorithm orchestration framework: **Gaudi** (LHCb, ATLAS)

>> Data format for algorithm input/output: **edm4hep**

>>> ROOT based, inspired by lcio (used in CALICE) and FCC-edm, built with **PODIO** (more later)

>> Detector geometry description: **DD4hep** (LHCb, CMS, …)

>> Package manager building the software stack: **Spack** (1.3k+ contributors)

> Interoperability enabled by the compliance to the above (aka being 'Key4hep compliant')

> When possible/practical, prefer interfacing existing solutions over starting from scratch

>> Inspired by LHC solutions and integrates e.g. iLCSoft packages (used in CALICE)

>>> Avoid re-inventing the wheel

>>> Can be used with edm4hep data (converter), as Gaudi algorithms (wrappers)

SW ecosystem for DRD6   Brieuc François   7

Calorimetry Simulation for HF Detectors

View from DRD6

ECFA Some general comment collected

Some general comment received (all are in the same line)

Harmonize the demands from each WG to the software, create better connection to the common framework e.g. Key4HEP, DD4HEP, etc.

Get as many people as possible to use the same software, so the collaboration between different teams will be stronger, progress faster and everyone will profit from it

a common repository where all the software used by the various group can be shared; this would help newcomers to not start from scratch. It could be good to have on a DRD6 software webpage a list of people to contact in case of problems on a specific software.

DRD6 presents a unique opportunity to streamline the software tools available to the test-beam communities. This would ensure long-term preservation of the code and enhance accessibility for the entire calorimetry community.

European Strategy Update

Progress in optical & DR simulation

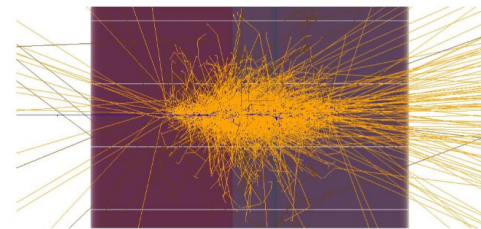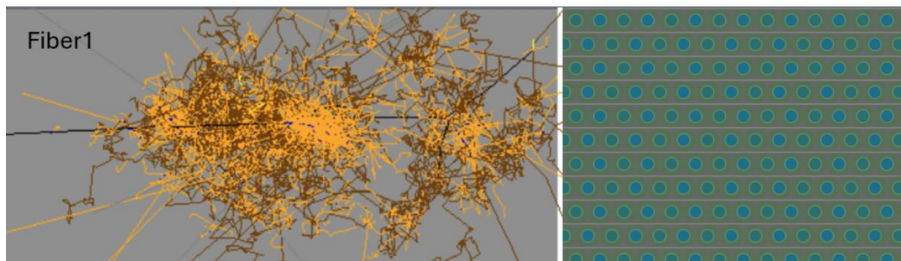**dd4hep geometry tools supporting multiple calorimtery options for testbeam modules**, eg

- Crystal ECAL
- Fiber HCAL
- Tile-Scint
- HHCAL

Available for use with
documentation

Array with HCAL

We have updated this to a flexible code allowing different configurations of HCAL + HCAL.
- ECAL currently has 2 crystal segments
- HCAL allows two options: a CMS-HCAL-like sampling calorimeter with scintillating and non-scintillating tile layers for active media and a IDEA-like fiber HCAL with scintillating and non-scintillating fibers in individual absorbers (either tube or square with circular hole).
- General user code at: gitlab
- Beta test version at: https://github.com/saraheno/DualTestBeam

Sarah Eno

Progress in optical & DR simulation

Fullsim mosel for IDEA baseline: crystal+fiber DR

- Fully parameterized projective geometry
- Subdetectors defined in compact XML
- Differentiable simulation in dd4hep

New IDEA baseline

Beampipe

LumiCal

Vertex Detector

Drift Chamber

Silicon Wrapper

Endplate Absorber

Dual-readout Crystal ECAL

Solenoid

Dual-readout Fiber HCAL

Muon System

Wonyong Chung
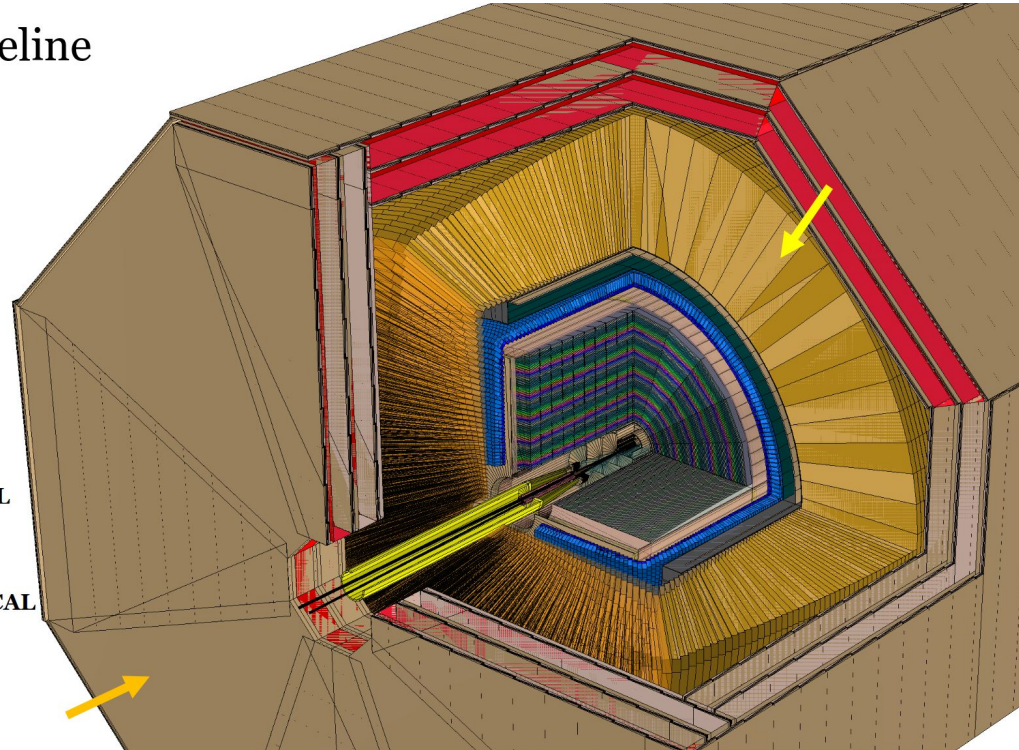
Progress in optical & DR simulation

Fullsim model for IDEA baseline: crystal+fiber DR

- Fully parameterized projective geometry
- Subdetectors defined in compact XML
- Differentiable simulation in dd4hep
- **Event displays integrated into a simple notebook framework**
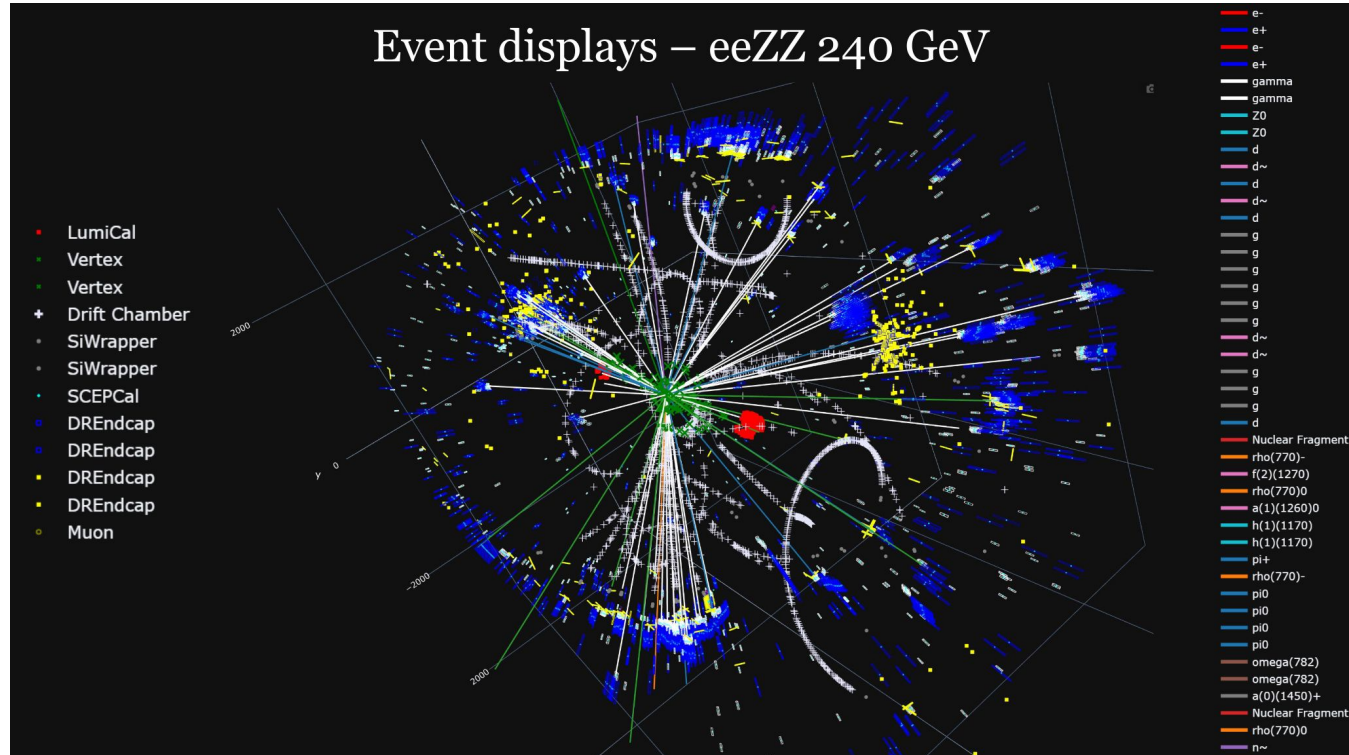
Event displays – eeZZ 240 GeV

Progress in optical & DR simulation

Standalone work aimed at fiber DR R&D

- **Studies of longitudinal segmentation via timing**
- Exploration of light propagation in different fiber types
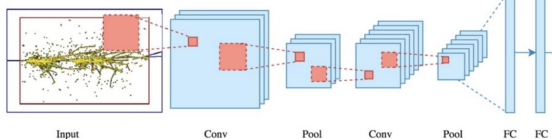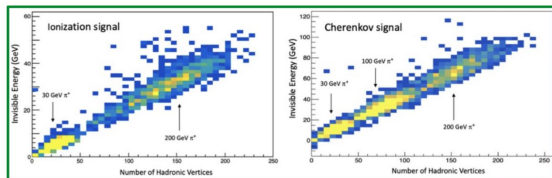
arxiv:2408.15385

Longitudinal Segmentation with Timing
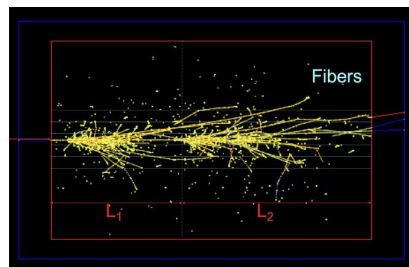
Signal time = $L_1/c + L_2/(c/n)$,
(c/n) ~1 cm/50 ps
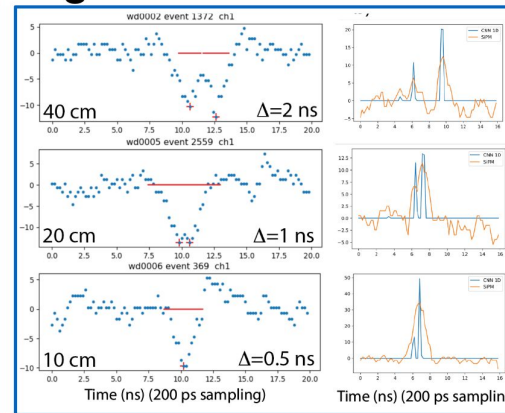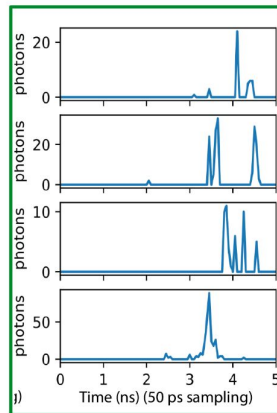
- **Hadronic showers can vary dramatically from event to event as shown in green**
- **With the use of a CNN we have demonstrated you can reconstruct signals resolving position dependence of hits using the timing information**
  - **Providing longitudinal segmentation to ~10 cm resolution**

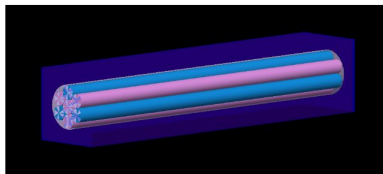<= Reconstruction with ML

Chris Madrid

TEXAS TECH

11

Progress in optical & DR simulation

Standalone work aimed at fiber DR R&D

- Studies of longitudinal segmentation via timing
- **Exploration of light propagation in different fiber types**
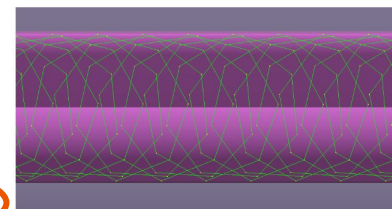
Simulation

- Current simulations are based on Geant4
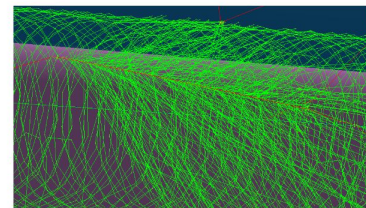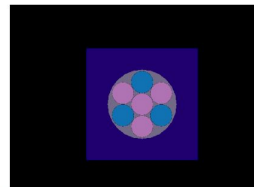
- Working on studying the (hadronic) shower developments and optical photon propagations in the fibers
 - **Focusing on the timing properties**

- Exploring different fiber parameters (size, multi-cladding, helical, etc in order to improve photon capturing efficiency
- **Plan to move to DD4HEP and Key4HEP once more mature**

Chris Madrid | SLAC HPCC Workshop

TEXAS TECH

[Chris Madrid](#)

MAPS simulation for Si-W

Digital MAPS ECal R&D

- EPICAL - full calorimeter tested by European group
- SiD - developing sensor optimized for Higgs Factory
- Current status is stand alone simulation, more effort welcome to build into dd4hep
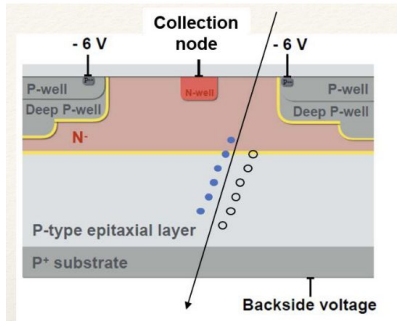
10 GeV Shower in 25 x 100 μm²
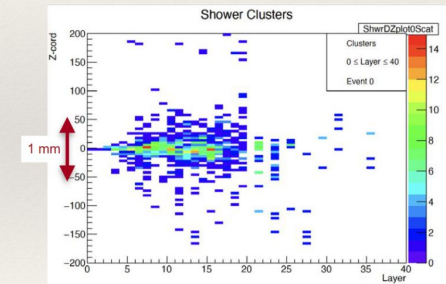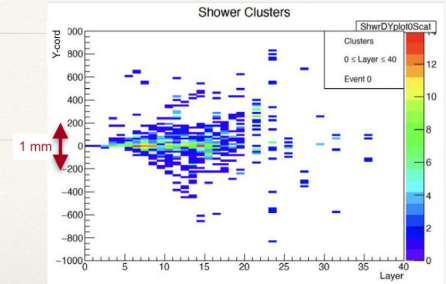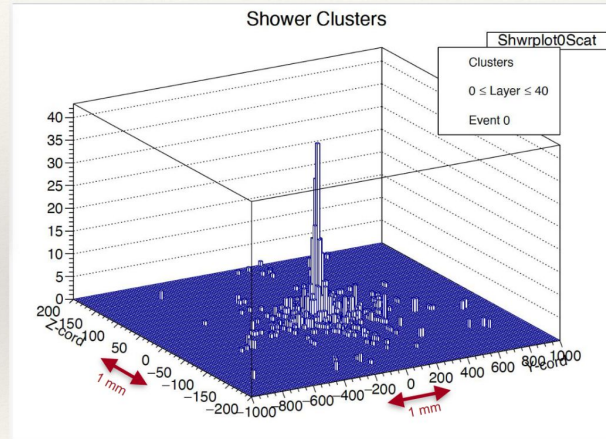
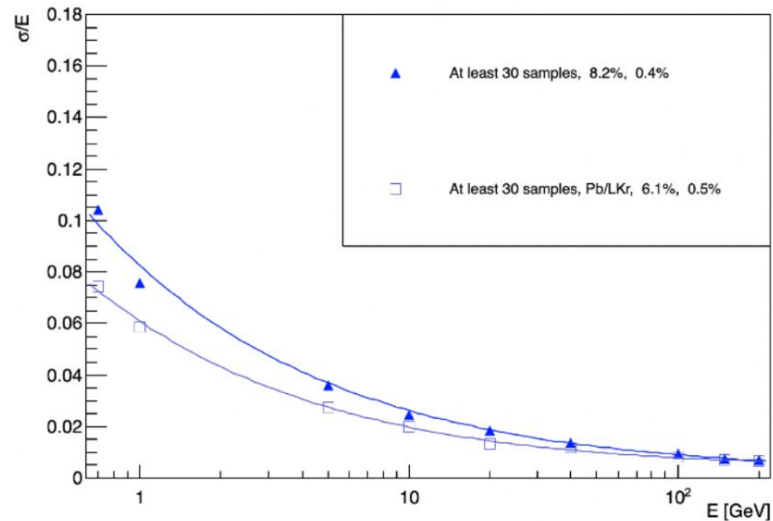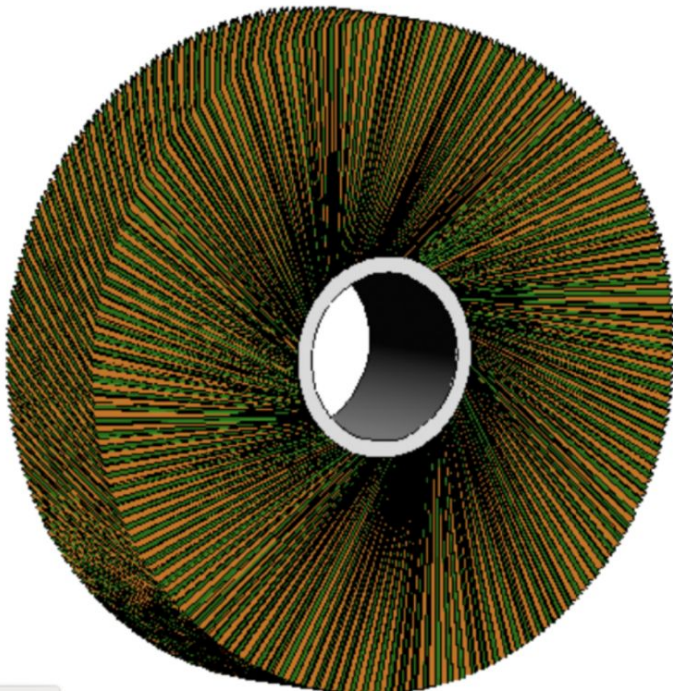SiW Calorimetry for the Higgs Factory   J. Brau - 19 December 2024   6

[Jim Brau](#)

Noble Liquid EM Endcap Calorimeter

- Geometry concept ("turbine" design):

- Energy resolution for single electrons (dd4hep full simulation):

Erich Varnes

General S&C considerations

- HPC access for high-quality sample production, OSG, grid VO
  - eg, 20 mins+/per event for optical simulations!
  - Both CPU and GPU capabilities for AI/ML inference, algorithm development, celeritas,…
- Storage resources for simulation samples and test beam data (eg calvison is already at ~ 10TB alone!)
  - Need <u>shared access</u> to facilitate collaboration/efficiency
- **US developer support for common frameworks (key4hep, dd4hep)**
  - Also provide support for investigator groups
- Interface from standard CAD programs (include material properties)