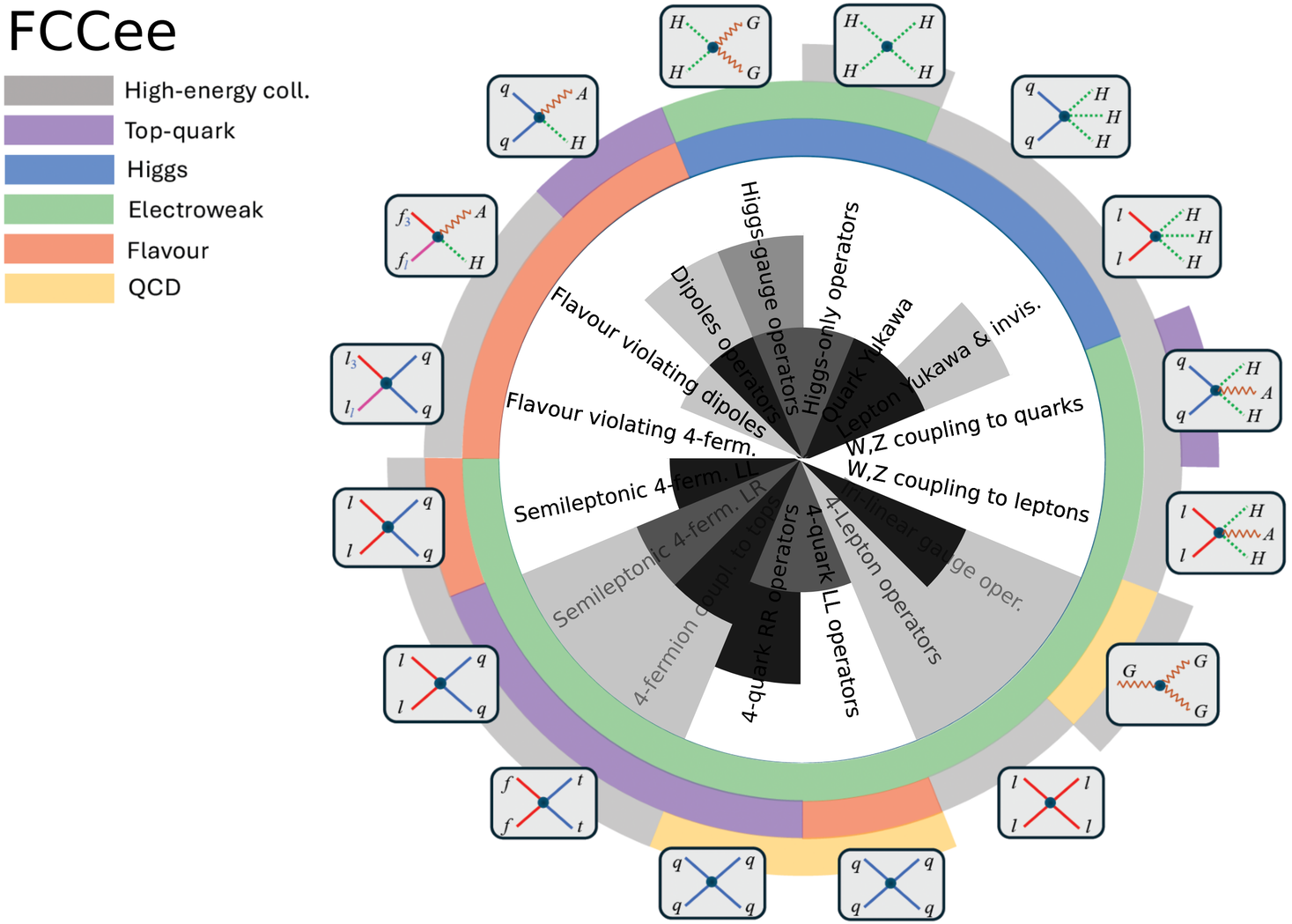
Summary and Forward Plans for Physics

Loukas Gouskos, Heather M. Gray and Patrick Meade

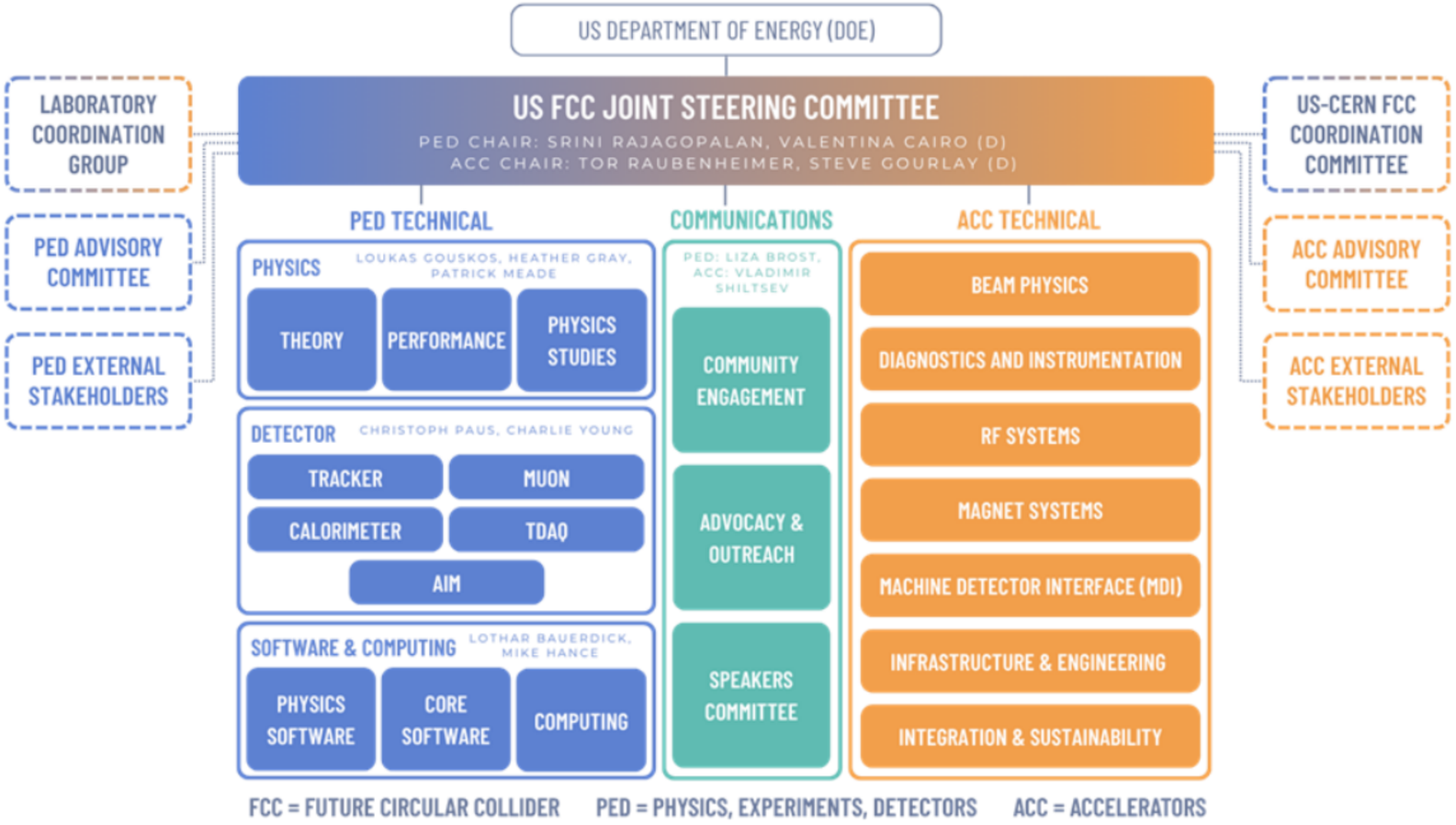
FCC-ee Physics Program

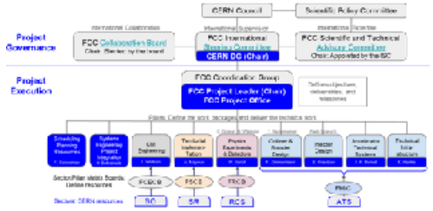
- Higgs
- Electroweak
- Flavour
- Top Quark
- BSM
- QCD and γ γ
- Global Fits
- MC Event Generators
- Precision Calculations
- Jet Flavour Tagging



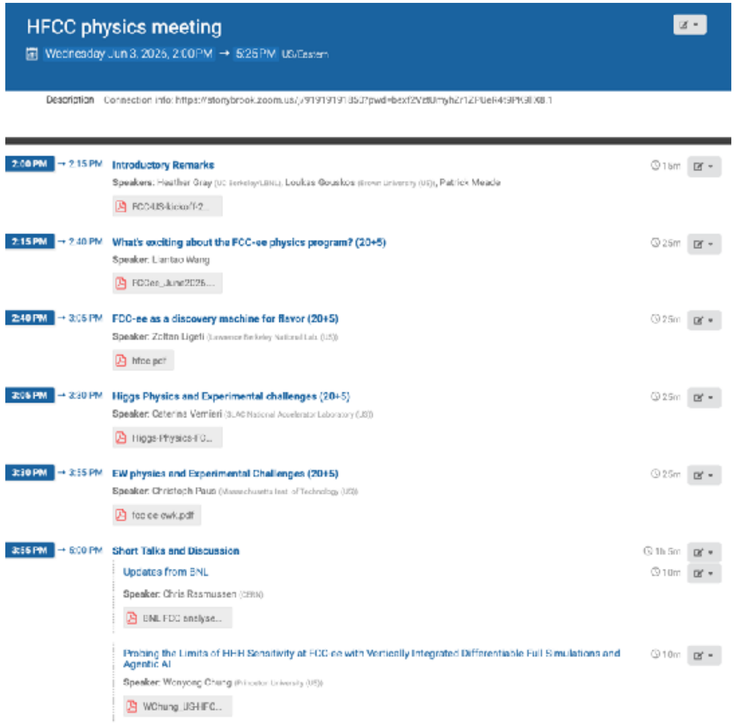
https://indico.cern.ch/category/15156/

Physics in US FCC





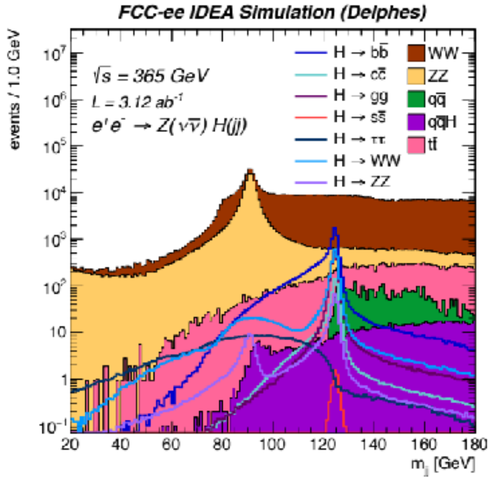
Kick Off Physics Meeting



Recent Physics Highlights

Precision measurements of Higgs hadronic decay modes at the FCC-ee

Andrea Del Vecchio,[a] Jan Eysermans,[f] Loukas Gouskos,[d] George Iakovidis,[c] Alexis Maloizel,[c] Giovanni Marchiori[c] and Michele Selvaggi[b]



$\sqrt{s}$	240 GeV		365 GeV	
$\mathcal{L}$	10.8 ab^{-1}		3.12 ab^{-1}	
Channel	ZH	$\nu_e\bar{\nu}_e H$	ZH	$\nu_e\bar{\nu}_e H$
$H \to b\bar{b}$	±0.21	±1.89	±0.39	±0.64
$H \to c\bar{c}$	±1.75	±20	±3.01	±3.36
$H \to s\bar{s}$	±110	±990	±340	±280
$H \to gg$	±0.85	±5.5	±2.13	±2.56

Table 5. Relative uncertainty (%) for $\sigma_{ZH} \times \mathcal{B}(H \to XX)$ and $\sigma_{\nu_e\bar{\nu}_e} \times \mathcal{B}(H \to$ combining the $\ell\ell jj$, $\nu\nu jj$, and $jjjj$ final states.

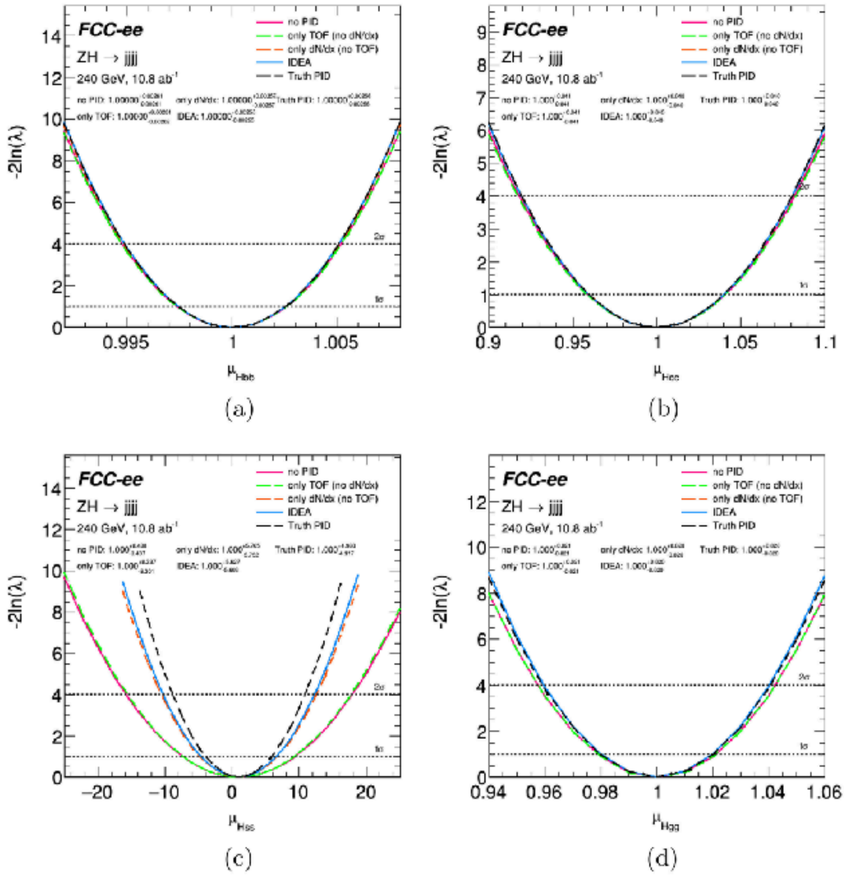
https://link.springer.com/article/10.1007/JHEP04(2026)181

FCC feasibility studies: Impact of tracker- and calorimeter-detector performance on jet flavor identification and Higgs physics analyses

Haider Abidi, Ketevi A. Assamagan, Diallo Boye, Elizabeth Brost, Viviana Cavaliere, Anna E. Connelly, George Iakovidis, Ang Li, Marc-André Pleier, Andrea Sciandra,* Scott Snyder, Robert Szafron, Abraham Tishelman-Charny, and Iza Veliscek
Physics Department, Brookhaven National Laboratory, Upton New York, USA

Michele Selvaggi
CERN, Geneva, Switzerland

(Received 15 April 2025; accepted 28 July 2025; published 9 September 2025)



https://journals.aps.org/prd/abstract/10.1103/m2zr-26yf

Recent Physics Highlights

Jet Flavour Tagging for Future Colliders with Fast Simulation

Franco Bedeschi[a] , Loukas Gouskos[b] and Michele Selvaggi[b]

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[b] *CERN, CH-1211 Geneva 23, Switzerland*

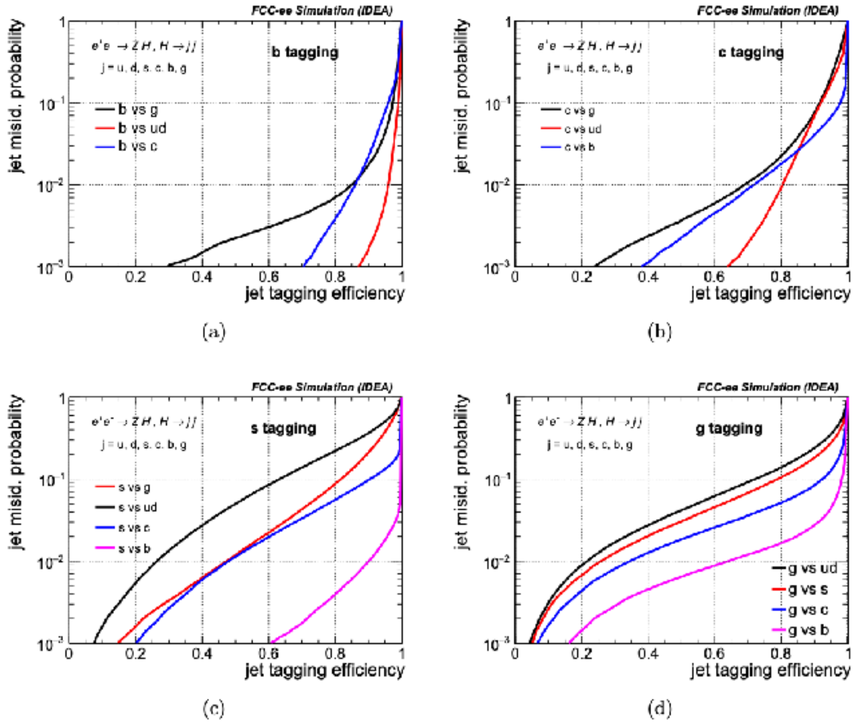


Figure 5. Evaluation of ParticleNetIdea performance in terms of a receiver operating characteristic (ROC) curve for the identification of different jet flavours i.e., b quarks (upper left), c quarks (upper right), s (lower left), and g (lower right). The different jet flavours considered background are indicated on the labels. The IDEA detector configuration is used.

https://arxiv.org/pdf/2202.03285

Energy Correlators from Partons to Hadrons: Unveiling the Dynamics of the Strong Interactions with Archival ALEPH Data

Hannah Bossi,[1] Yi Chen,[2] Yu-Chen Chen,[1] Max Jaarsma,[3,4] Yibei Li,[5] Jingyu Zhang,[2] Ian Moult,[6] Wouter Waalewijn,[3,4] Hua Xing Zhu,[7,8] Anthony Badea,[9] Austin Baty,[10] Christopher McGinn,[1] Gian Michele Innocenti,[1] Marcello Maggi,[11] and Yen-Jie Lee[1]

[1] *Massachusetts Institute of Technology, Cambridge, MA, 02139*

[2] *Vanderbilt University, Nashville, TN, 37215, USA*

[3] *Nikhef, Theory Group, Science Park 105, 1098 XG, Amsterdam, The Netherlands*

[4] *Institute for Theoretical Physics Amsterdam and Delta Institute for Theoretical Physics,*

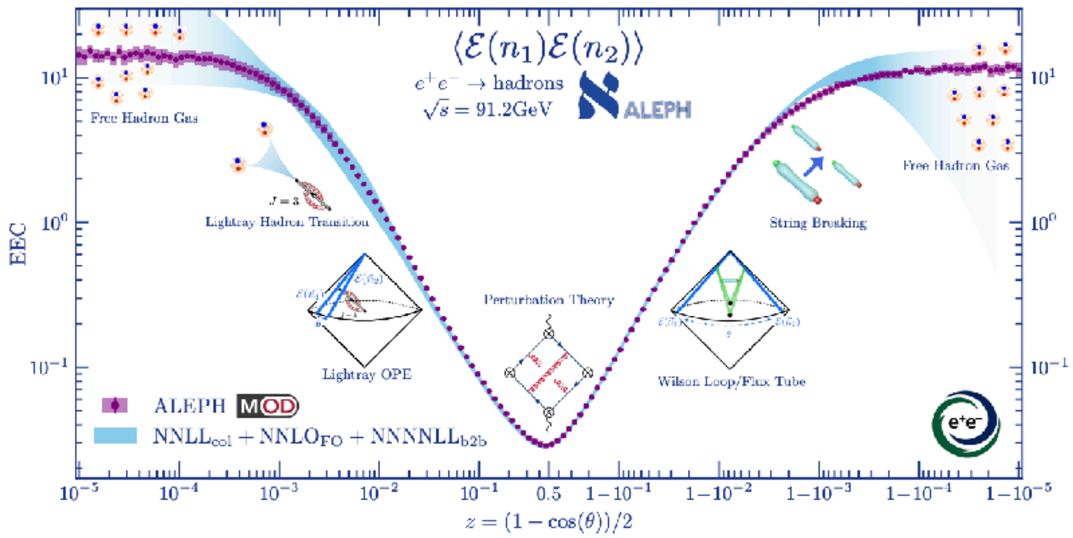


FIG. 4: The energy correlator from partons to hadrons: A measurement of the EEC using archival data from the ALEPH tracker. Statistical error bars are shown as vertical lines and systematic error bars as purple boxes. ALEPH data is compared with state-of-the-art theoretical predictions, shown in light blue. Our re-analysis greatly extends both the precision, and angular range of the measurement, enabling a complete view of the dynamics of QCD.

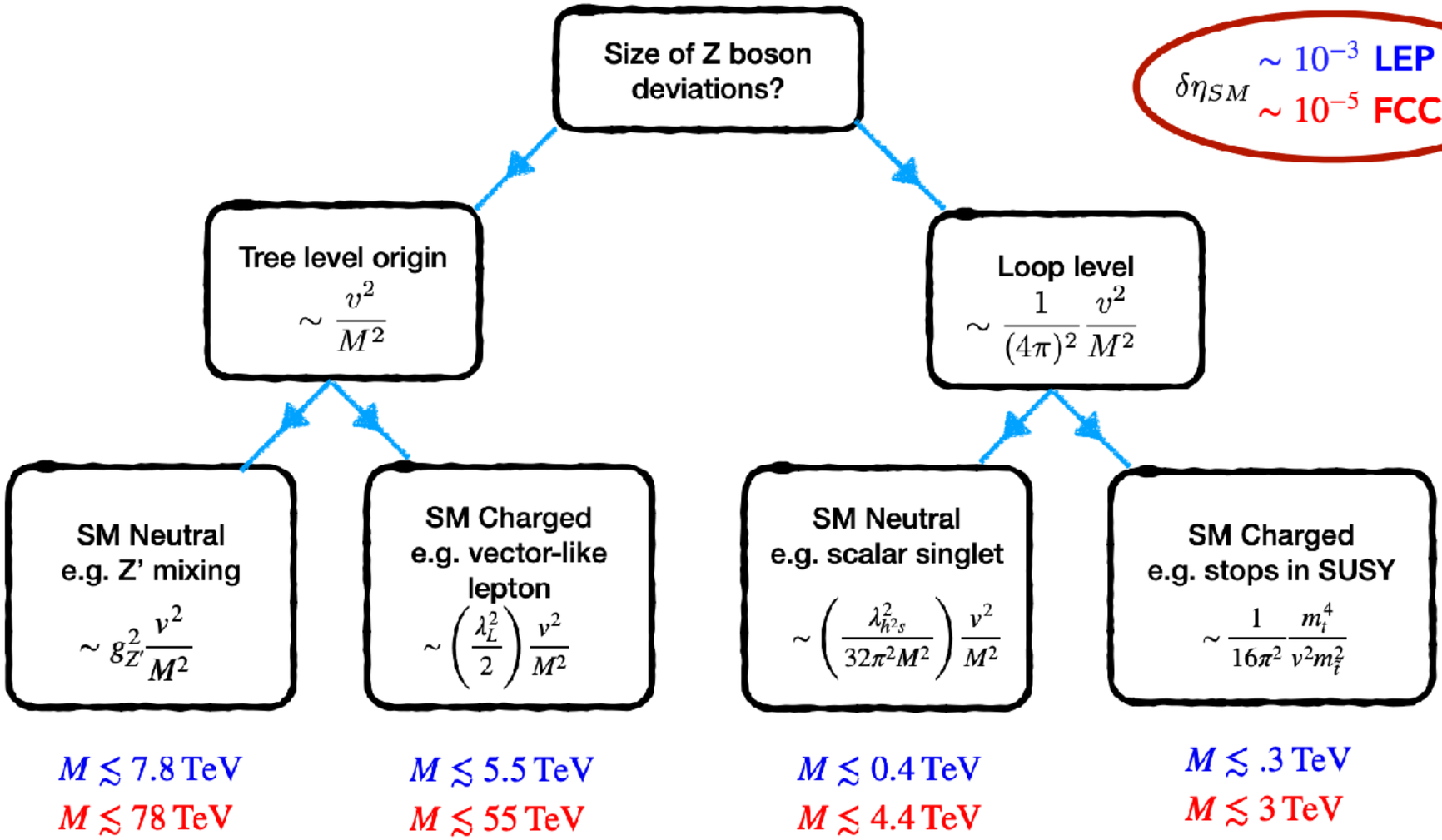
https://arxiv.org/pdf/2511.00149

Analysis expertise and interests at BNL

- H to invisible decays – contact: *K. Assamagan, S. Snyder*
- H self couplings – contact: *L. Brost, A. Tishelman-Charny*
- Model-independent ZH production cross section, Higgs Boson Mass with Natural-Width Precision – contact: *A. Li*
- Detector variations, H branching fractions to cc and ss – contact: *A. Sciandra, I. Veliscek*
- Precision Measurements of Higgs Hadronic Decay Modes – contact: *G. Iakovidis*
- BSM: Higgs + dark sector at the Z-pole/higher $\sqrt{s}$ – contact: *L. Brost, A. Tishelman-Charny*

https://indico.slac.stanford.edu/event/10213/contributions/15887/attachments/6893/17175/FCC-PED-LDRDs-BNL-Pleier-100926.pdf

BSM Physics Reach from Z-pole



Conservative Scaling for Upper Limit on Mass Scale Probed by Z-pole Precision

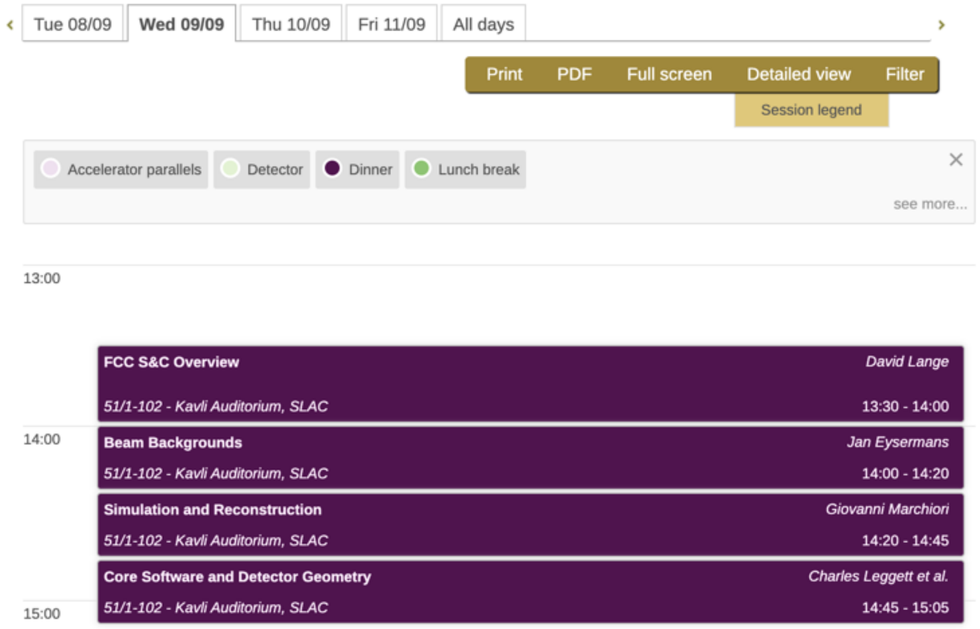
P. Meade

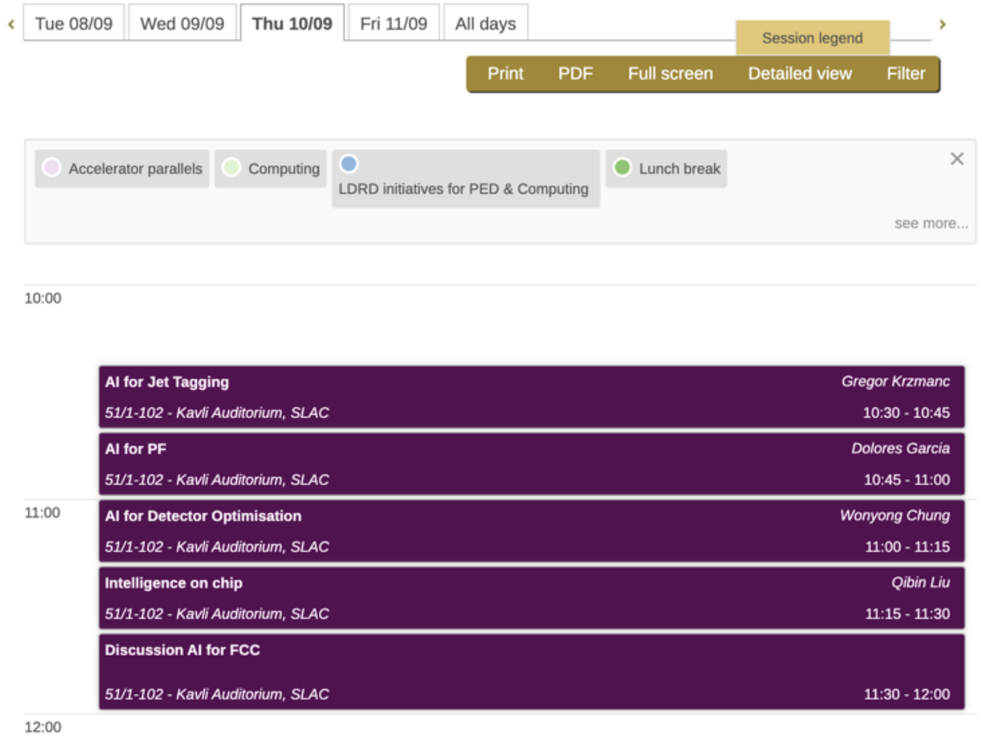
Objectives

Objectives of Physics, Experiments, Detectors

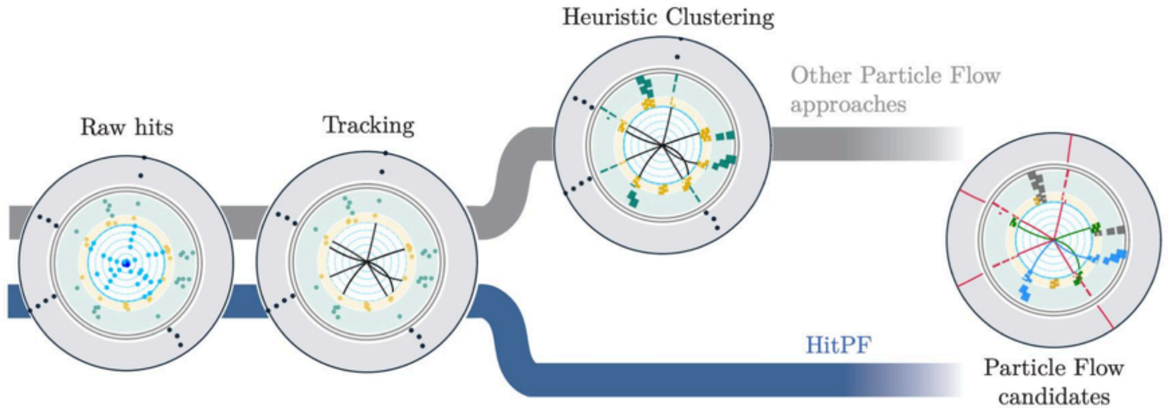
- Continue developing the international high-energy physics community
- Consolidation of the interaction region layout, detector integration and beam-background mitigation.
- Optimized procedures for $\sqrt{s}$ calibration & possible monochromatic (125) operation.
- Finalizing common software/analysis framework and developing common computing architecture.
- Realistic studies of exp. systematic uncertainties for some EW precision measurements & consolidation of pertaining requirements on colliders, detectors and theory.
- Engagement of theory community to address theory challenges
- Proposal for staging implementation and improvements of the staged/descoped FCC-ee
- Prepare to answer call for (at least 4) documented EoI's for FCC-ee experiments end 2028.
- Engaging the early career researchers and the next-generation scientists.

Parallel Sessions connected to Physics

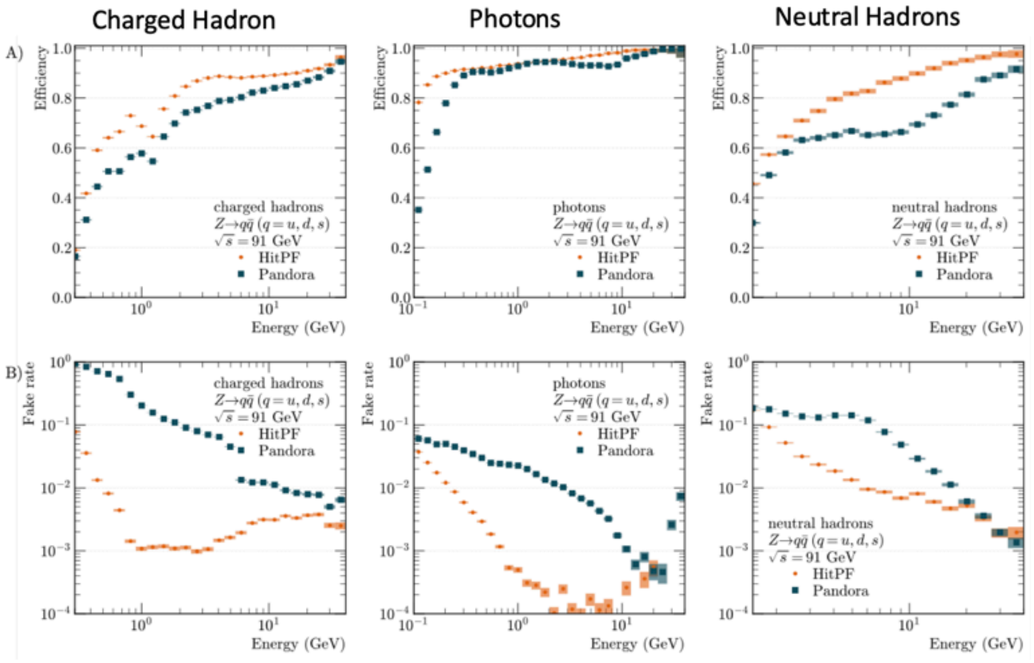




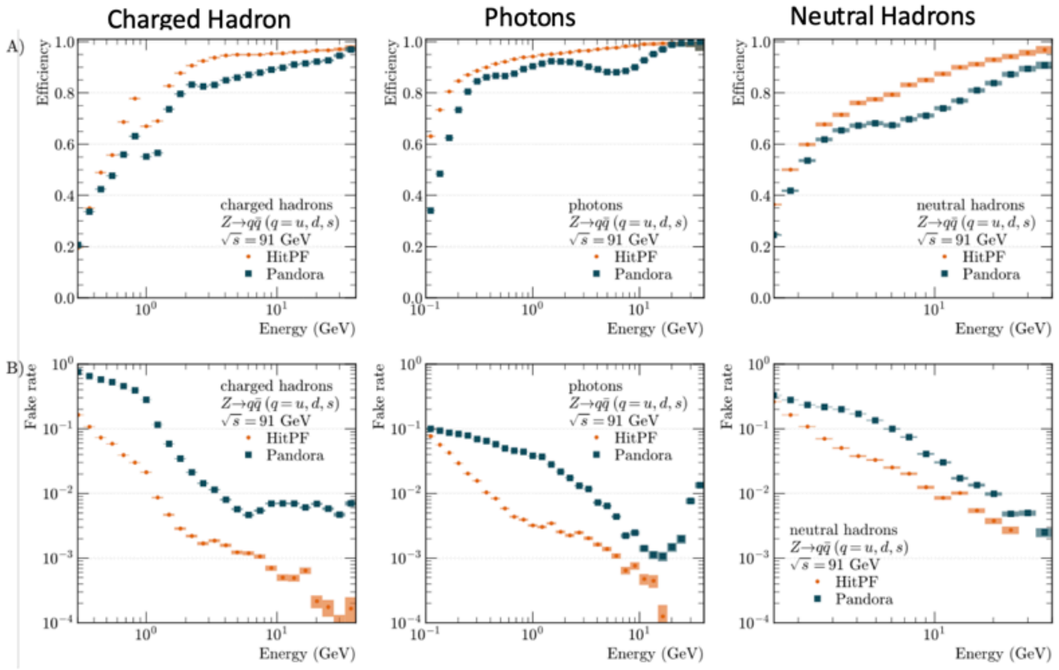
Highlights from Parallel Sessions: Particle Flow



D. Garcia



CLD



ILD

Highlights: Beam Backgrounds

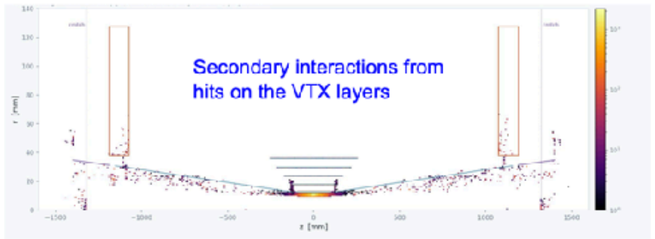
Particle hit rates from IPCs

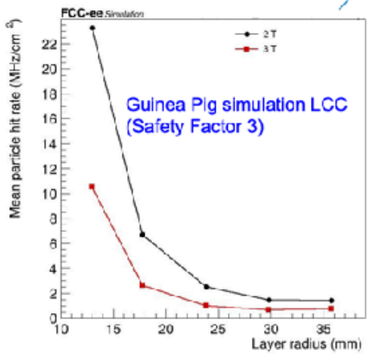
Estimated particle hit rates from IPC on the vertex detector

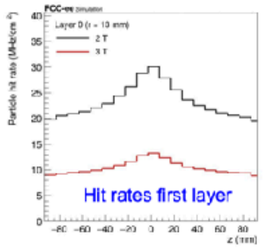
- Count particles crossing idealized 50 μm Si cylindrical layers
- Compare 2 T and 3 T detector magnetic fields
- Apply a safety factor of 3

Innermost vertex layer (r = 13 mm): 20 MHz/cm^2 (affordable!)

- Mostly induced by loopers, particles hitting the same layer multiple times
- Increasing the field from 2 T to 3 T reduces the rate by about a factor of 2
- Most vertex hits directly from the IP, with particles traversing the beam pipe
- Forward/endcap disks have significantly lower hit rates







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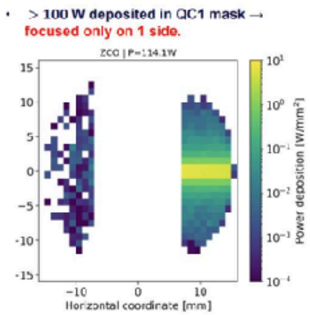
Impact on vertex detectors

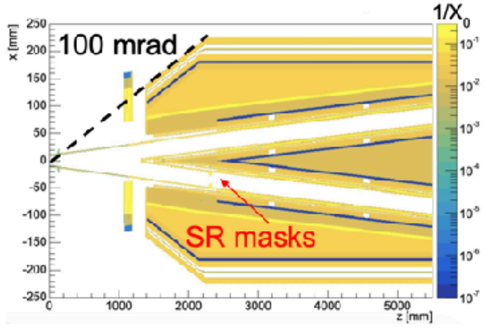
SR photons propagated through the detector simulation

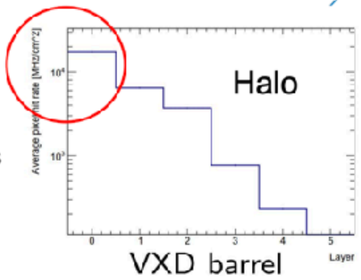
- Two SR masks in place, gold coating on inner beam pipe
- Preliminary estimates O(GHz/cm2) on first vertex layer

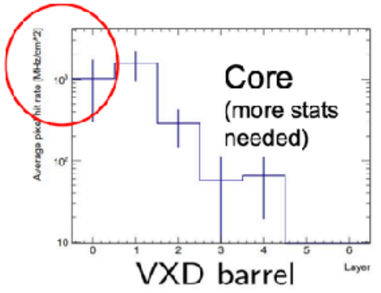
Work ongoing to further suppress the SR radiation using dedicated masks

- Two additional SR masks closer to the IP for further SR suppression
- Need to verify beam impedances, total power deposition on the masks
- For original masks, more than 100 W deposited!









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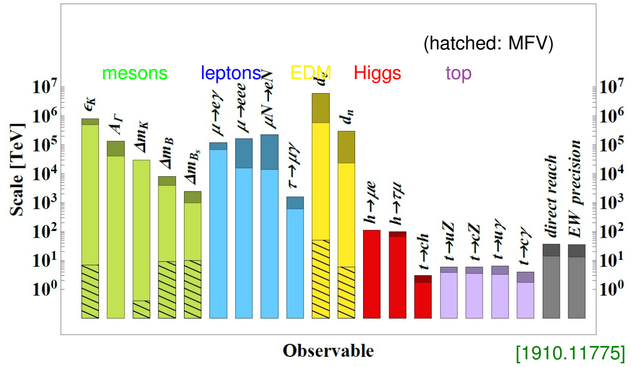
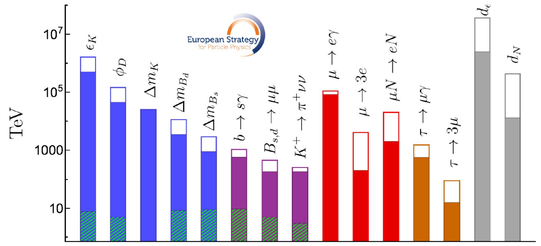
J. Eysermans

Highlights: Flavor

Scales, as shown in European strategy



[1910.11775]



[2511.03883]

- All TeV-scale NP models must contain some mechanism to avoid violating constraints
  Models devised to make deviations from SM small, revisit model building when tensions with SM arise
- Suppressions in SM are strongest for kaons, often Δm_K & ϵ_K are the most constraining

What are the largest useful data sets?

- No one has seriously explored it!
- Many measurements will remain far from being limited by theory uncertainties:
  - The CKM angle $\gamma(\equiv \phi_3)$
  - $B_{s,d} \to \mu\mu$, $B \to \mu\nu$ and other leptonic decays
  - $A_{\rm SL}^{d,s}$ — CPV in $B_{(s)}$ mixing
  - Lepton flavor violation & lepton universality violation searches
  - Dark sector searches, etc.
- In some decays, even in 2040s we'll have (exp. bound)/SM $\gtrsim 10^3$
- NP sensitivity would improve with data $\gg$ LHCb, Belle II, tera-Z

$\Rightarrow$ Case for an experiment focused on flavor at FCC-hh

Z. Ligeti

US FCC Physics Priorities

- **1. Detector solenoid field (2/3/4 T) at the Z pole.** Looking for interested contributors
  - Quantify how field strength trades off momentum resolution, beamstrahlung/beam-induced backgrounds and luminosity against Z-pole precision observables.
  - Exploit superconducting-magnet design and construction expertise at the US national labs together with ATLAS/CMS experience of operating precision tracking in high-field solenoids.
  - Needs to be fixed by 2028
- **2. Continuous vs 25 ns bunch structure.** Looking for interested contributors
  - Assess the physics impact of the two beam-timing options (machine-background overlap, timing/trigger requirements) using Z-pole measurements as the benchmark.
  - Joint with US accelerator groups that carry the beam-dynamics and beam-background simulation heritage of the US e+e- collider program
  - Needs input from physics now

US FCC Physics Priorities

- **3a. Higgs benchmarks in full simulation: ZH coupling and H->ss.**
  - Validate a full-simulation chain (starting from CLD in Key4hep) against the fast simulation used for sensitivity claims, with the Higgs recoil measurement and charm tagging as the drivers.
  - Build on US leadership in Higgs-coupling and heavy flavor tagging at the LHC
  - Sets the vertexing, tracking and jet-flavour performance requirements for detectors
- **3b. Z-pole benchmark in full simulation: R_b.**
  - Fast-vs-full comparison at the Z pole, where the 10^12 Z statistics push systematic control far beyond LEP.
  - Builds on US flavor tagging expertise
  - Fixes the vertex-detector and material-budget targets for the Z-pole run.

US FCC Physics Priorities

- **4. Realistic silicon-tracker digitization + TDAQ design in Key4hep**
  - Sensor-level simulation providing the data stream needed to evaluate streaming readout, data-volume reduction and real-time FPGA/GPU tracking.
  - Builds on US leadership in LHC silicon trackers, ML-on-FPGA inference and L1-trigger tracking
  - Determines sensor geometries and bandwidth requirements against beam-induced backgrounds.
- **5. Integrated tracking, calorimetry, timing and PID ("5D particle flow")**
  - Evaluate the interplay of fast timing, dual-readout calorimetry, RICH-based PID and a silicon timing wrapper, with H->ss as the flagship benchmark.
  - Builds on US leadership in dual-readout/5D calorimetry, RICH-for-Higgs-factory, and HL-LHC timing-detectors (MTD/HGTD, HGCAL)
  - Defines which technology combinations justify their cost and integration complexity.

Please get in touch with additional ideas, for example lots of room in dark searches

How to get involved

- Contact the physics coordinators (contact info below)
- Join our new new mailing list meetings, mattermost
- International FCC meetings

Loukas Gouskos

Heather Gray

Patrick Meade

Conclusion

- The FCC project has been evolving quite rapidly since the European Strategy process
  - Project approval in 2028 is soon
- The US has set up similar structures to international FCC to organize our efforts
- Now is the time to start launching projects to allow the US to play a key role in defining the physics program at the FCC
  - We plan to focus on high-profile, high-importance physics topics which are extremely relevant for the accelerator and/or detector choices
  - Unique opportunity with contributions possible to most areas
  - Possible to make significant contributions with a small amount of effort
- Please get in touch with us if you have ideas or are interested in contributing
- Question: what is needed now to get more people to engage with FCC physics?