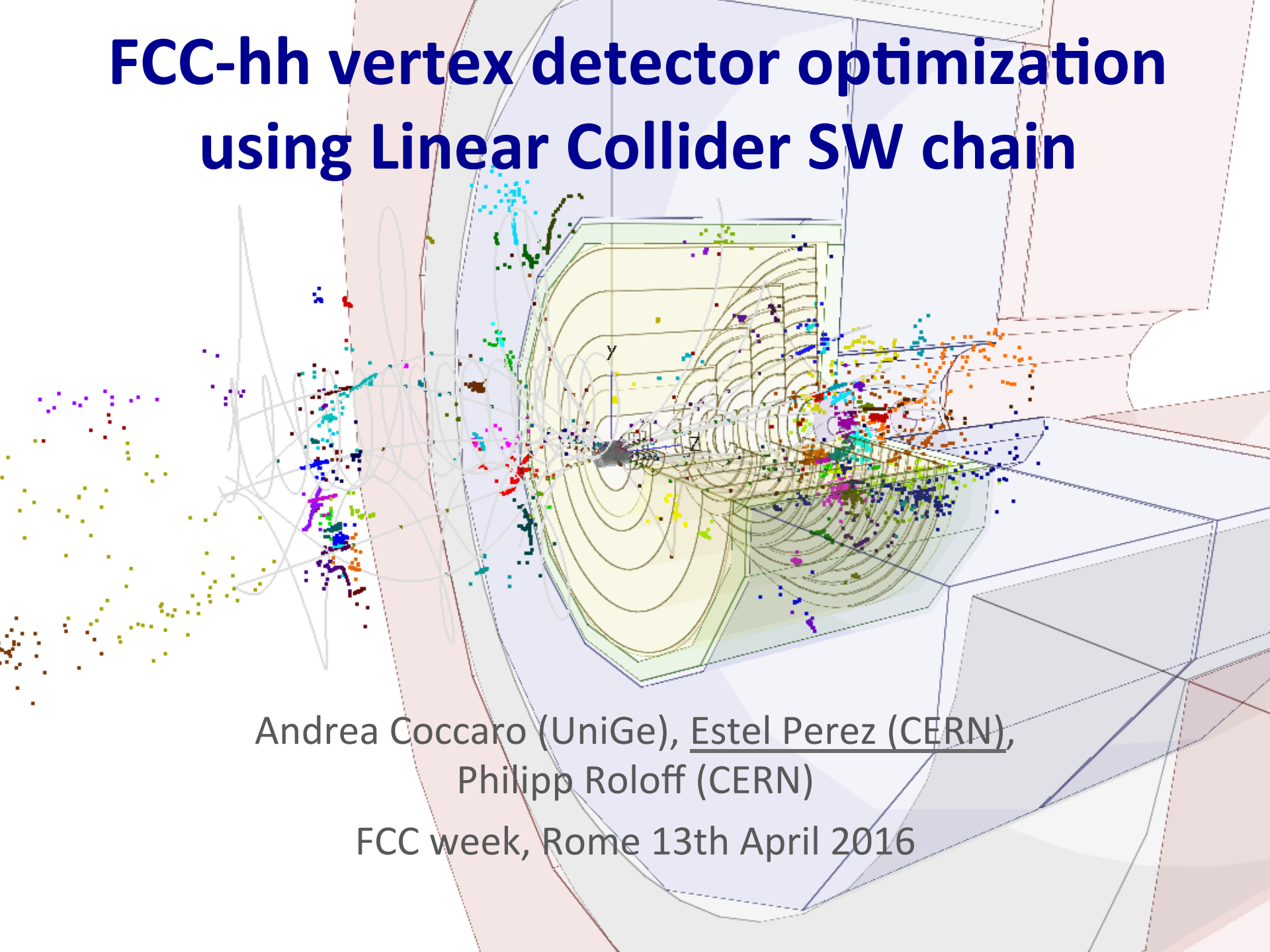
FCC-hh vertex detector optimization using Linear Collider SW chain



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FCC week, Rome 13th April 2016

Introduction

- Optimize FCC-hh Vertex detector based on flavor tagging performance → Need **full simulation**
- Use **linear collider (LC) software** chain
- Challenges:
  - Need to reconstruct and tag jets over a **large range of p_T**: from O(50 GeV) to O(10 TeV)
  - Flavor tagging in the **forward region** (crucial for processes like double Higgs production)
  - **Pile up** O(200 events/bunch crossing) →Not yet addressed
- 2 steps:
  - **Barrel region**
  - Forward direction

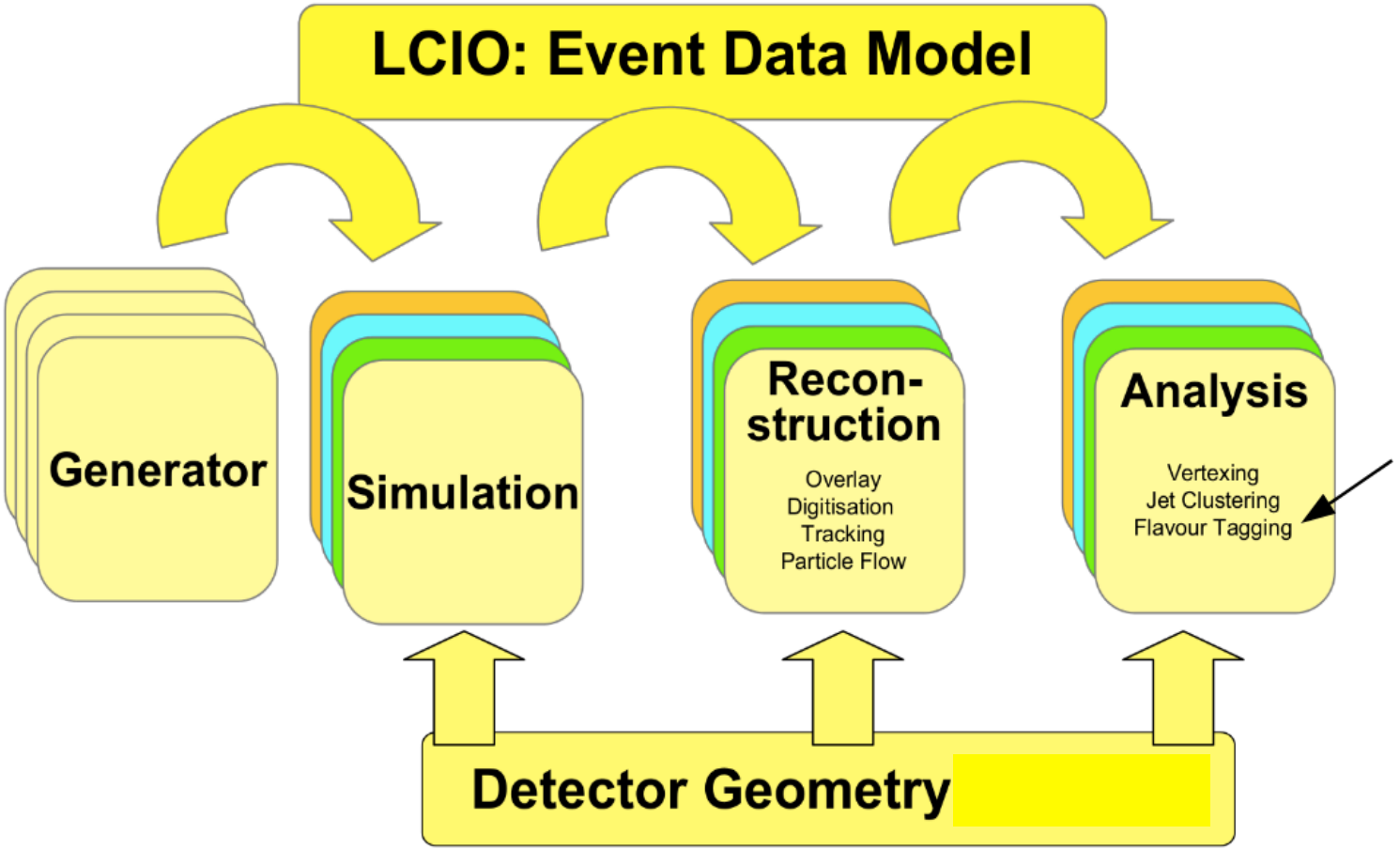
Status

1) Use **LC software chain** to simulate and reconstruct **pp collisions** at √s =100 TeV– **done**
2) Check **flavor tagging performance** in pp events using a CLIC detector model – **ongoing**
3) Change the **detector geometry** so that the vertex detector has the FCC-hh geometry
   a) Barrel region - **ongoing**
   b) Forward region
4) Compare flavor tagging performance for different designs and detector parameters (single point resolution, material budget, sensor sizes…)

MC Samples for barrel studies

- Generated using **Madgraph5 + Pythia6**, writing stdhep files compatible with LC framework.
- **Central** ($|\eta|<0.05$) dijet samples ($pp \longrightarrow b\bar{b}/c\bar{c}/u\bar{u}$) $\sqrt{s}$=100 TeV
  - **inclusive**: $p_T(q) > 50$ GeV
  - **mono-energetic:**
    - $p_T(q) = 50$ GeV (between 47.5 GeV and 52.5 GeV)
    - $p_T(q) = 200$ GeV
    - $p_T(q) = 500$ GeV
    - $p_T(q) = 1$ TeV
    - $p_T(q) = 5$ TeV GeV
    - $p_T(q) = 10$ TeV GeV
  - **angular separation**: $\Delta R(q,q)>0.4$

LC software chain

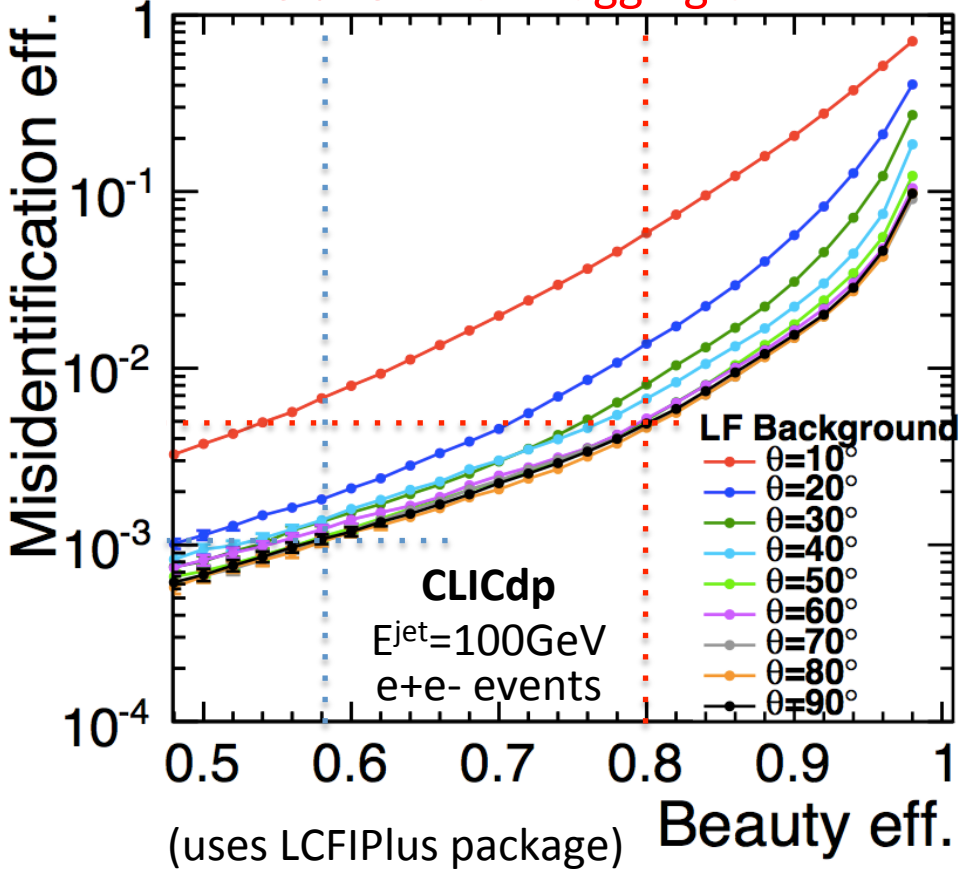


- Vertexing and **flavor tagging is done after particle flow** analysis (Pandora)

Flavor tagging

- **B-tagging performance** in CLIC **comparable to LHC**

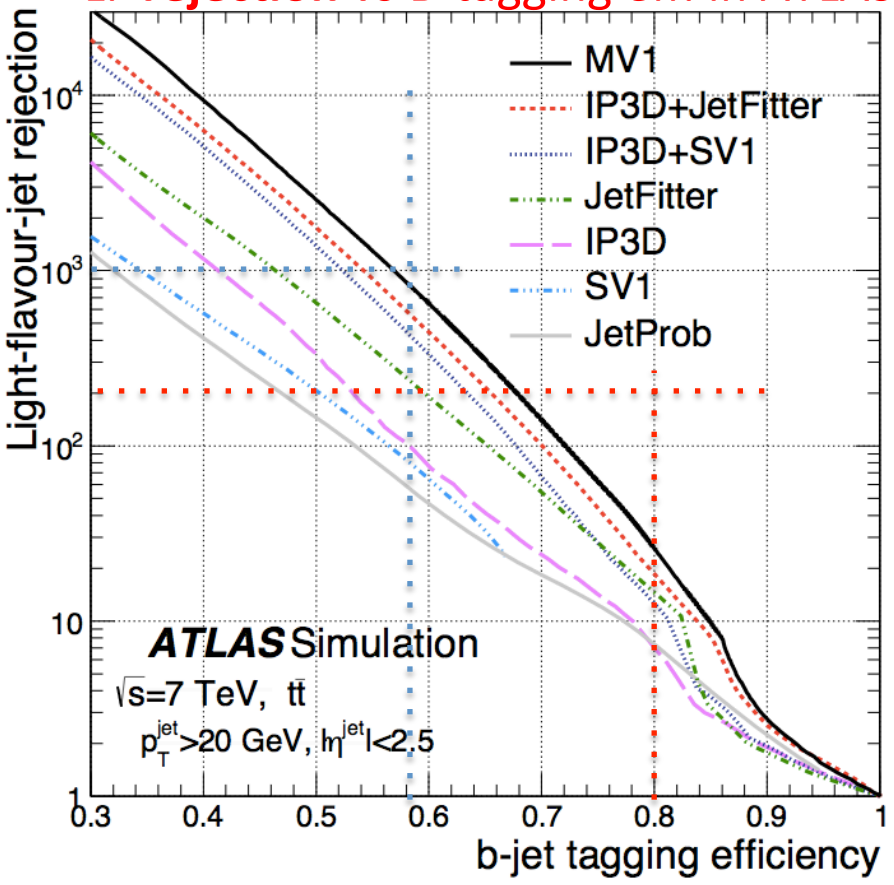
LF **misid. eff**. vs B-tagging eff. in CLIC



(uses LCFIPlus package)

https://cds.cern.ch/record/1742993

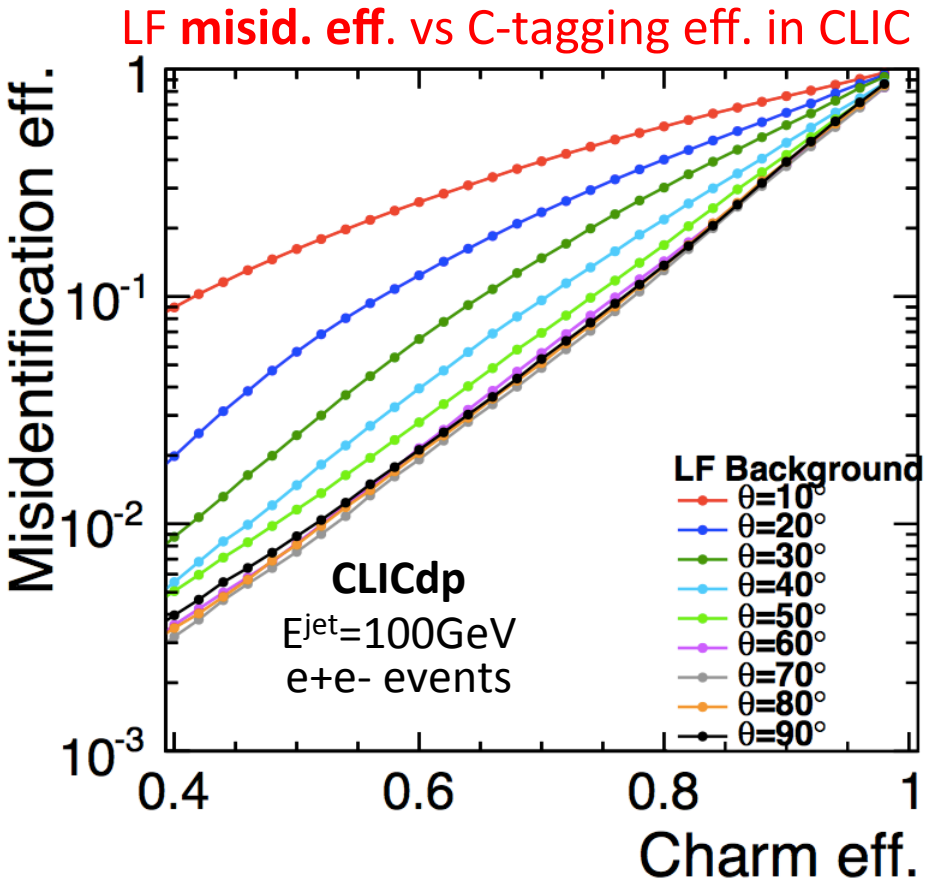
LF **rejection** vs B-tagging eff. in ATLAS



http://arxiv.org/pdf/1512.01094v2.pdf

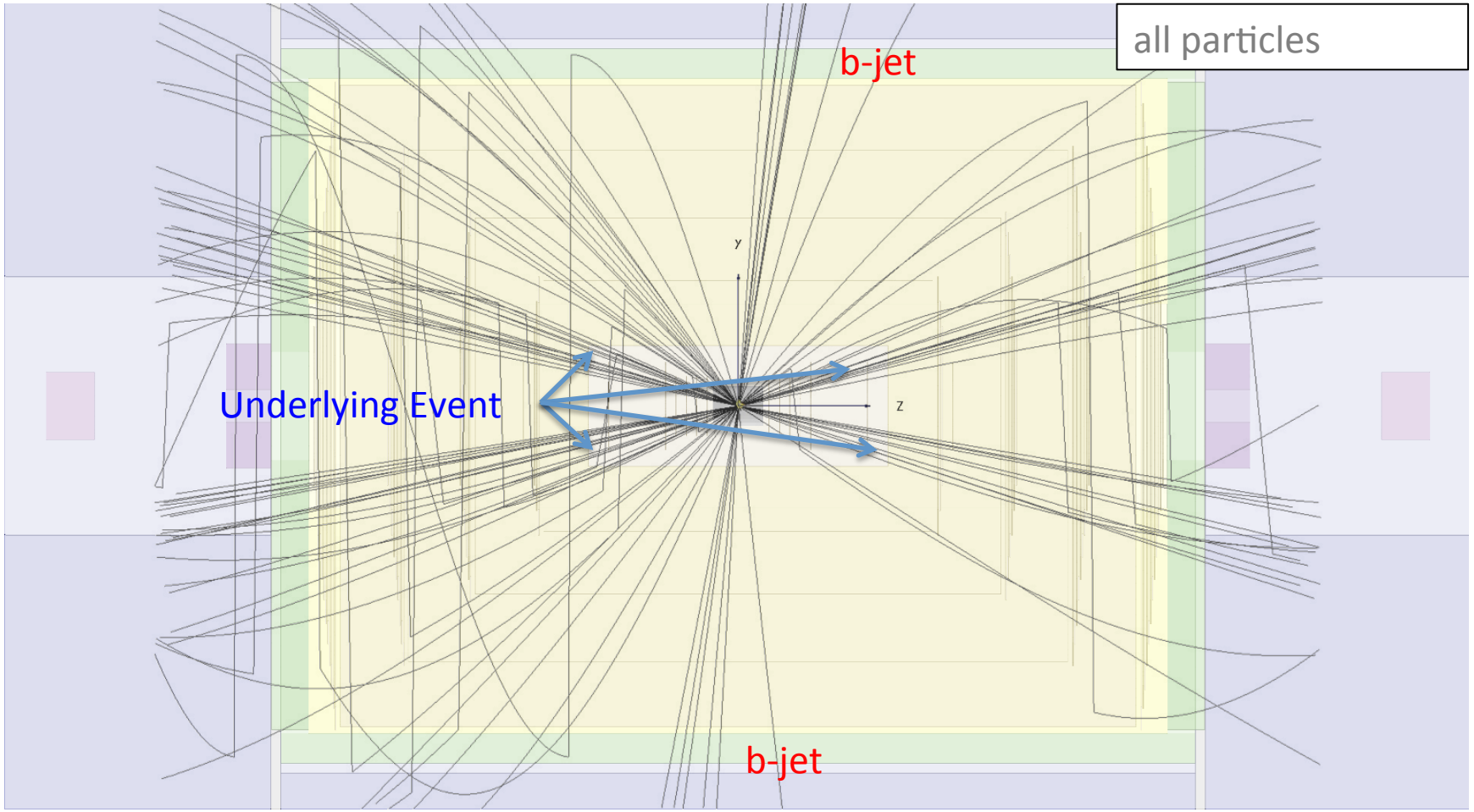
Flavor tagging

- In addition LC flavor tagging can provide **very good c-tagging performance** as well

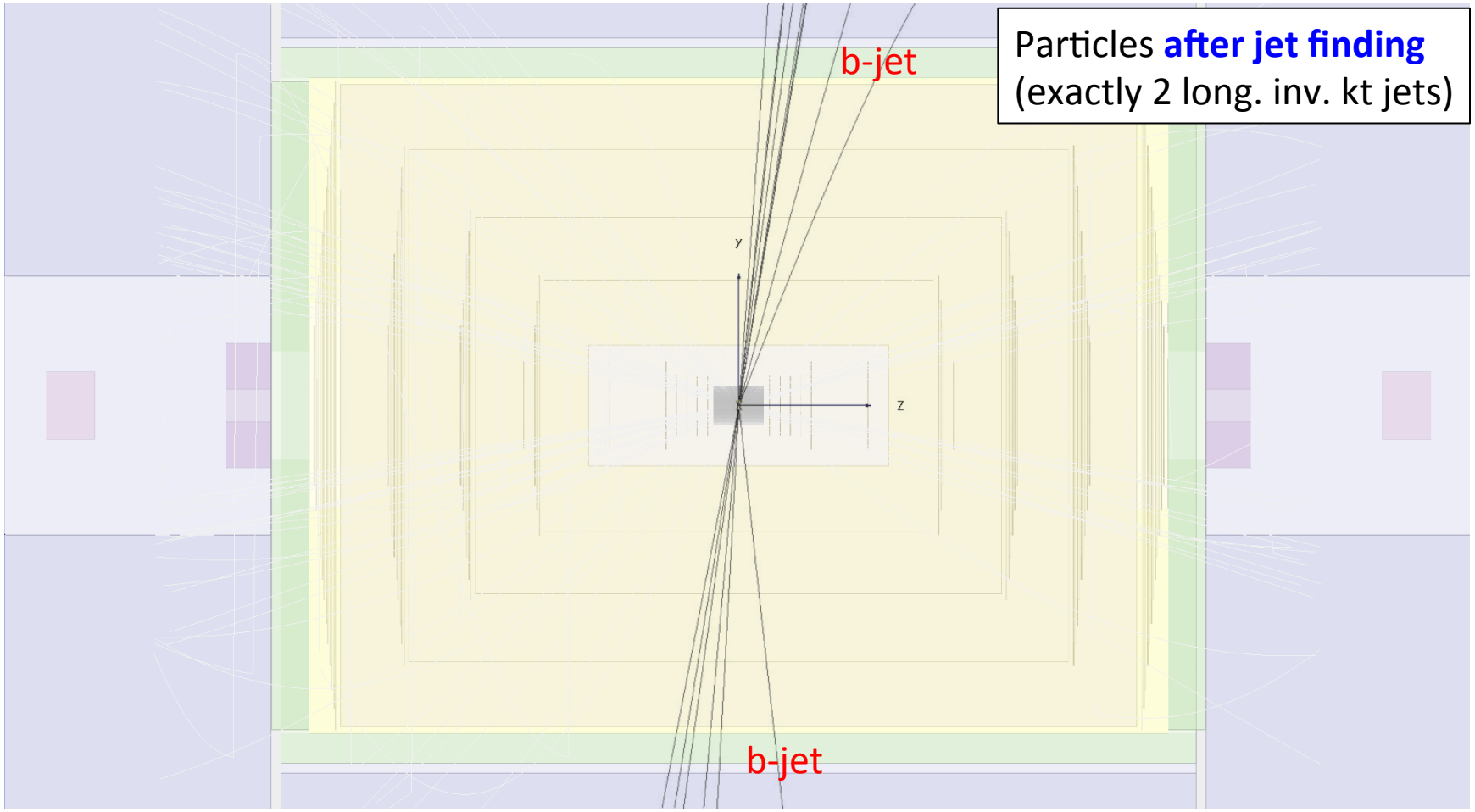


c-tagging **important for FCC-hh physics**?

$pp \longrightarrow b\bar{b}$ collision at $\sqrt{s}$=100 TeV reconstructed in the CLIC detector



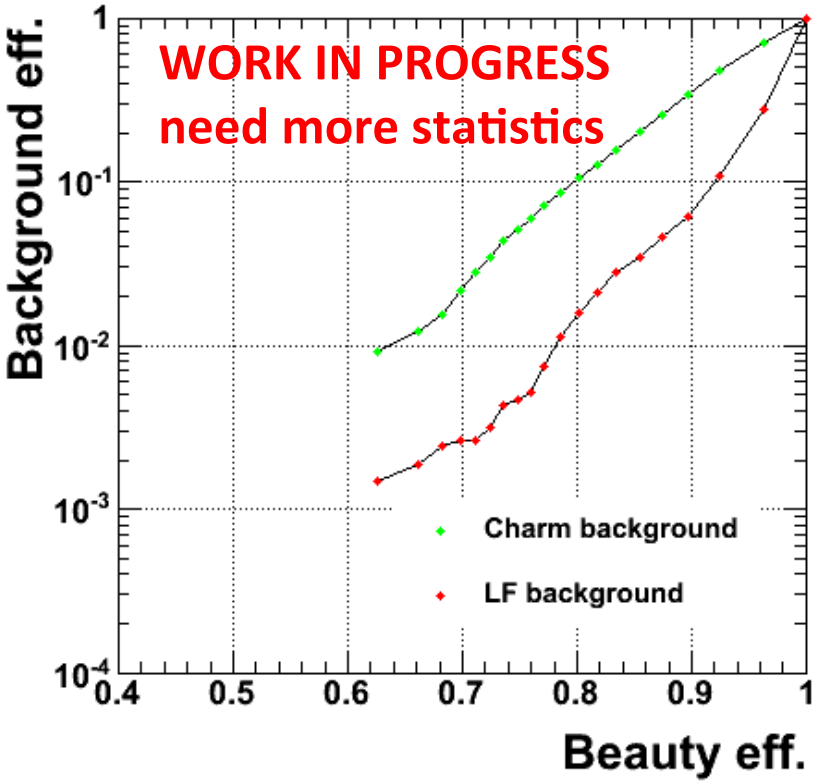
$pp \longrightarrow b\bar{b}$ collision at $\sqrt{s}$=100 TeV reconstructed in the CLIC detector

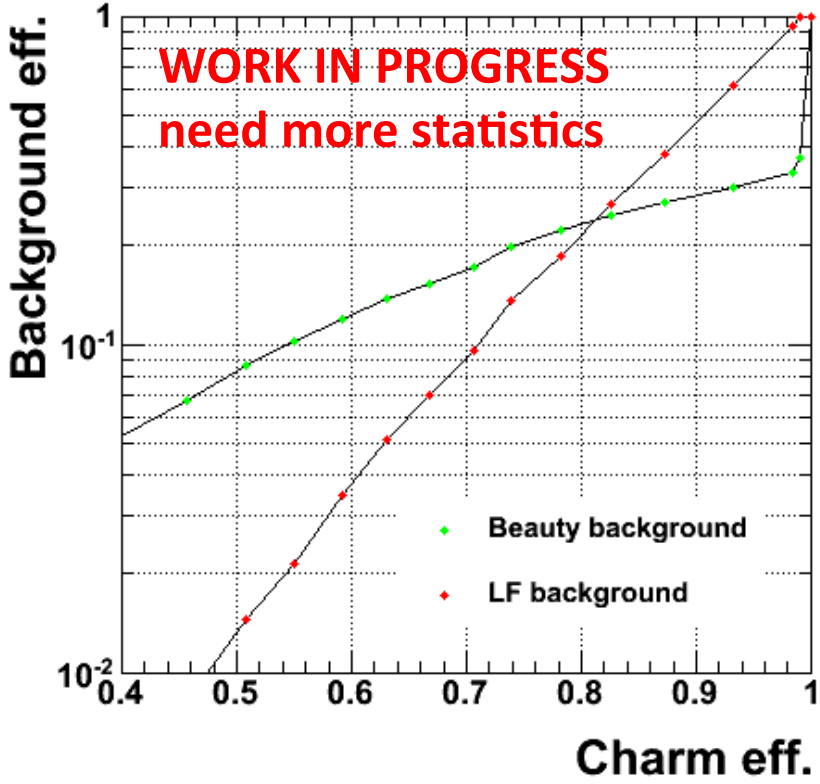


These particles are the **input to the Vertexing algorithm and flavor tagging**

Flavour tagging performance with CLIC_SiD detector on pp events

- Prelim. **proof of concept**: use **inclusive** sample: **$p_T(q)>50$ GeV**
- Use only particles with $p_T>500$ MeV, clustered in 2 long. inv. kt jets of R parameter of 0.3. Require p_T(jet) between 50-100 GeV
- **More statistics needed** to draw a conclusion





FCC Vertex Detector geometry

- Start with the barrel region
  1) Increase inner radius of CLIC_SiD tracker to make space for the FCC vertex detector
     - Avoid modifying the calorimeters by now, to be able to use the same calibrations
  2) Add Vertex Layers (1+8)
  3) Modify Pixel modules material composition

Kept 3μm single point resolution (as for CLIC)

Keep CLIC magnetic field of 5T

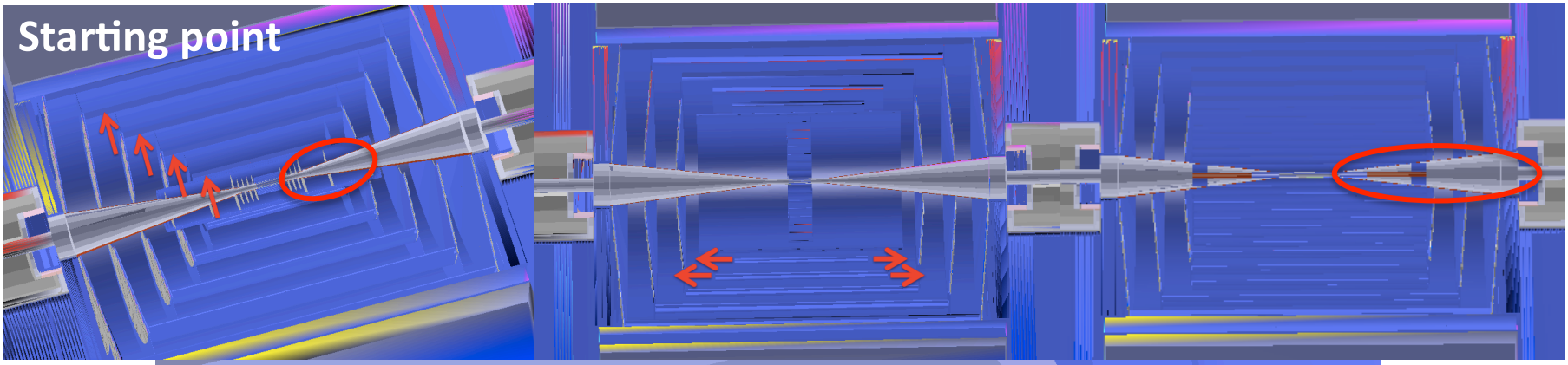
* The Pixel detector:
- consists of 8+1 barrel layers equidistantly positioned from 25mm - 600mm
- first layer is 500mm long
- other layers are 1000mm long
- consists of 8 discs equidistantly positioned from 1250mm - 3000mm
- the discs extend from 25mm - 600mm

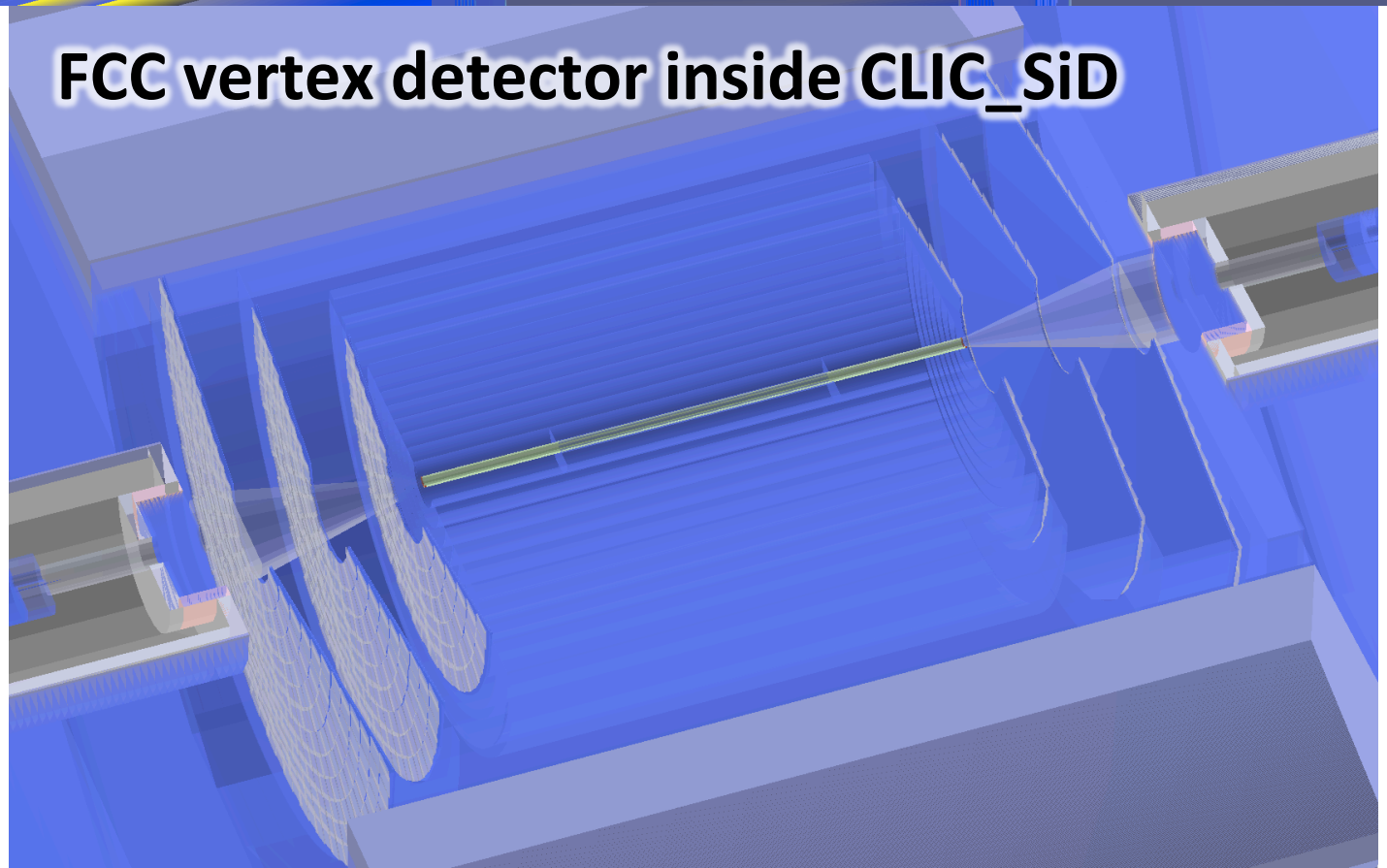
* Extension of a pixel detector for high eta
- consists of 10 discs equidistantly poisitioned from 3500mm - 8000mm
- the discs extend from 25mm - 600mm

The material budget will by alwas the same:

* 0.43 cm thickness per layer (or disc)
- Si 20%
- C 42%
- Cu 2%
- Al 6%
- Plastic (PE) 30%

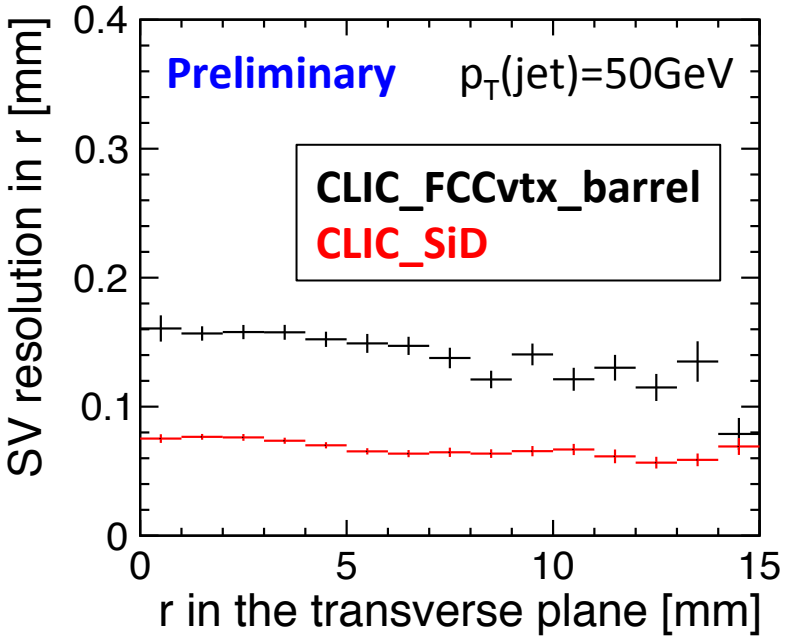
Vertex Detector geometry

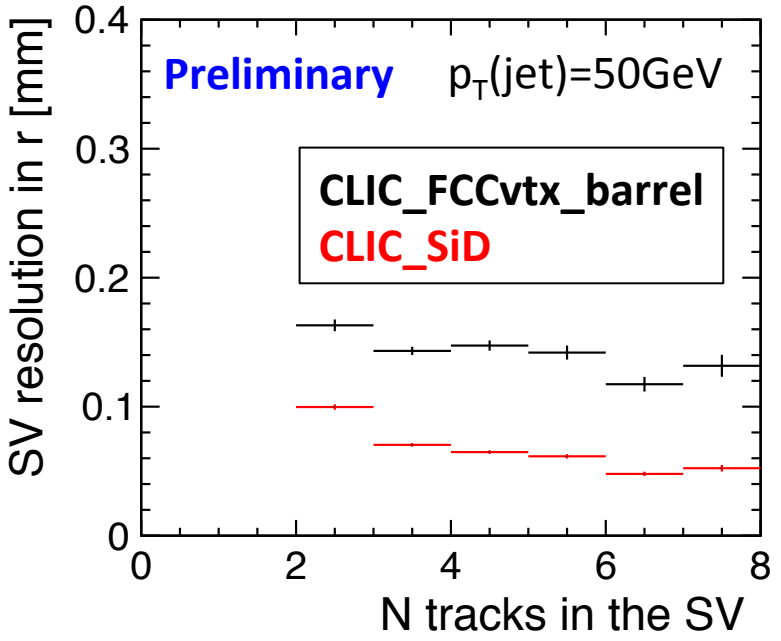




Flavor tagging performance with modified geometry

- **Adapted track finding** strategy to the modified geometry
- **Working on flavor tagging** performance (need more statistics)
- **Secondary Vertices resolution**:



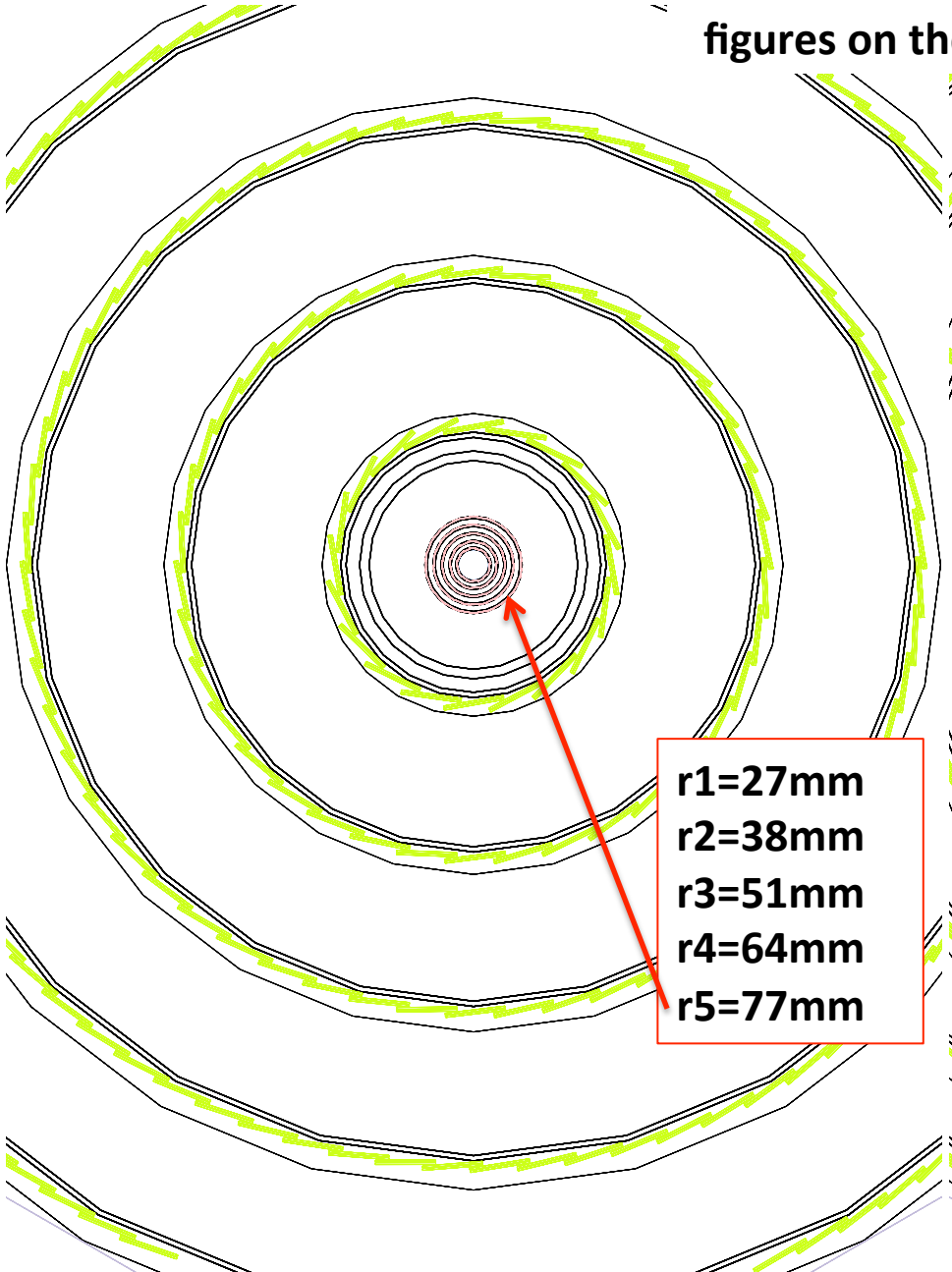


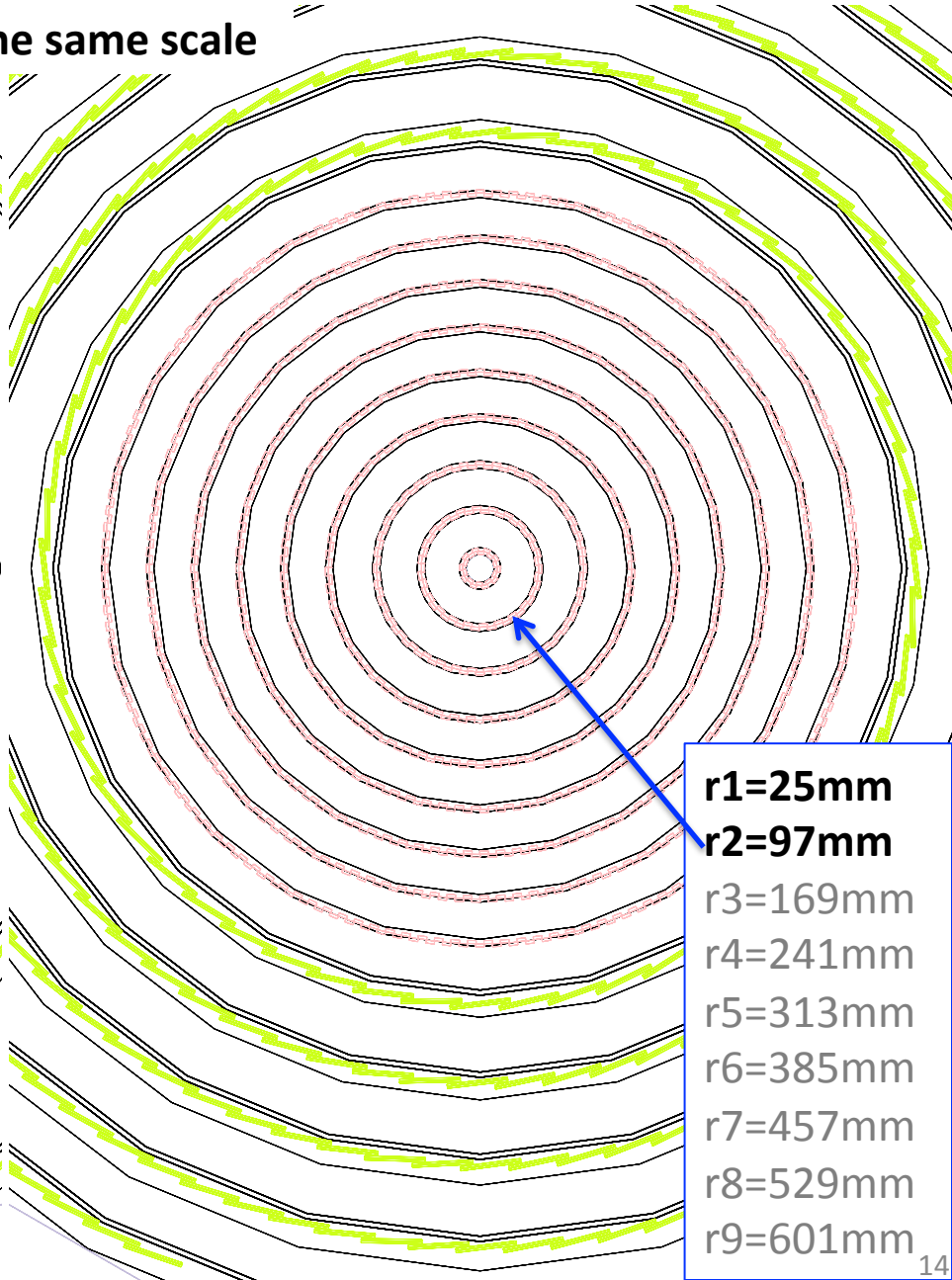
→ **Our baseline FCC vertex design seems not to be optimal for flavor tagging on low momentum jets** (has only one layer close to the IP)

CLIC_SiD

CLIC_FCCvtx_barrel

figures on the same scale





Next steps

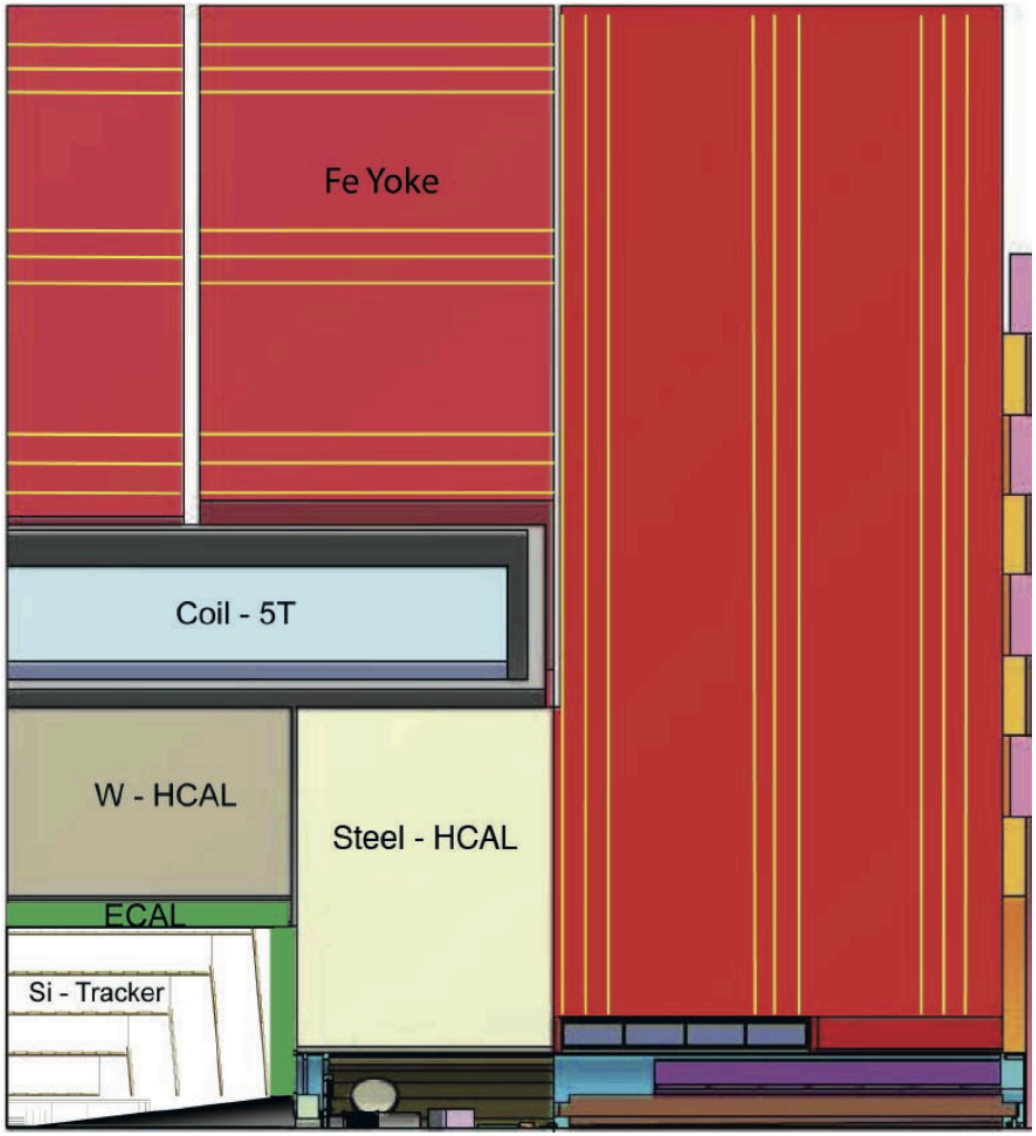
- Analyze flavor tagging performance as function of the **jet energy** (50 GeV to 10 TeV)
  - Comparing different barrel layouts
  - Comparing different sensor parameters (material budget, sensor resolution…)
- Tackle the **forward** region
  - Implement FCC forward vertex detector geometry
  - Adapt flavor tagging strategy if needed

Conclusions

- The **FCC-hh vertex detector optimization** effort has **kicked off**
- Important **milestones achieved**
  - Run LC software chain on pp collisions at √s=100 TeV
  - Modify detector geometry to fit the FCC-hh barrel vertex detector
- First results using FCC geometry coming soon

Backup

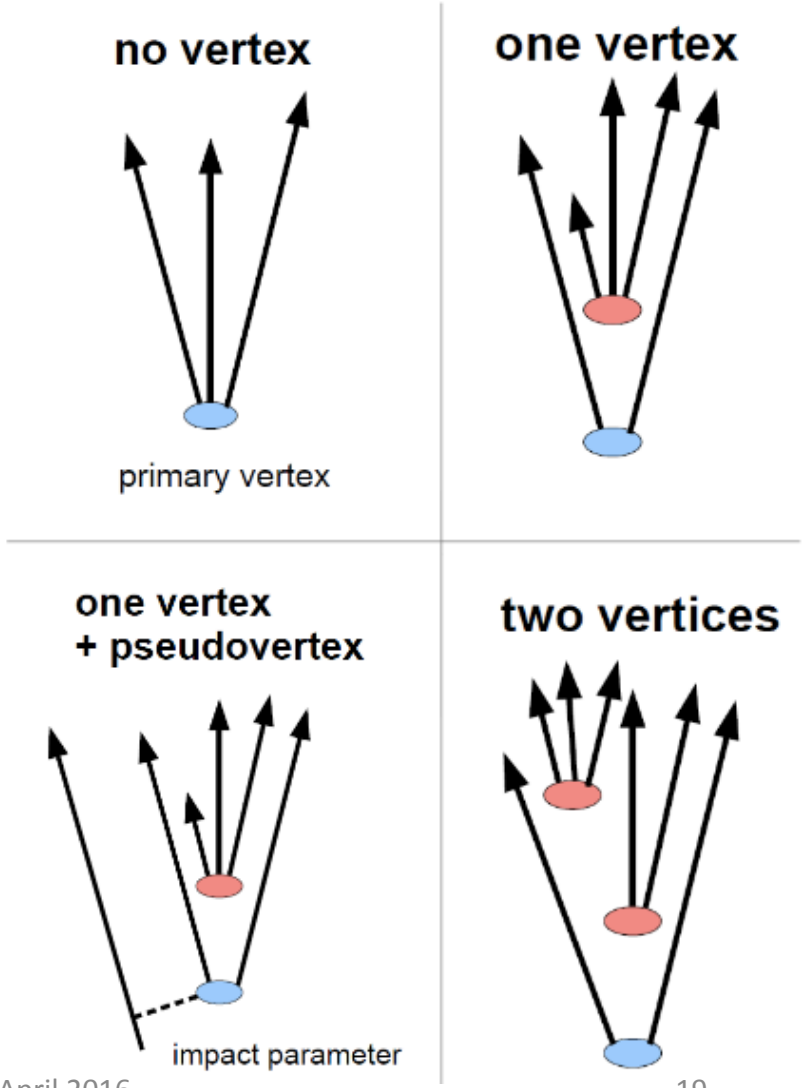
CLIC_SiD detector



Flavour tagging at CLIC

Based on the LCFIPlus package:
(arXiv:1506.08371)

- Jets grouped into 4 categories
- 2 classifiers trained for each category: b-tag, c-tag
- In the following, using only tracking and vertexing information
- Performance can be improved using lepton ID, but not relevant for vertex geometry optimisation



ATLAS Vertex layout