STATUS OF FAST SIMULATION AND PHYSICS ANALYSIS

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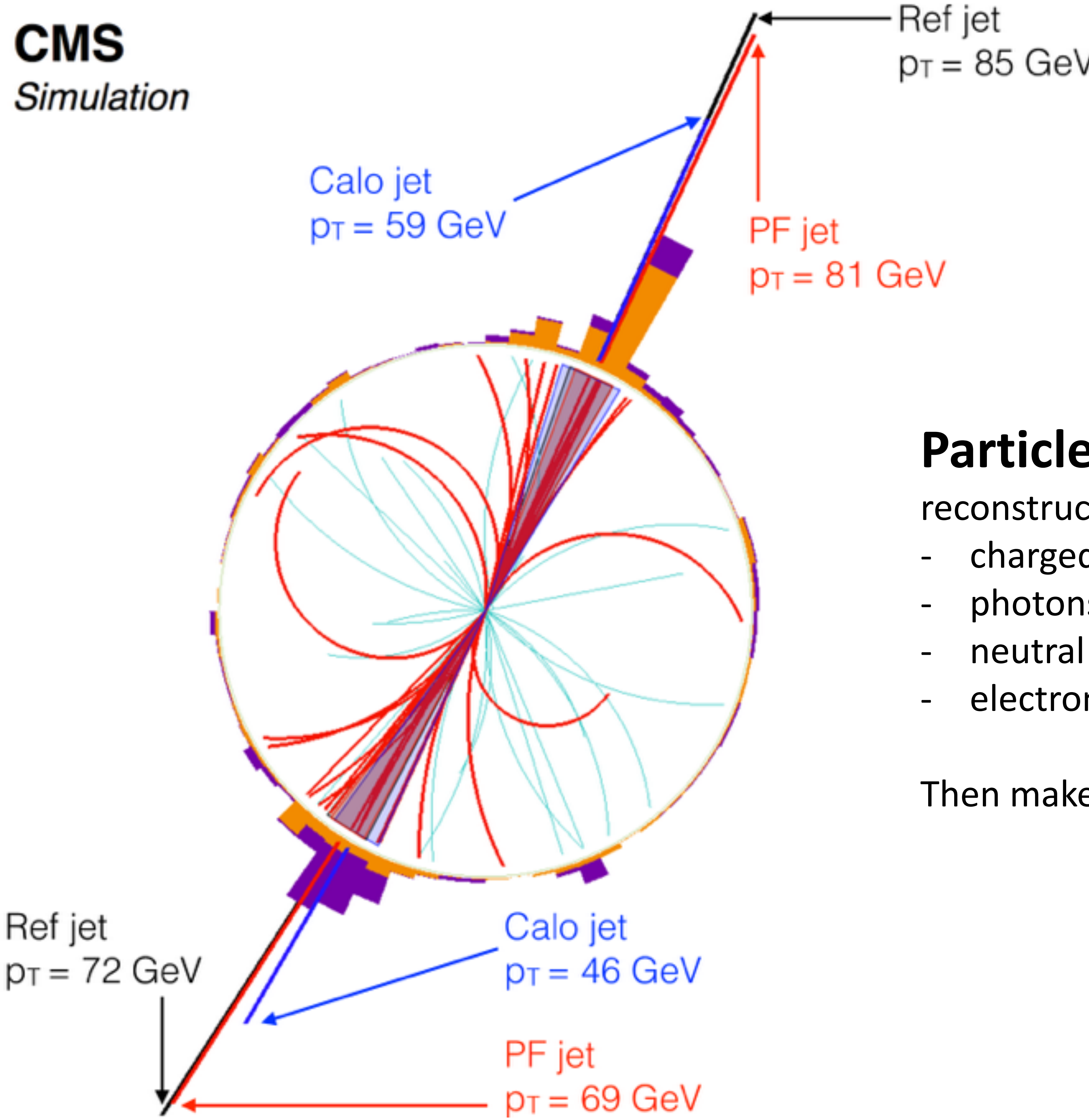
thanks to Paolo Azzurri, Colin Bernet, Roberto Tenchini, etc..

why fast simulation

- FastSimulation of detector concept can be used in several ways:
  - to push forward the studies for the physics analysis potential
  - to help in the design of the detector concept allowing quick checks of different performance on physics quantities
- Particle flow and global event reconstruction have been proven to be the best way to achieve precise physics results. A « particle flow based » fast simulation can also:
  - help in the developement of future algorithms for particle identification while the FullSim is being put together and not available yet
- PAPAS: newly developed for the FCC-ee:
  - features a full particle flow algorithm
  - models validated with CMS and CLD FullSimulation
  - Lots of analyses ready
- should add the IDEA concept (work in progress about adding the DR values)



Particle Flow:

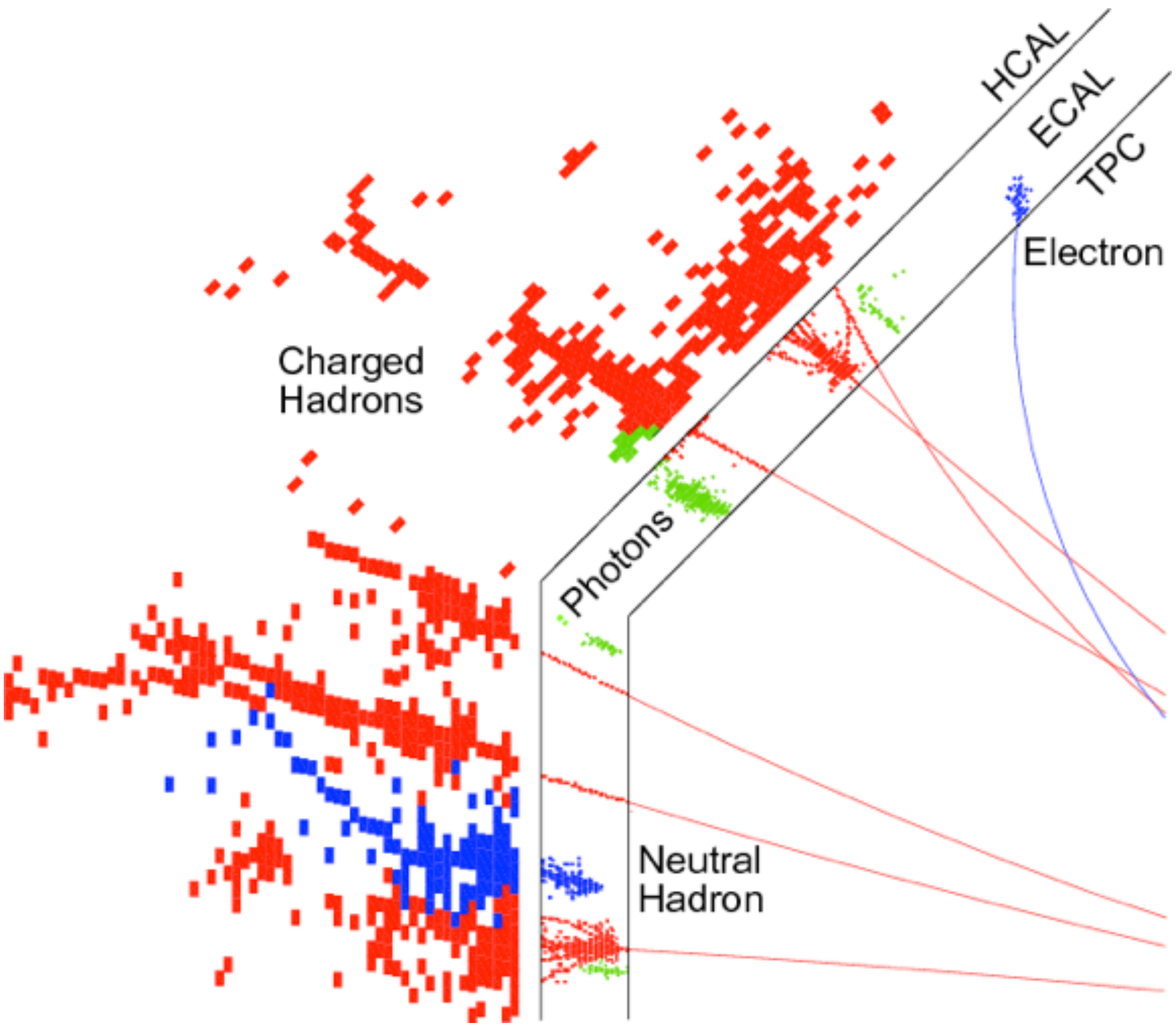
reconstruct all stable particles

- charged hadrons
- photons
- neutral hadrons
- electrons, muons

Then make jets, taus, MET, …

from Colin Bernet

Particle Flow is the Future



CLIC

Need to resolve the energy deposits of nearby particles

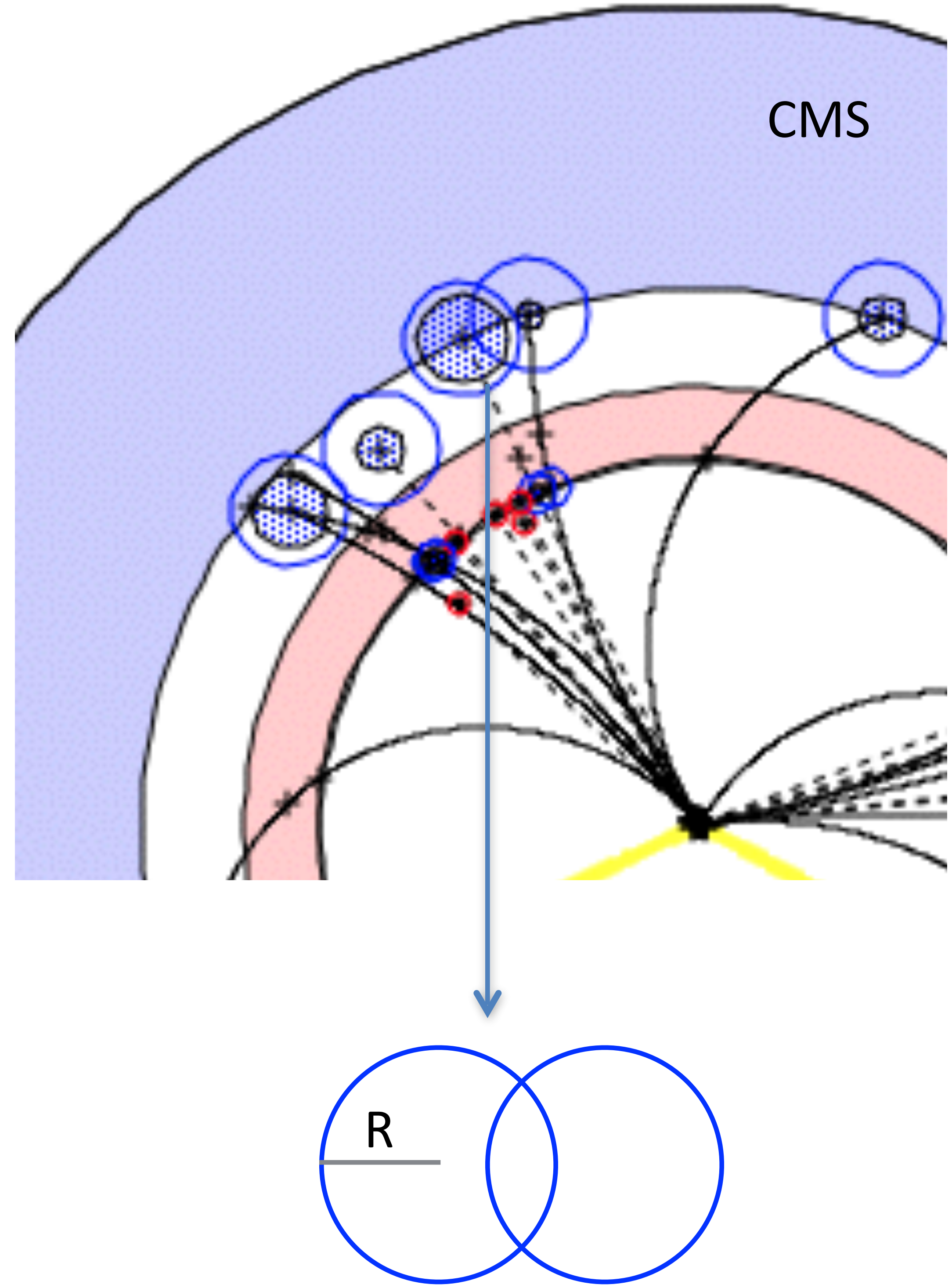
Future detectors designed for this: pixel calorimeters

FCC detector design:
Need detailed fast simulation of the particle flow

from Colin Bernet

Papas

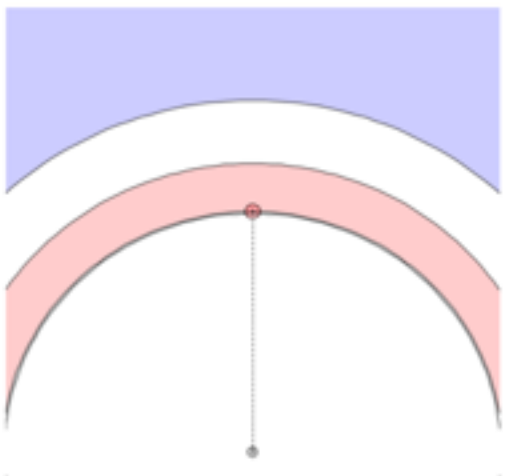
- Simple geometry (cylinders)
- Material
  - for hadron shower in ECAL
- Energy resolution Response
- Acceptance
  - thresholds
- Cluster size R
  - models calorimeter granularity



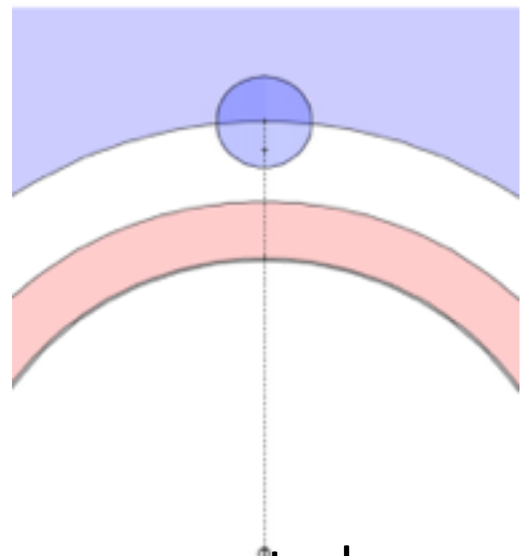
Sum energy and create a merged cluster

from Colin Bernet

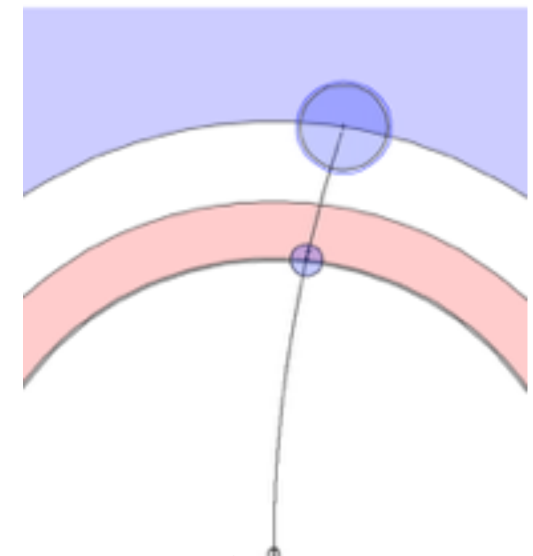
Papas: Particle Flow



photon

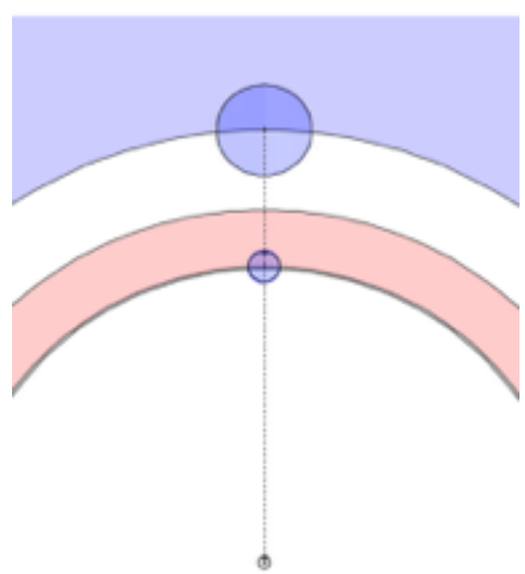


neutral hadron

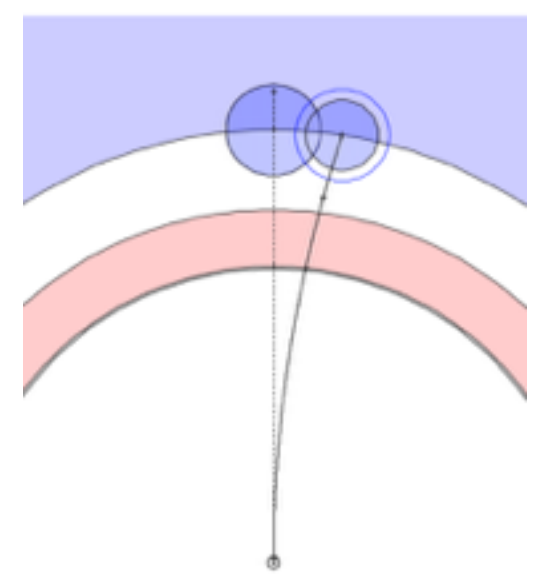


charged hadron

Full PF algorithm similar to CMS

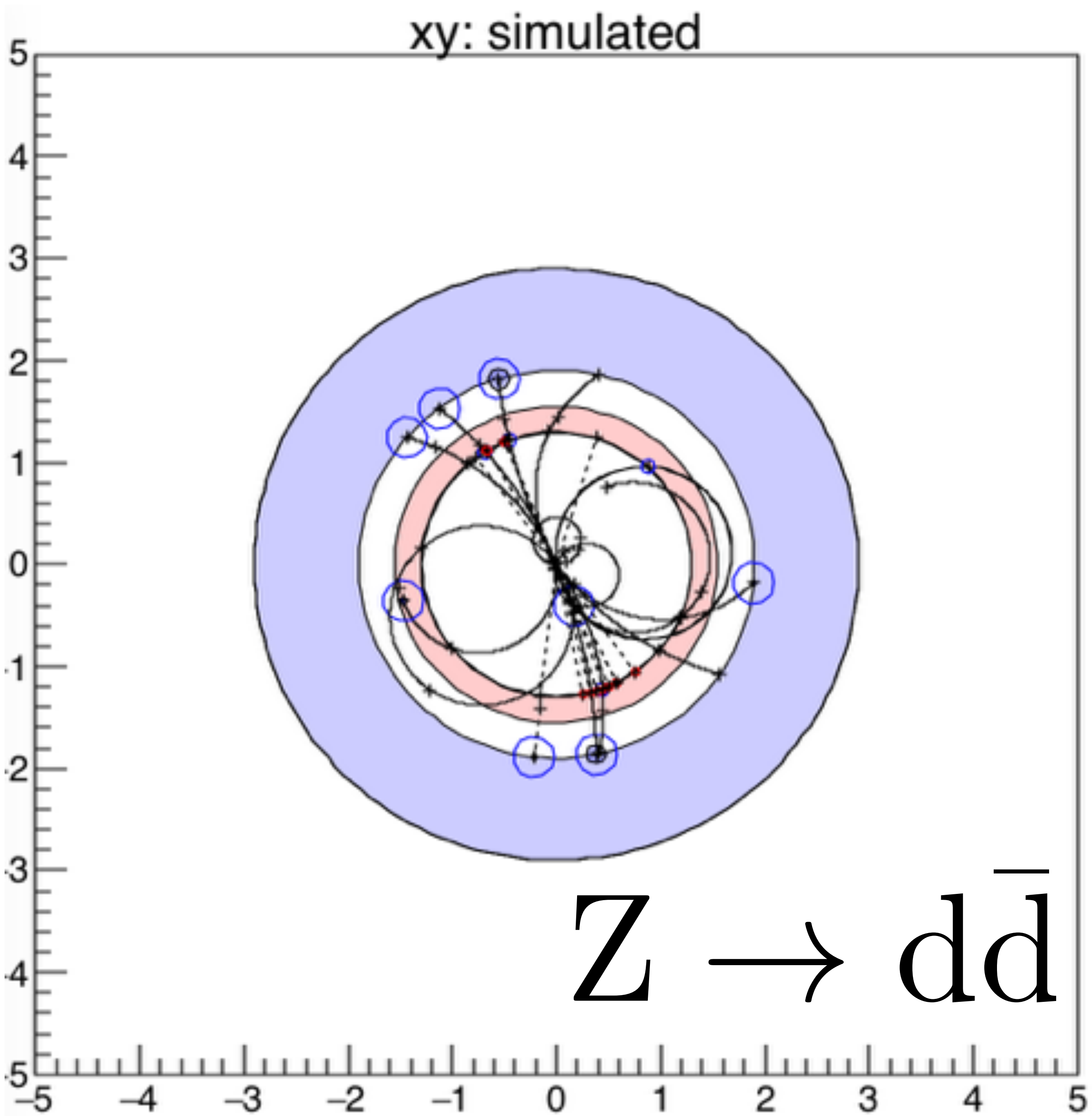


neutral hadron + photon

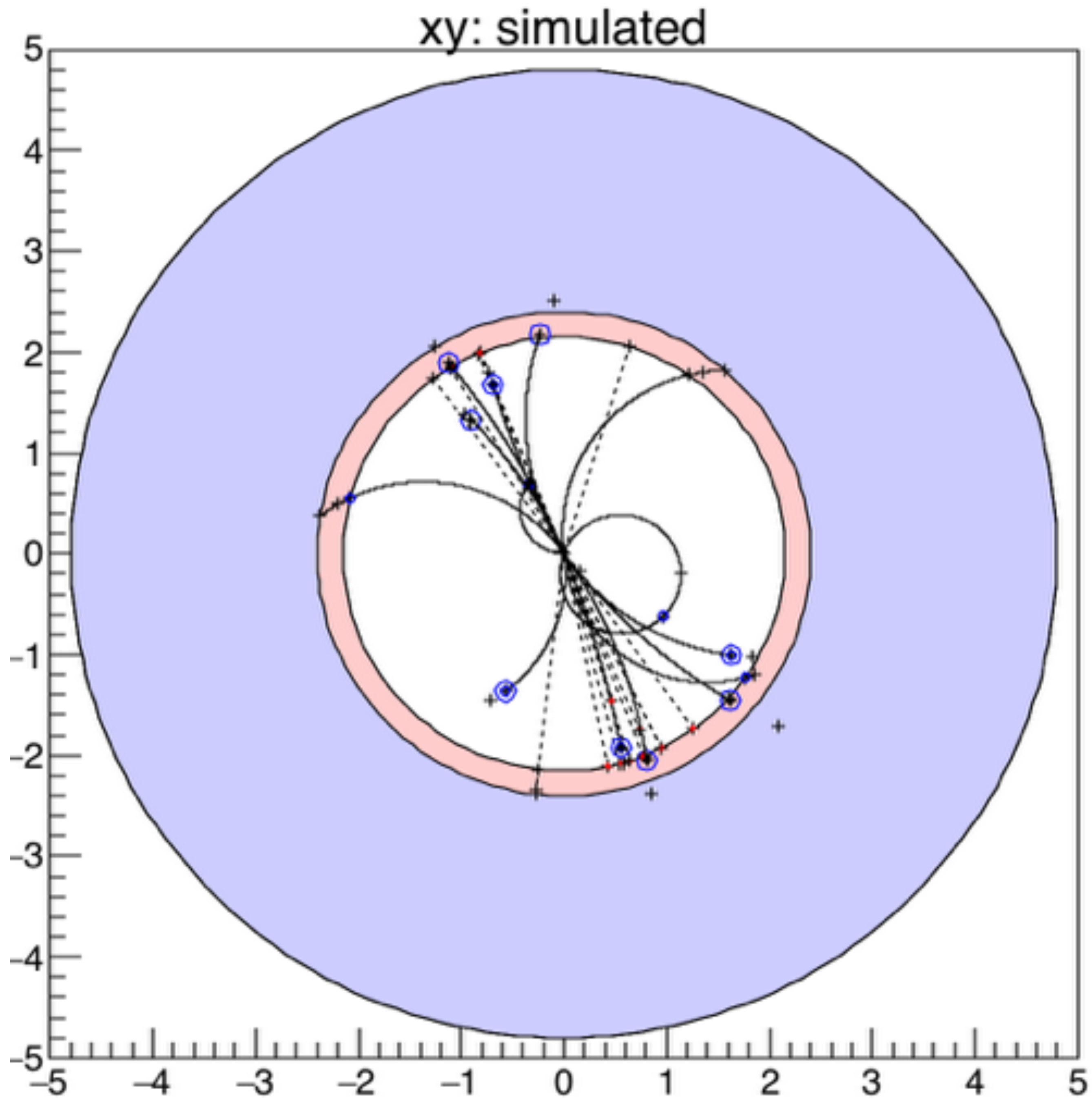


charged and neutral hadrons

Two Detector Models Available



CMS

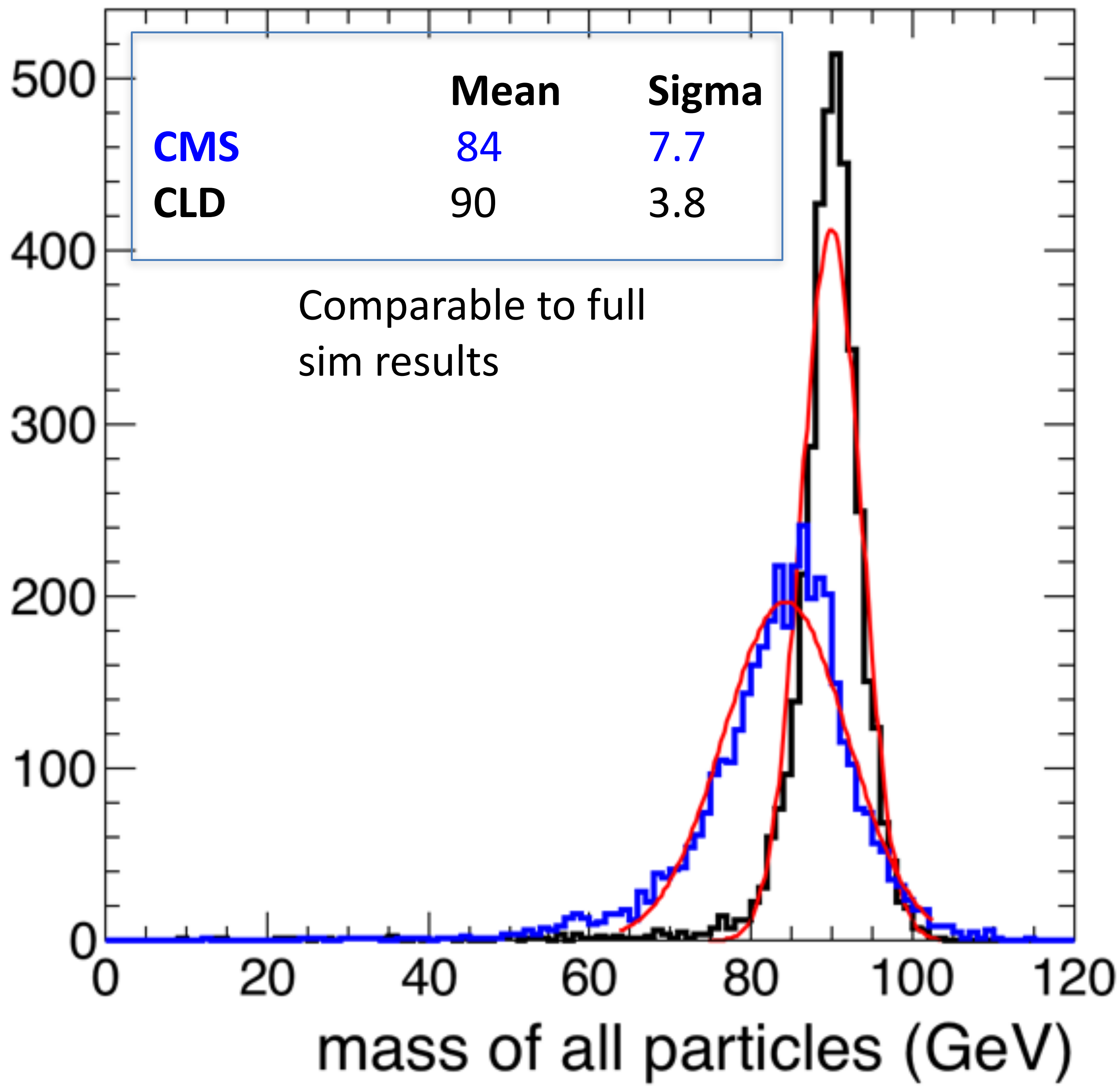


CLD

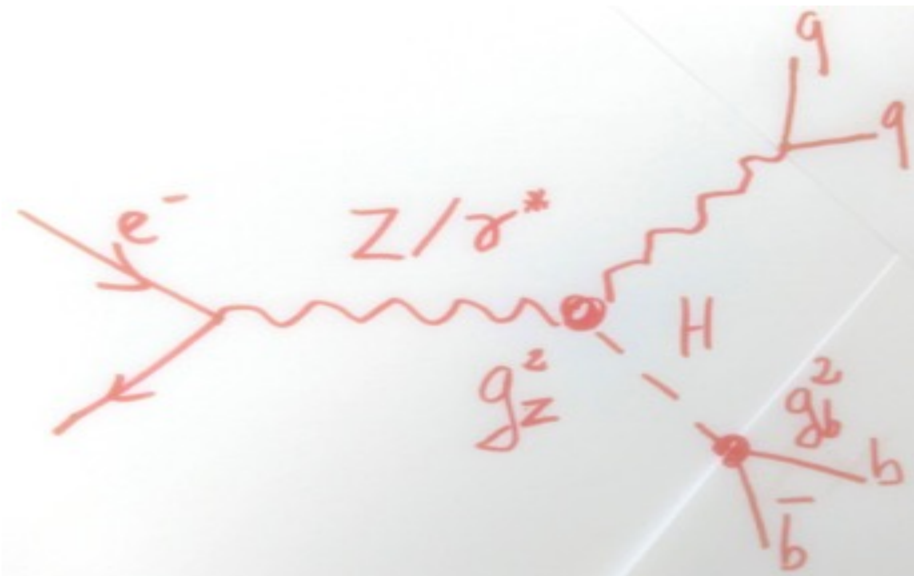
from Colin Bernet

$Z \rightarrow d\bar{d}$ mass reconstruction

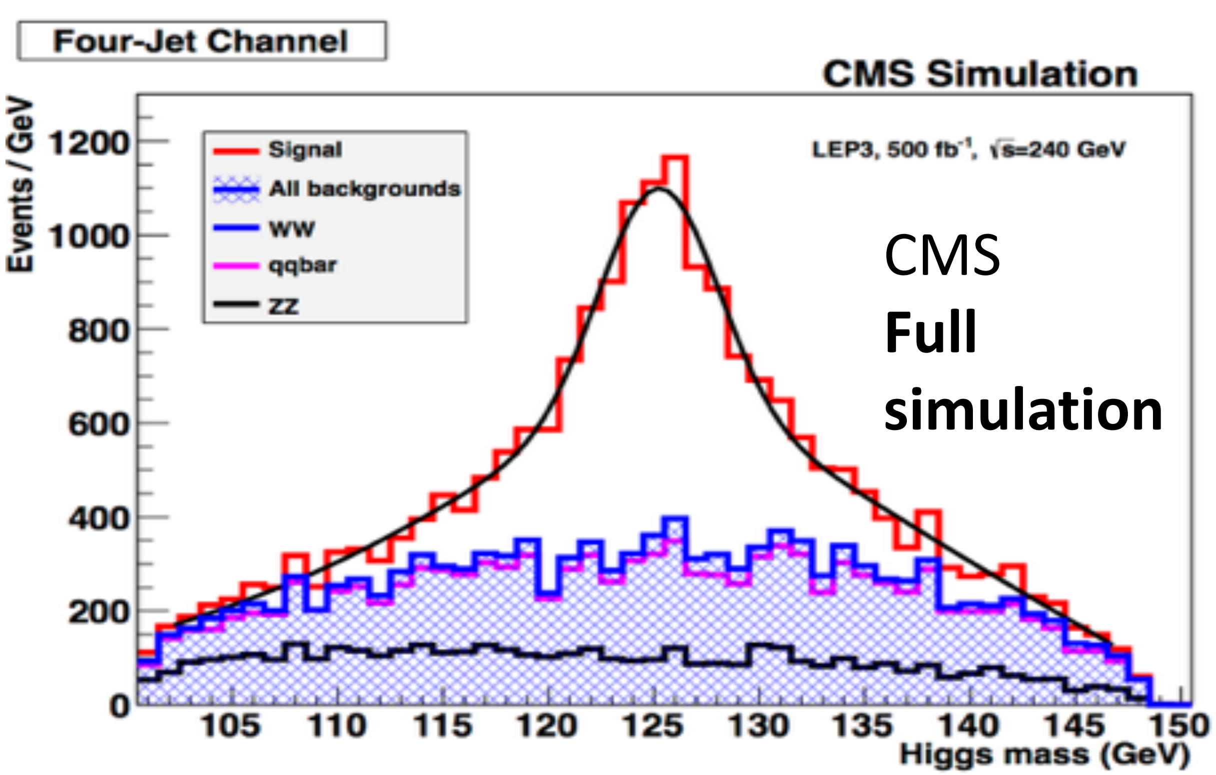
Invariant mass of all reconstructed particles
No jet reconstruction

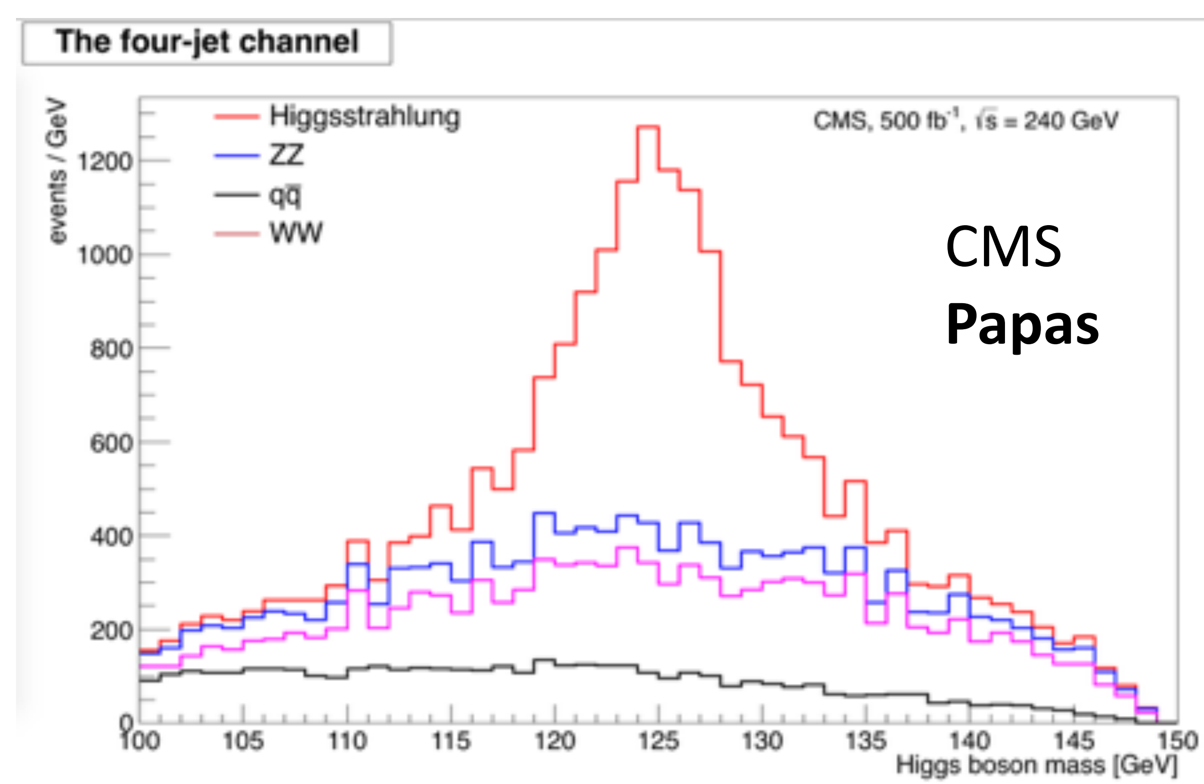


Validation in a physics channel

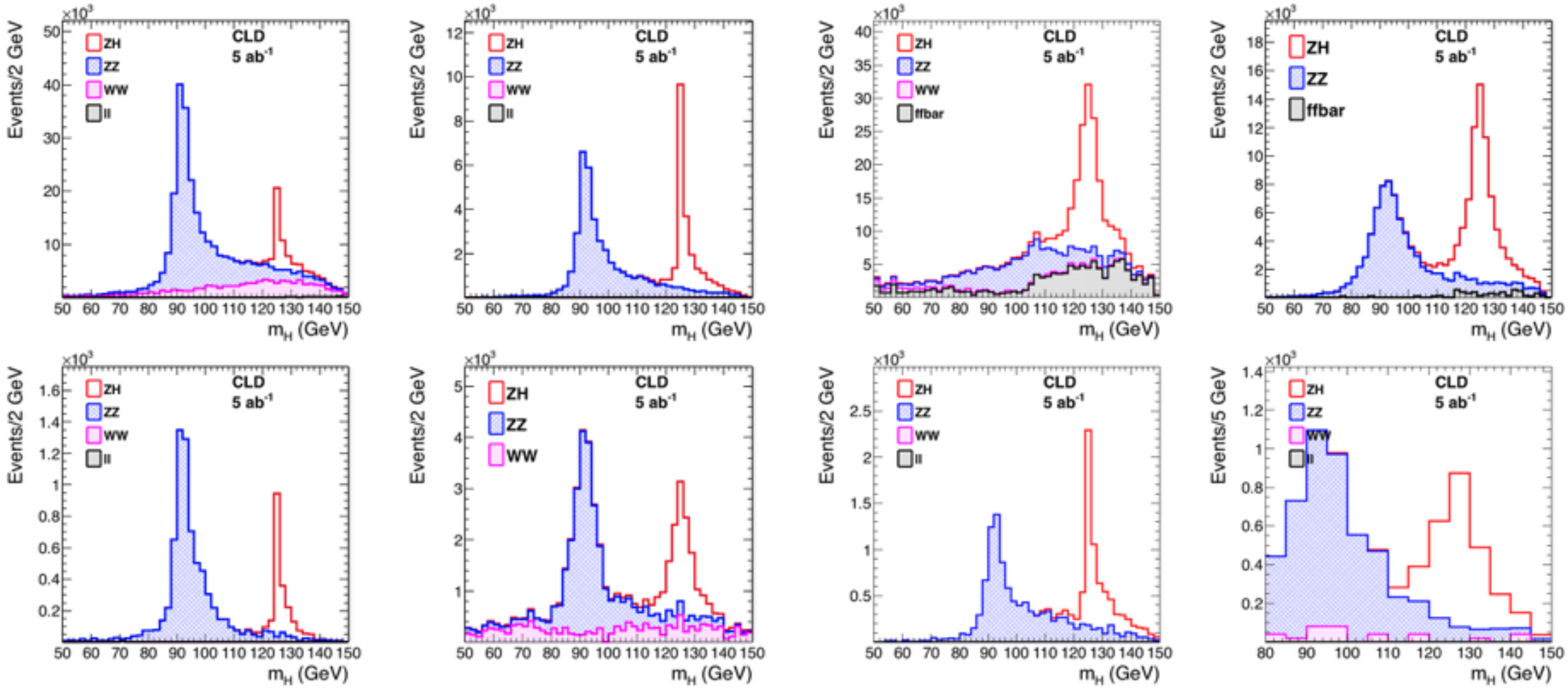


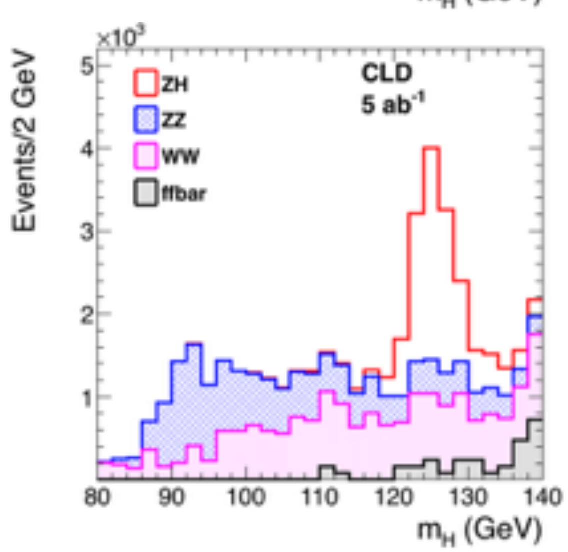
- exclusive 4 jet reconstruction,
- rescale jet energies for p4 conservation
- reject combinations with di-jet masses - compatible with ZZ and WW
- select best combination for H→bb (b tag)





Many Physics Analyses ready (CLD)





- Higgs production cross-section measurement in a variety of decay channels
  - Higgs coupling measurement around the corner
- Other analyses can be done easily (WW, top, …)

What about IDEA?

```
from heppy.papas.detectors.CLIC import clic
from heppy.papas.detectors.CMS import cms
detector = clic

### definition of input samples
### from components.ZH_Znunu import components as cps
##from fcc_ee_higgs.components.all import load_components
##cps = load_components(mode='pythia')

from fcc_datasets.fcc_component import FCCComponent

zh = FCCComponent(
    'pythia/ee_to_ZH_Oct30',
    splitFactor=4
)

zz = FCCComponent(
   'pythia/ee_to_ZZ_Sep12_A_2',
   splitFactor=1
)

ww = FCCComponent(
   'pythia/ee_to_WW_Dec6_large',
```

- Change 1 line in the analysis configuration file
- Re-run the computing
  - ~4 hours / analysis
- Analyses probably optimized for IDEA as well
- Powerful & generic analysis scripts available

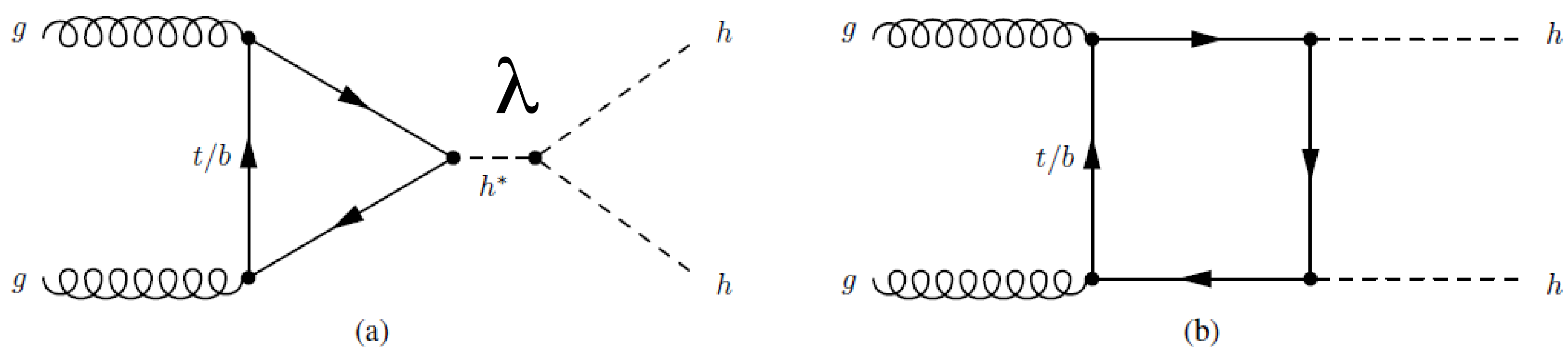
- Adding a detector model for IDEA.
- tricky thing is the DR calorimeter: easy to use the better resolution, not easy to describe the clustering/ overlap effect
- Work in progress with me/Lorenzo/ Colin

Physics analysis in Italy for FCC

- Activities have been now cristallized for a few years on (very)few main contributions:
  - FCC-ee Studies at the WW production threshold for Mass and Width measurement by Paolo Azzurri
    - generator level study, no simulation
  - FCC-ee Studies of top physics at threshold for mass, width and yukawa and outside threshold for other properties (EWK couplings, FCNC) by Patrizia Azzi
    - used mostly Delphes and checks with FullSim(CLIC)
    - new student (non italian, starting in September) working with PA. on improving measurement at threshold using PAPAS
  - Studies for FCC-hh of self coupling in HH to 4lbb and lnubbjj
    - https://indico.cern.ch/event/656491/contributions/2925419/attachments/1630967/2599925/HH_fccweek_v4.pdf
    - using Delphes
- All these results will be included in the FCC-CDRs
- Need to start something new if we want to engage a larger community.

HH studies for FCC-hh in CDR

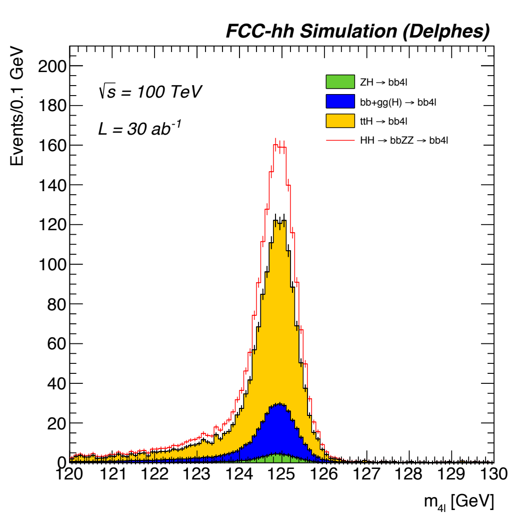
S. Braibant, L. Borgonovi, N. De Filippis,B. E. Fontanesi, Di Micco, , M. Testa, M. Verducci

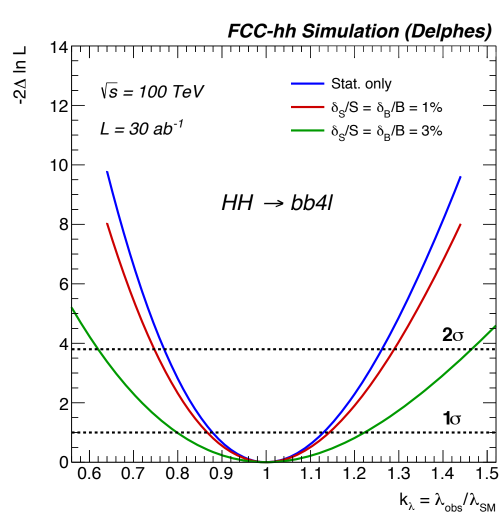


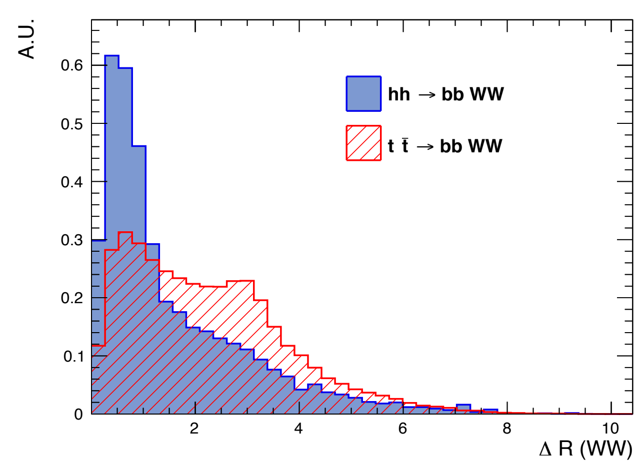
- Di-Higgs production expected in the SM through top-box and Higgs self-coupling term. The self-coupling is direct consequence of the Higgs potential shape.
- It can be probed at 100 TeV pp colliders thanks to the high production cross section at high energy.
- hh has many final states, it is important to probe all of them. Italian contribution in the VVbb final state

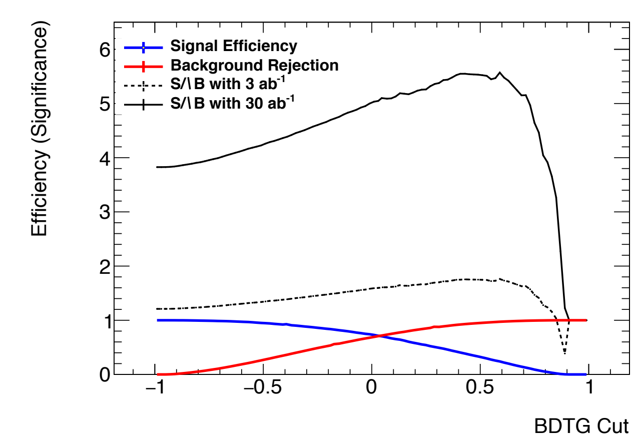
pp→ZZbb→4lbb

pp→WWbb→lvqqbb







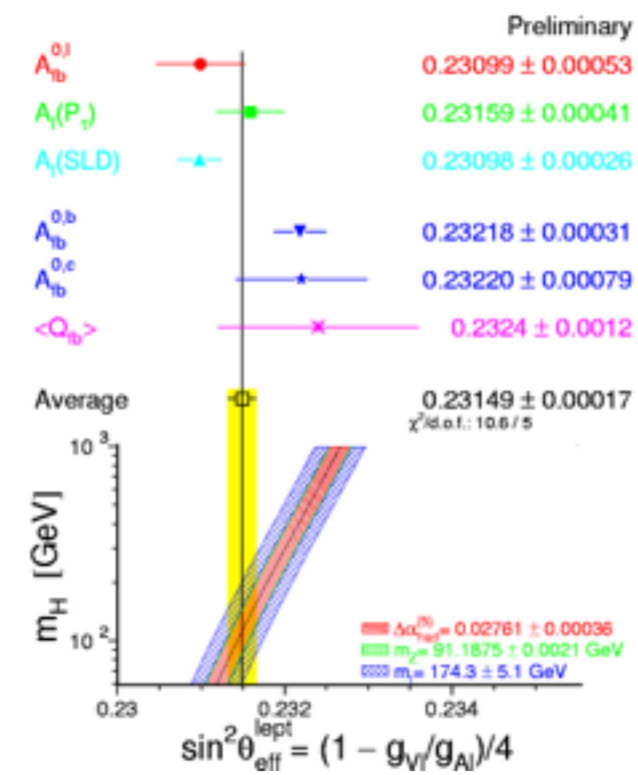


Proposal by Roberto Tenchini

FCC-ee strategy for neutral couplings and $\sin^2\theta_{eff}$

$$\mathcal{A}_e = \frac{2 g_{Ve} g_{Ae}}{(g_{Ve})^2 + (g_{Ae})^2} = \frac{2 g_{Ve}/g_{Ae}}{1 + (g_{Ve}/g_{Ae})^2}$$

- Muon forward backward asymmetry at pole, $AFB^{\mu\mu}(m_Z)$ gives $\sin^2\theta_{eff}$ with 5×10^{-6} precision
  - uncertainty driven by knowledge on CM energy
  - assumes muon-electron universality
- Tau polarization can reach similar precision without universality assumption
  - tau pol measures Ae and Aτ, can input to AFBμμ =3/4 Ae Aμ to measure separately electron, muon and tau couplings, (together with Γe , Γμ , Γτ)
- Asymmetries AFBbb, AFBcc provide input to quark couplings together with Γb, Γc



NOTE that LEP approach was different: all asymmetries were limited by statistics and primarily used to measure $\sin^2\theta_{eff}$

Proposal by Roberto Tenchini

tau polarization plays a central role at FCC-ee

- Separate measurements of A_e and A_τ from

$$A_{pol} = \frac{\sigma_{F,R} + \sigma_{B,R} - \sigma_{F,L} - \sigma_{B,L}}{\sigma_{tot}} = -A_f$$

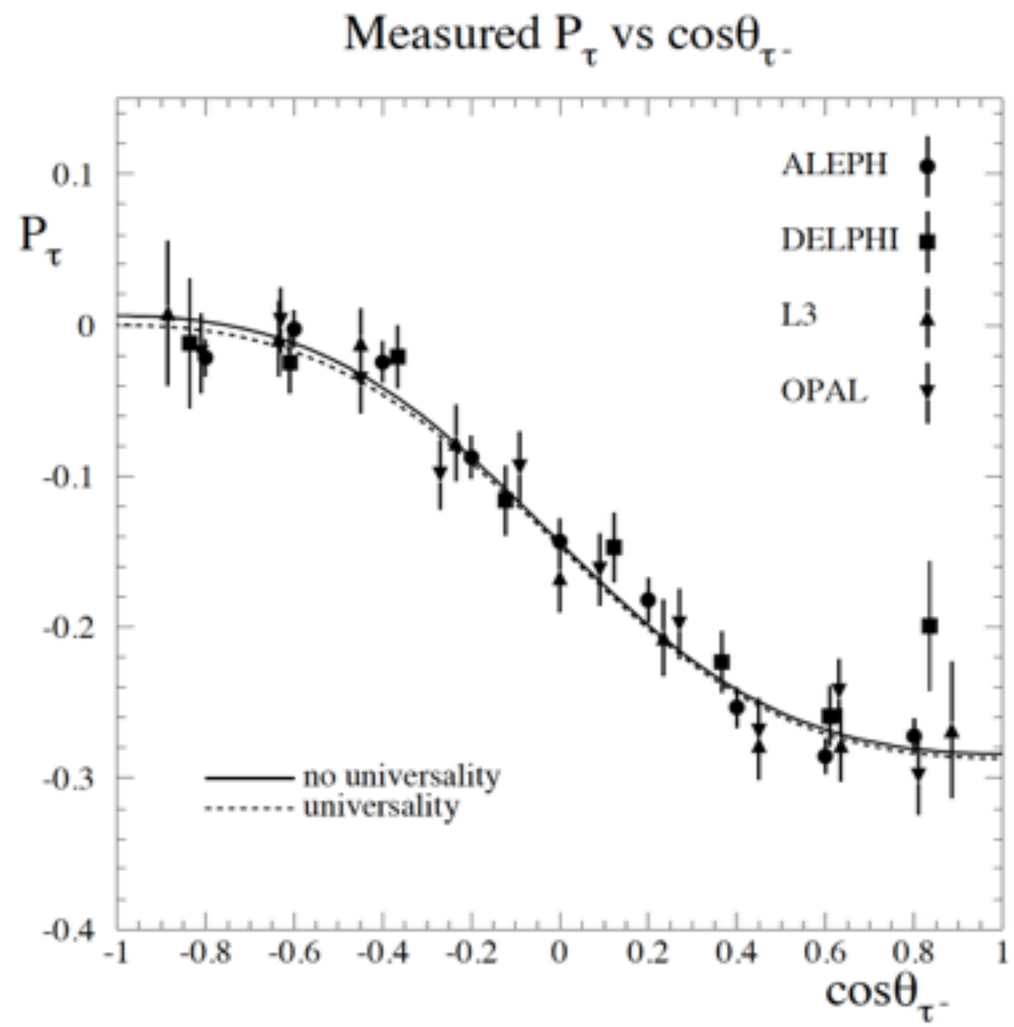
$$A_{pol}^{FB} = \frac{\sigma_{F,R} - \sigma_{B,R} - \sigma_{F,L} + \sigma_{B,L}}{\sigma_{tot}} = -\frac{3}{4} A_e$$

$$P_\tau(\cos\theta) = \frac{A_{pol}(1+\cos^2\theta) + \frac{8}{3}A_{pol}^{FB}\cos\theta}{(1+\cos^2\theta) + \frac{8}{3}A_{FB}\cos\theta}$$

At FCC-ee

- very high statistics: improved knowledge of tau parameters (e.g. branching fraction, tau decay modeling) with FCC-ee data
- use best decay channels (e.g. $\tau \rightarrow \rho\nu_\tau$ decay very clean), note that detector performance for photons / π^0 very relevant

→ **measure $\sin^2\theta_{eff}$ with 6.6 10^{-6} precision**



Proposal by Roberto Tenchini

Few consideration on this analysis

- Systematics different from $A_{FB}\mu\mu$
- Smaller dependence on beam energy, which is the biggest systematics in $A\mu\mu$
- Smaller dependence on alphaQED, because the slope is smaller (proportional to alphaQED)
  - Drawback is that (obviously) you cannot measure alphaQED with this

- Once we have the analyses techniques in place they can be applied for H->tautau(tau->rhonu, rho->pipi0)
- The coplanarity of pions depends of the scalar nature of Higgs and can measure the CP phase/mixing angle of Higgs to a few degrees (ILC analyses) https://arxiv.org/abs/1804.01241

Proposal by Roberto Tenchini

Precisions on coupling ratio factors, A_f

$$\mathcal{A}_e = \frac{2 g_{Ve} g_{Ae}}{(g_{Ve})^2 + (g_{Ae})^2} = \frac{2 g_{Ve}/g_{Ae}}{1 + (g_{Ve}/g_{Ae})^2}$$

	Statistical uncertainty	Systematic uncertainty	improvement w.r.t. LEP
$\mathcal{A}_e$	$5. \times 10^{-5}$	$1. \times 10^{-4}$	50
$\mathcal{A}_\mu$	2.5×10^{-5}	1.5×10^{-4}	30
$\mathcal{A}_\tau$	$4. \times 10^{-5}$	$3. \times 10^{-4}$	15
$\mathcal{A}_b$	2×10^{-4}	30×10^{-4}	5
$\mathcal{A}_c$	3×10^{-4}	80×10^{-4}	4
$\sin^2\theta_{W,eff}$ (from muon FB)	10^{-7}	$5. \times 10^{-6}$	100
$\sin^2\theta_{W,eff}$ (from tau pol)	10^{-7}	6.6×10^{-6}	75

Relative precisions, but for $\sin^2\theta_{eff}$

Conclusions

- The physics analysis contribution from the italian community have been very specific and driven by few individuals.
  - simulation tools for physics (Delphes) have always been available it is not really an excuse
  - however now there is a certain maturity in the overall software tools/tutorial that certainly can make it easier to join in
    - (even I made things run very quickly!!!)
- While FullSim needs to be put in place with high priority to help the detector design and noise/background performance, the FastSim is needed to grow a new generation of ee physics experts.
- The desire to contribute in particular to EWK precision physics can be expressed starting with the tau polarization measurement
- Hopefully the TestBeam experience will inspire a larger group of people to join in and the physics studies are the quickest way for someone with analysis experience from the LHC community.

SUMMARY TABLE: It is time to converge on a baseline a start making plots with Idea. Suggested deadline: September. Volunteers?

	CEPC - ILC	CEPC - IDEA	FCCee- CLD	FCC-IDEA
FAST SIMULATION		DELPHES 		PAPAS 
FULL SIMULATION				 FCCSW  STANDALONE

 PEOPLE WORKING ON IT  USABLE  LOOKING FOR PEOPLE