Detector design, optimization & Franco-Chine cooperation toward FCCee/CEPC physics

Manqi RUAN

IHEP, Beijing

Why an e^+e^- Higgs factory

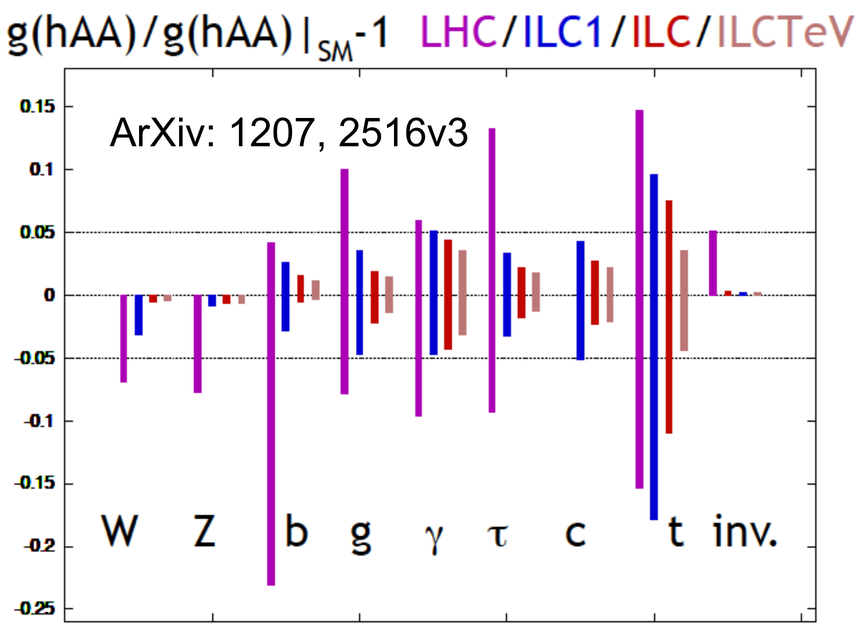
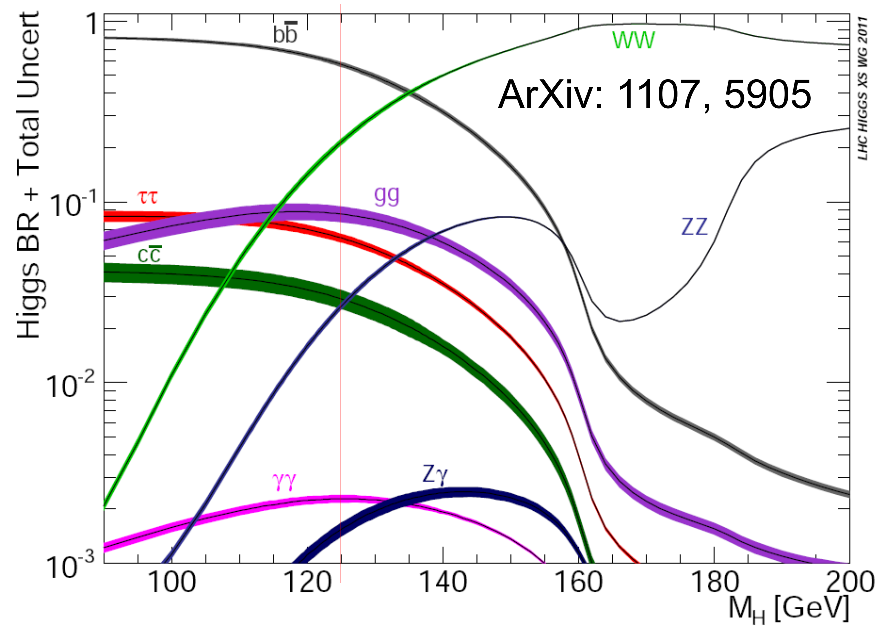


Figure 2: Comparison of the capabilities of LHC and ILC for model-independent measurements of Higgs boson couplings. The plot shows (from left to right in each set of error bars) 1 σ confidence intervals for LHC at 14 TeV with 300 fb^{-1}, for ILC at 250 GeV and 250 fb^{-1} ('ILC1'), for the full ILC program up to 500 GeV with 500 fb^{-1} ('ILC'), and for a program with 1000 fb^{-1} for an upgraded ILC at 1 TeV ('ILCTeV'). More details of the presentation are given in the caption of Fig. 1. The marked horizontal band represents a 5% deviation from the Standard Model prediction for the coupling.

SM Higgs Branching ratio



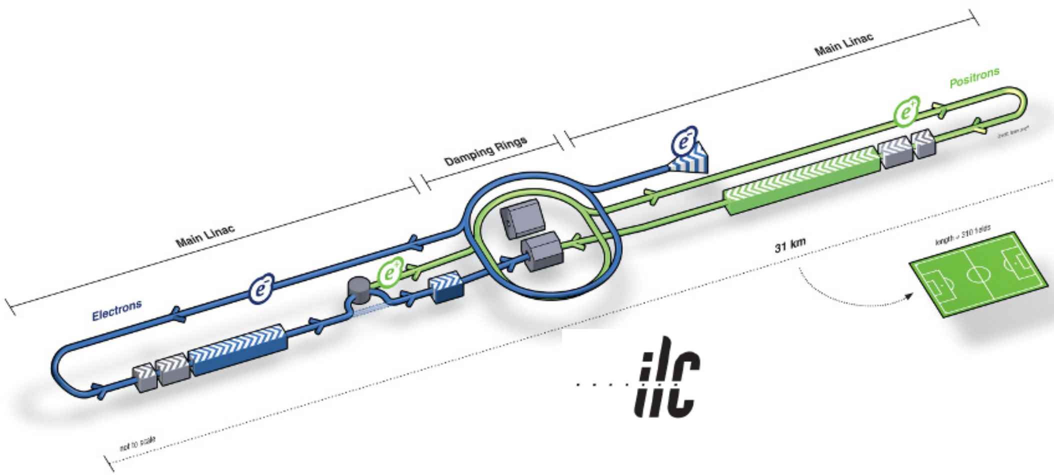
Bb: 58%; WW, 21%; gg, 9%; ττ, 6%; cc, 3%; ZZ + others, 3%

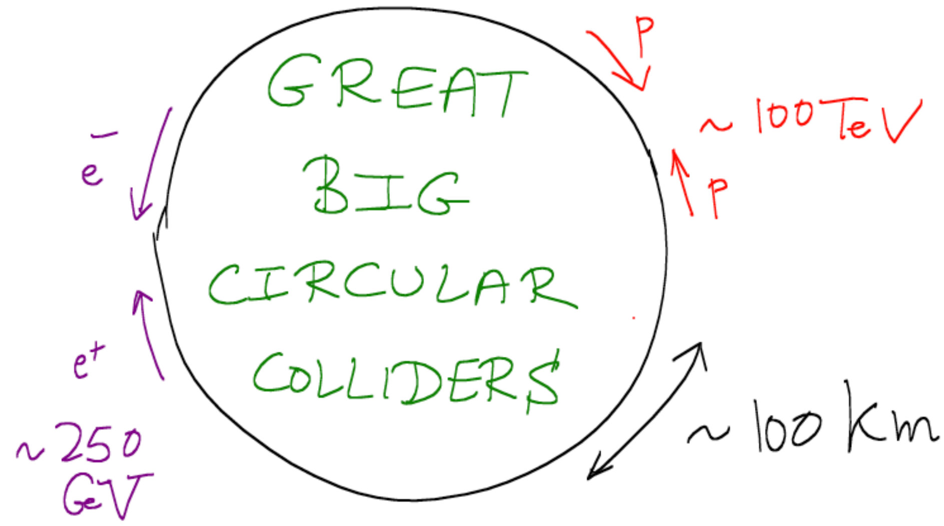
Precisely verify the standard model – searching for possible new physics
Higgs couplings must be measured to at least 10% to reveal TeV scale new physics

$$\frac{g_{HXX}}{g_{HXX}^{SM}} \approx 1 + \delta \times \left(\frac{1\,\text{TeV}}{\Lambda_{NP}} \right)^2$$

LHC: high productivity, no tagging signal, huge backgrounds & systematics.
Ultimate precision in Higgs coupling limited
e^+e^- machine: low background – triggerless mode, precisely known/adjustable initial state, allowance of model independent measurement...
a precise Higgs factory must be a lepton machine (ILC/CLIC, TLEP/FCC, **CEPC**...)

Higgs factory: Linear or Circular

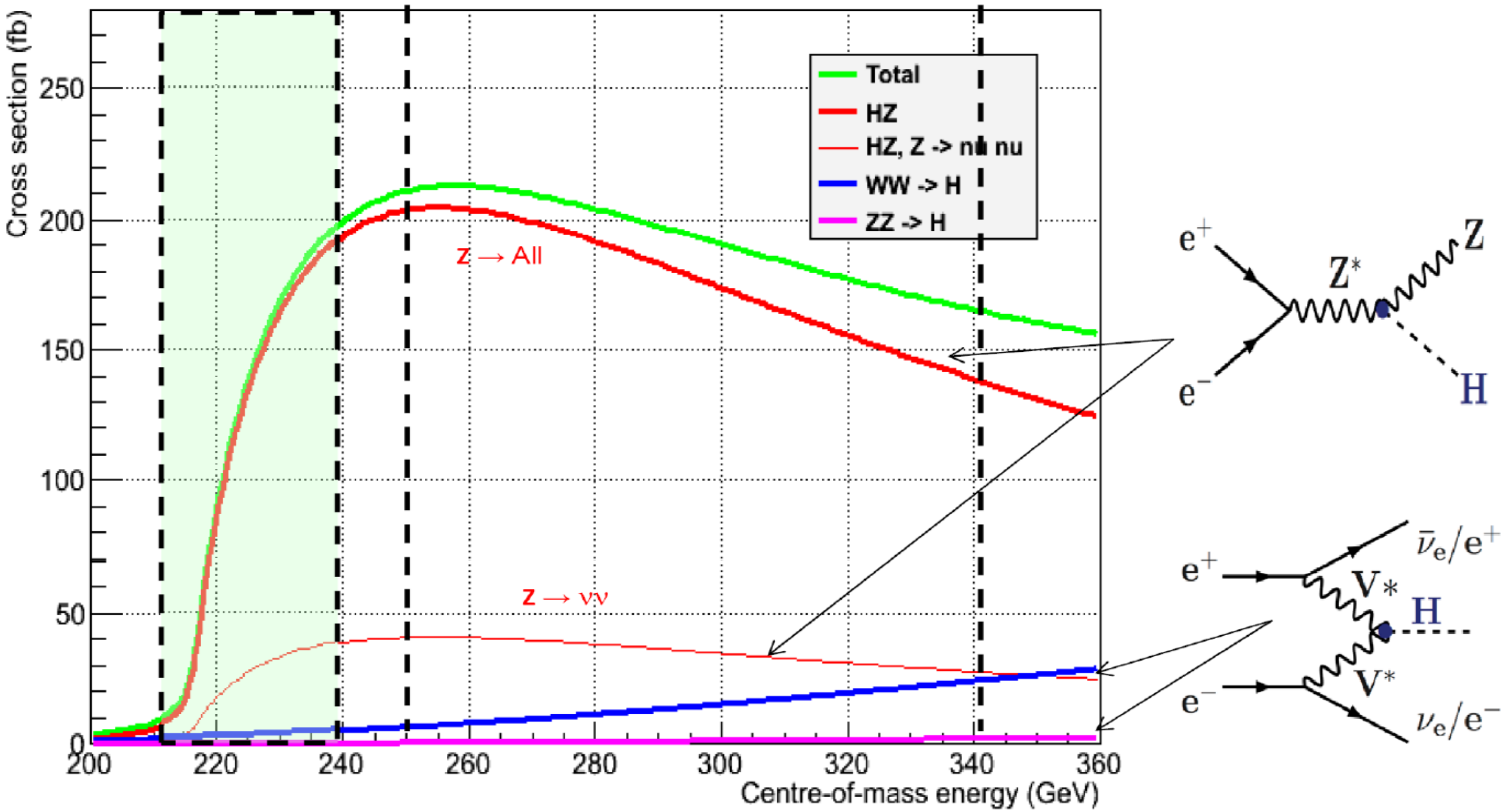




	Linear: ILC, CLIC	Circular: FCC, CEPC
Pro	C.o.M energy can be upgraded to 1-3 TeV Longitudinal polarized beam Power pulsed detector	Cost-efficient, component-mature technology Multiple interaction point High luminosity & beam quality
Con	Expensive (~ 8 – 10 B euros) Single interaction point, might need push-pull	Center of mass energy limited in e^+e^- phase (but can be upgraded to ~ 100 TeV in pp phase) No beam polarization at high energy No power pulse

Muon & photon colliders are also possible Higgs factories, but...

Higgs productivity at e^+e^- machine



σ(HZ, 240 GeV) ~ 200fb with non-polarized beam

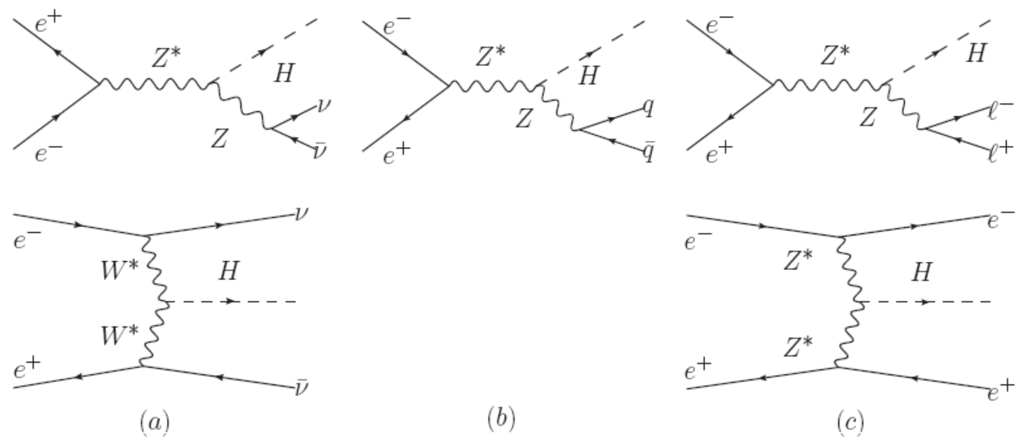
L $\sim 10^{34}$ $cm^{-2}s^{-1} \sim 100fb^{-1}/y$: 10^5 - 10^6 Higgs

Beam polarization can enhance the Higgs productivity by ~ 50% at ILC, and reduce the SM Background at the same time. However, it's not crucial for Higgs measurement

8 + 5 + 1 SM Higgs observables

- From 10^5 - 10^6 Higgs: Direct observables
  - Mass, spin, σ(ZH)
  - Branching ratios (b, c, tau, g, W)
  - Branching ratios (gamma, mu)

    \+
  - Branching ratios (Z - gamma)
  - Invisible Branching ratio
  - σ(vvH)*Br(H→bb)



- Calculate: width – coupling

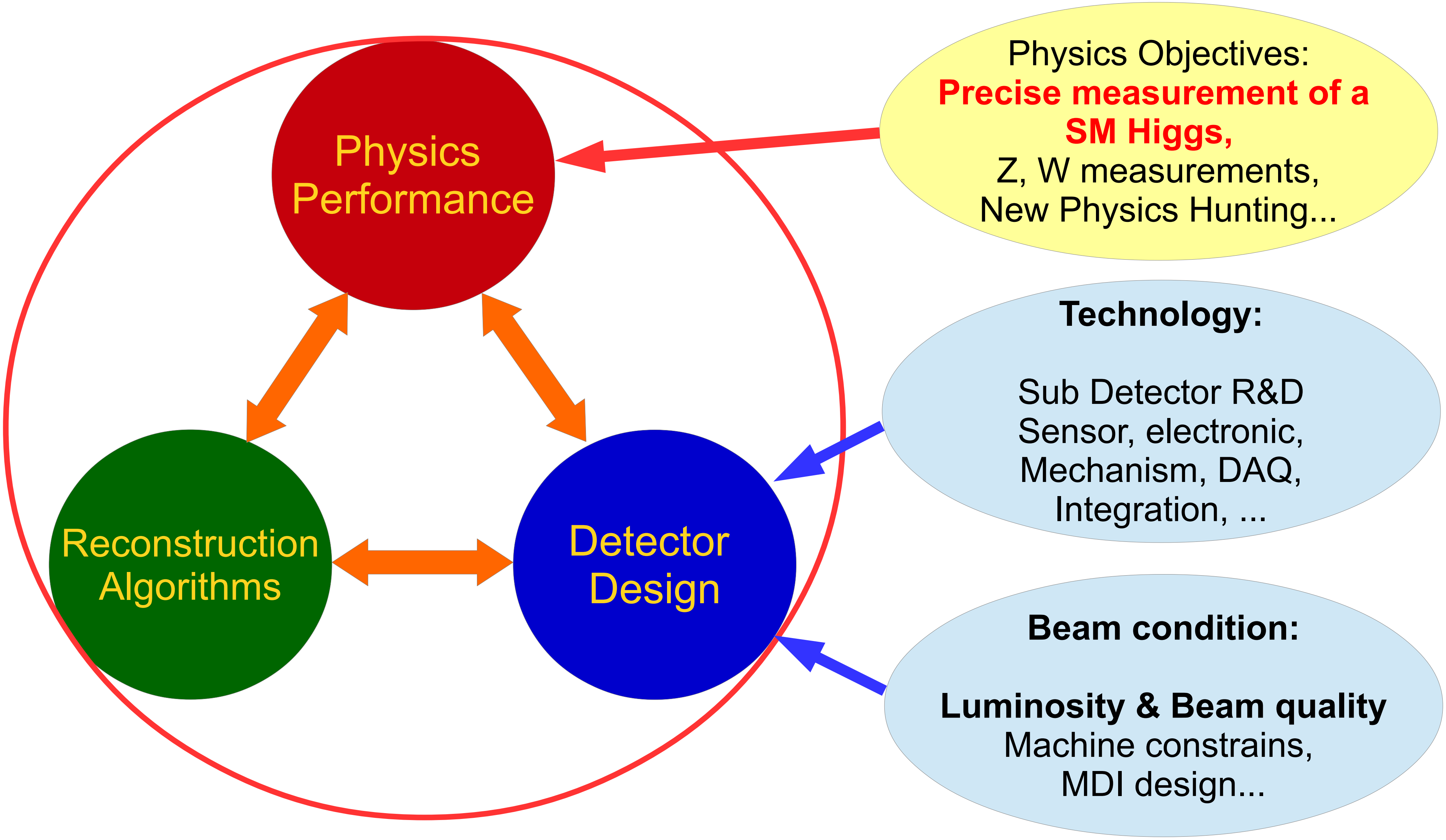
Mode	$b\bar{b}$	$c\bar{c}$	gg	WW^*	$\mu^+\mu^-$	$\tau^+\tau^-$	ZZ^*	$\gamma\gamma$	$Z\gamma$
BR (%)	57.8	2.7	8.6	21.6	0.02	6.4	2.7	0.23	0.16

g(Hbb), g(Hcc), g(Htt), g(HWW)/Γ_H, g(Hμμ), g(Hττ), g(HZZ)/Γ_H, g(HWW)/g(Htt)

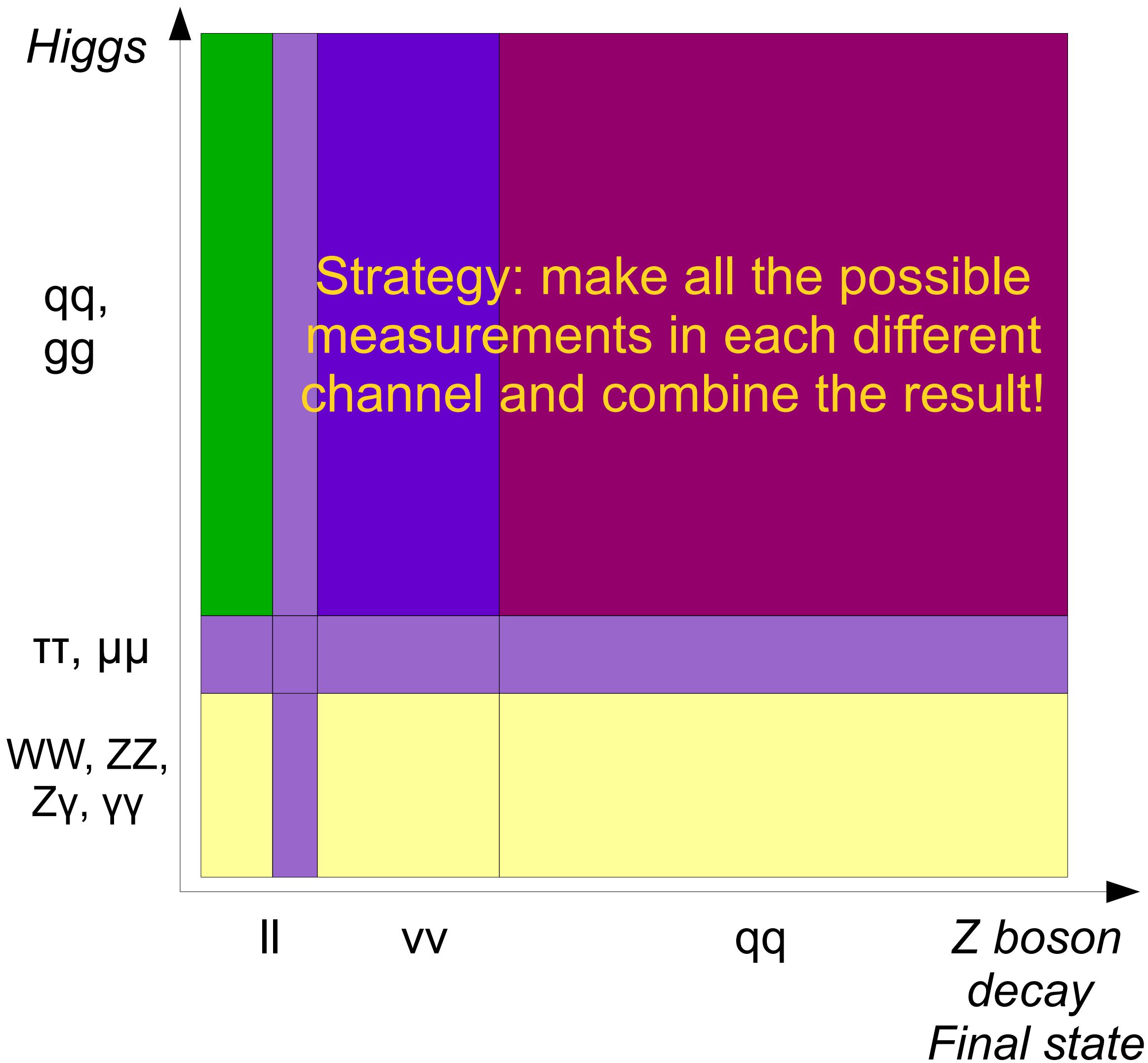
Z & W measurements

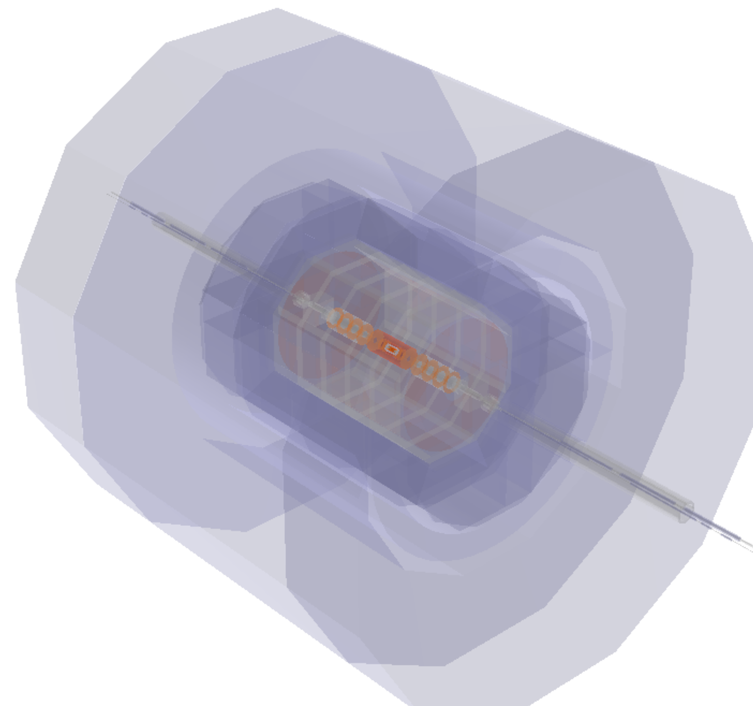
- Numbers:
  - e+e-: 17 M Visible Z boson at LEP & 500k at SLC;
  - Many measurements are updated from Tevatron/LHC
  - $10^{10} – 10^{12}$ Z can be easily produced at CEPC/FCC: efforts need to be put to control the systematics
- Observables:
  - All LEP measurements (mass, width, Weinberg angle, A_{fb}, A_l, R_b, R_l...)
  - Neutrino generation: though Zγ events
  - Rare decays of Z and its daughters
  - α_S: though Ratio of 3-jet events to 2-jet events
  - W measurements (mass, width & g(ZWW))
- Manpower allocated (Zhijun Liang, convener of SM measurement at ATLAS)

Detector optimization: Basic ingredients



ZH event: requirement on detector





ILD: fulfill the Physics requirement
Of Higgs measurement at ILC – our
Reference detector

LC-REP-2013-021

From ILD to FCC/CEPC detector

- Many new designs
  - Changed granularity (no power pulsing)
  - Changed L*
  - Changed VTX inner radius
  - Changed TPC outer Radius
  - Changed Detector Half Z
  - Changed Yoke/Muon thickness
  - Changed Sub detector design
  - …
- All Changes need to be implemented into simulation, iterate with physics analysis (Fast – Full Simulation) and cost estimation

Kick-off @ Sep 2013

Training @ Oct 2013

Regular meetings, communications

Physics and Detector Meetings

November 2013

- 29 Nov CEPC Calorimeter Group Meeting 3rd New!
- 20 Nov CEPC Physics & Detector 5th New!
- 18 Nov - 19 Nov Franco-Chine Detector Discussing
- 15 Nov CEPC Tracking Group Meeting 2nd
- 07 Nov Simulation - Physics Analysis Meeting 1st
- 07 Nov CEPC Physics & Detector 4th
- 04 Nov CEPC Vertex Working Group Meeting 1st
- 01 Nov CEPC Tracking Group Meeting 1st
- 01 Nov CEPC Calorimeter Group Meeting 2nd

October 2013

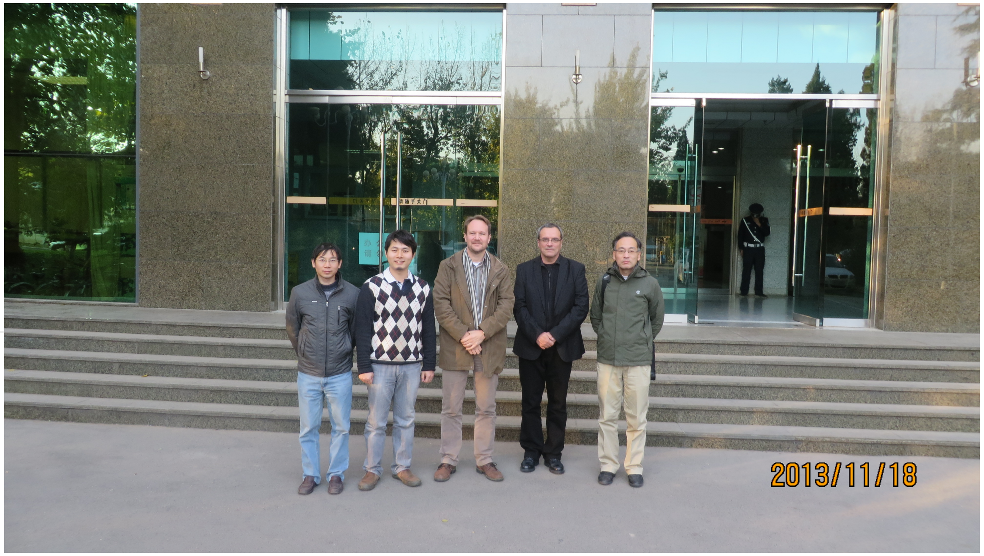
- 23 Oct CEPC Physic & Detector 3rd
- 18 Oct CEPC Calorimeter Group Meeting 1st
- 09 Oct CEPC Physics & Detector 2nd

CEPC

CEPC + SppC events

Managers: WEN, S.; Zhu, H.; Yang, H.; Hu, T.; Ruan, M.; QI, H.

- General Meetings 2 events
- Physics and Detector Meetings 13 events
- Training 1 event



Annual Meeting: toward pre-CDR

Third Workshop on Future High Energy Circular Colliders

chaired by Xinchou Lou (IHEP, Beijing)

from Tuesday, March 18, 2014 at **08:30** to Wednesday, March 19, 2014 at **18:30** (Asia/Shanghai)
at **IHEP (C305)**

Description ***The Program***

The workshop will bring together people interested in circular high energy e+e- colliders as a Higgs factory as well as a future circular high energy pp collider beyond the Higgs factory. Participants will report on the progress made in theory, accelerator design and detector simulations since the kick-off meeting in September 2013. The focus will be on the preparation for the CEPC CDR. International collaboration and study organization will also be examined.

Steering Committee meeting will be on March 18,2014.

Go to day

Tuesday, March 18, 2014

18:30 - 21:00 CEPC-SppC Steering Committee & Conveners Meeting *2h30'* (B410)

Wednesday, March 19, 2014

08:30 - 09:00 Registration *30'*

09:00 - 10:15 Opening Session
Convener: Prof. Xinchou Lou (IHEP, Beijing)

- 09:00 **Welcome and Introduction** *30'*
  Speaker: Prof. Yifang Wang (IHEP)
- 09:30 **Global Efforts for High Energy Accelerators** *45'*
  Speaker: Dr. Weiren Chou (FNAL)
  Material: Slides

10:15 - 10:35 Photo session and coffee break

10:35 - 12:15 Accelerator Session
Convener: Dr. Qing QIN (Institute of High Energy Physics)

- 10:35 **Lattice design for CEPC** *20'*
  Speaker: Ms. Huiping Geng (Institute of High Energy Physics)
  Material: Slides
- 10:55 **Final focus design for CEPC** *20'*
  Speaker: Dr. Dou Wang (IHEP)
  Material: Slides
- 11:15 **Beam-beam simulations for CEPC** *20'*
  Speaker: Mr. Yuan Zhang (IHEP, Beijing)
  Material: Slides
- 11:35 **CDR Discussion** *20'*

12:15 - 13:30 Lunch at Guest House Restaurant ( )

13:30 - 15:00 Theory Session I
Convener: Prof. 守华(Shou-hua) 朱(Zhu) (北京大学(Peking Uni))

- 13:30 **Why we need CEPC/SPPC? An Effective Theory Understanding of Our Weak Scale Particle Physics** *30'*
  Speaker: Prof. Jing Shu (Institute for Theoretical Physics, Chinese Academy of Sciences)
- 14:00 **Searching for Supersymmetry at the SPPC** *30'*
  Speaker: Dr. Timothy Cohen (SLAC)
  Material: Slides
- 14:30 **Discussion on theory CDR** *30'*

15:00 - 15:15 Coffee break

15:15 - 16:30 Detector Session
Convener: Prof. Shan Jin (IHEP)

- 15:15 **Web and Document Management** *15'*
  Speaker: Dr. Hongbo Zhu (IHEP)
  Material: Slides
- 15:30 **Status report on CEPC Physics Analysis and Detector optimization** *15'*
  Speaker: Mr. Manqi Ruan (IHEP)
  Material: Slides
- 15:45 **Status report of the vertex detector group** *15'*
  Speaker: Prof. Meng Wang (Shandong University)
  Material: Slides
- 16:00 **Status report of the TPC detector group** *15'*
  Speaker: Dr. Huirong QI (Insititu of High Energy Physics, CAS)
  Material: Slides
- 16:15 **Status Report of the Calorimeter Group** *15'*
  Speaker: Prof. Haijun Yang (Shanghai Jiao Tong University)
  Material: Slides

16:30 - 17:30 CDR Discussion Session
Convener: Yuanning GAO, Jie GAO, Hong-jian HE; Scientific Secretary: Hongbo ZHU

CEPC Detector: Institutes

Theory

VTX	TPC	Calo	Physics Requirement
ShanDong University (SDU) IHEP ...	Tsinghua University (THU), University of Chinese Academic of Science (UCAS), IHEP ...	University of Science and Technology of China (USTC), Shanghai Jiaotong University (SJTU), Wuhan University (WhU), Nanjing University IHEP ...	Nankai University, HKSTU Pekin University (PKU), Beihang University, Center China Normal University (CCNU), IHEP ...

Machine

Perspective of CEPC Higgs measurement

	ILC @ 250 fb^{-1} (-0.8, 0.3)	CEPC @ 500 fb^{-1} (0, 0)	Status
mH (MI)	29 MeV	25 MeV	FS Validated
σ(ZH)	2.6%	2.2%	
Δ(σ*Br)/(σ*Br)			
ZH, H→bb	1.2%	1.0%	FS Estimated
H→cc	8.3%	6.6%	
H→gg	7.0%	5.6%	
H→WW*	6.4%	**4.0%**	PKU, SJTU L. Yuan
H→ττ	4.2%	3.7%	USTC
H→ZZ*	19%	16%	SDU
H→γγ	29-38%	25%	IHEP, WhU
H→μμ	-	?	L. Yuan
H→Inv.	0.95%	0.8%	
ννH, H→bb	10.5%	**12%**	PKU

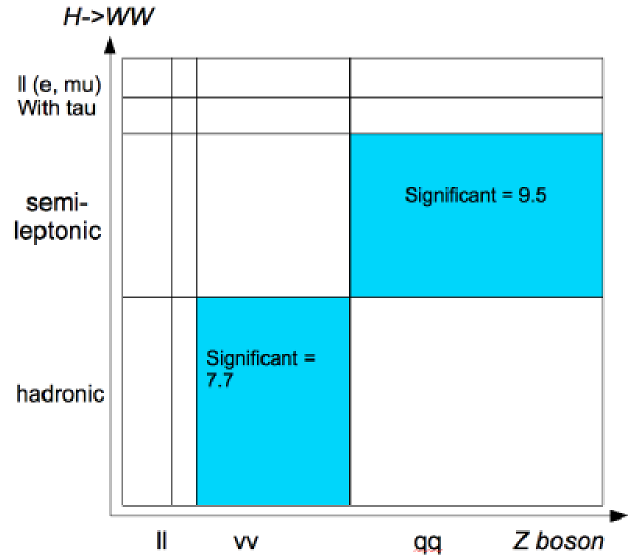
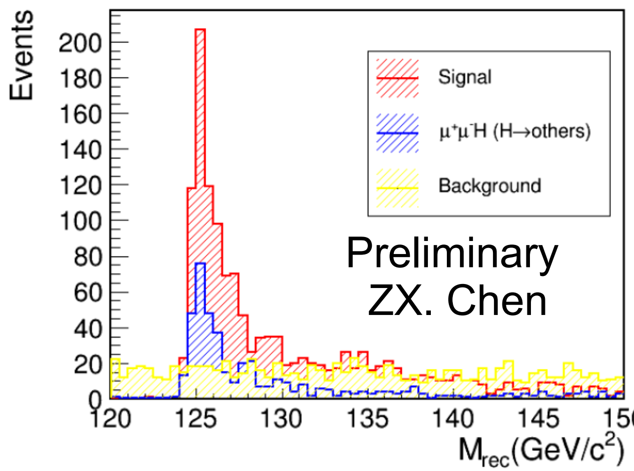


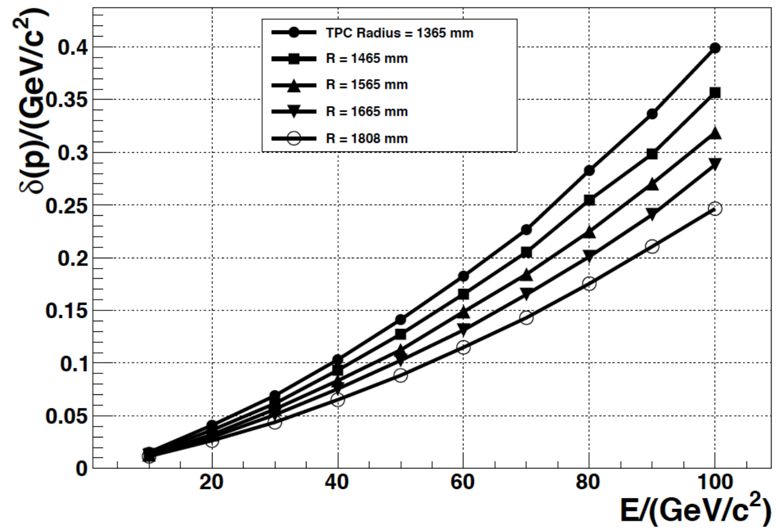
Figure 8. Result of ILC Analysis on $Br(H \to WW^*)$

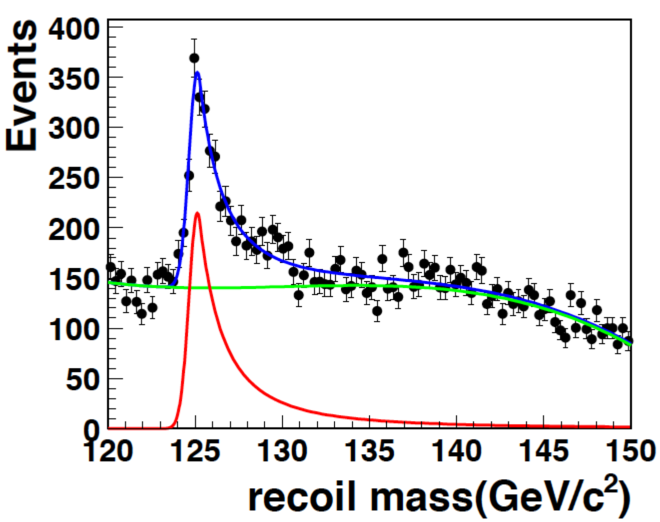


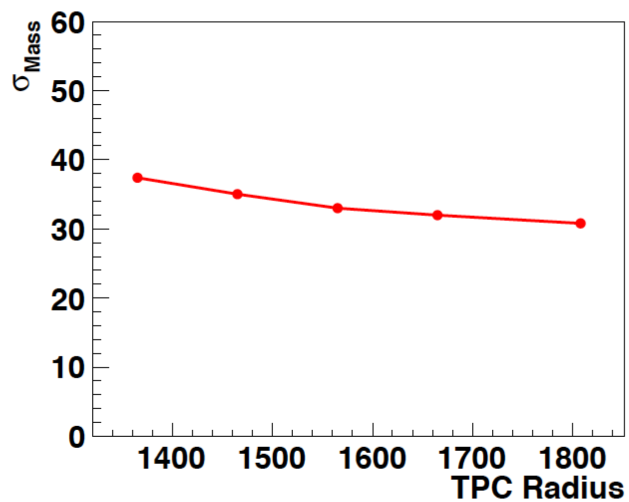
In communication/cooperation with ILC efforts

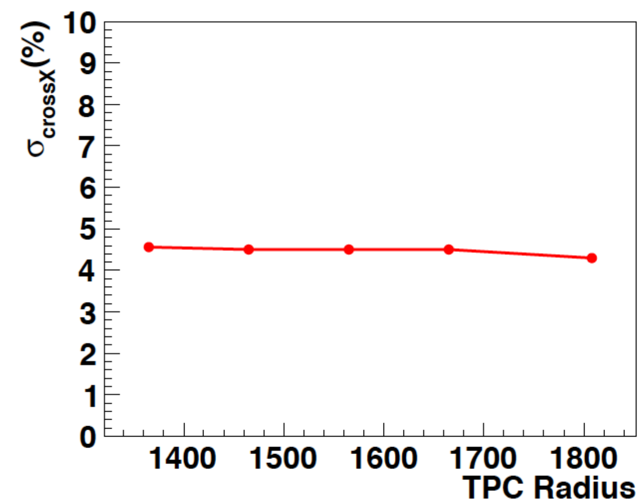
Yangying: mass & Xsec measurement

- A combined study on physics analysis & Detector optimization
  - Reproduce ILC result
  - Flexible FS tools developed, applied to different geometry, can also be applied to different beam condition, and other measurements (i.e, Br(H→μμ), Br(H→inv))
  - To be published

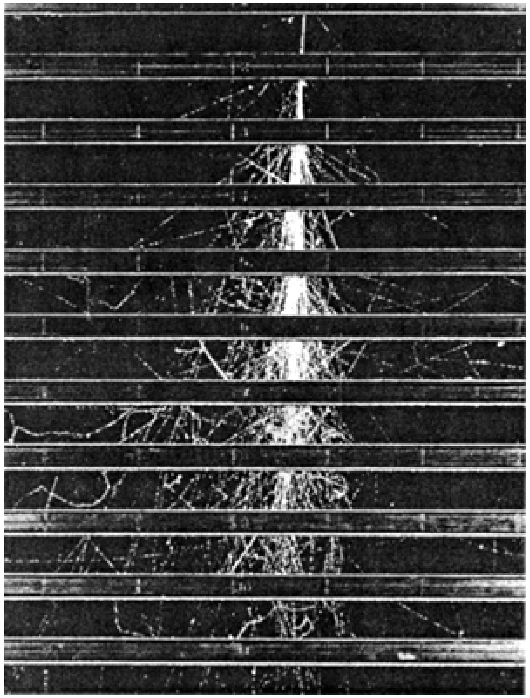


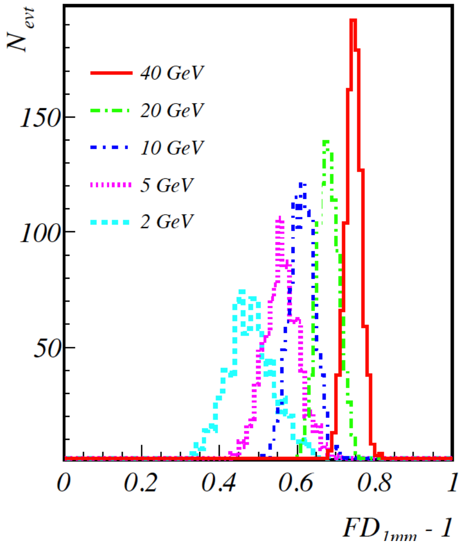


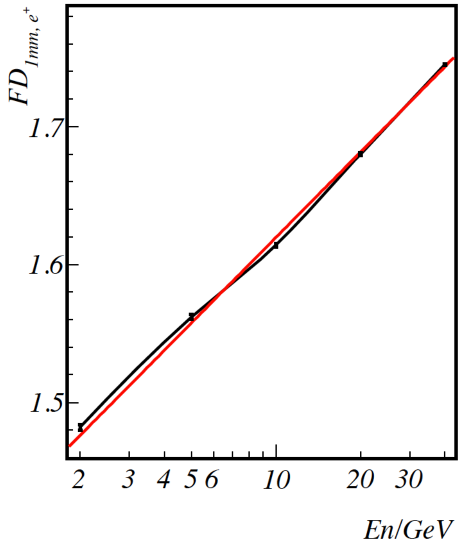


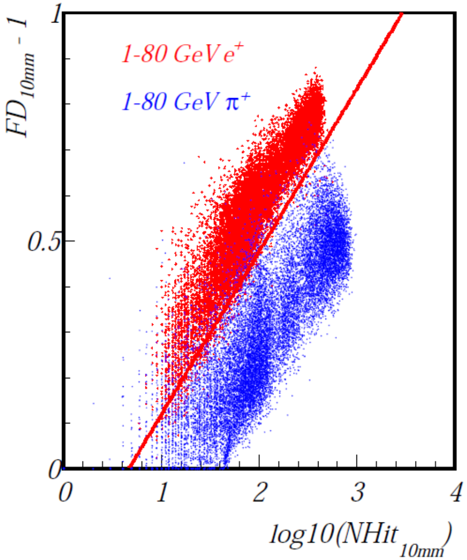


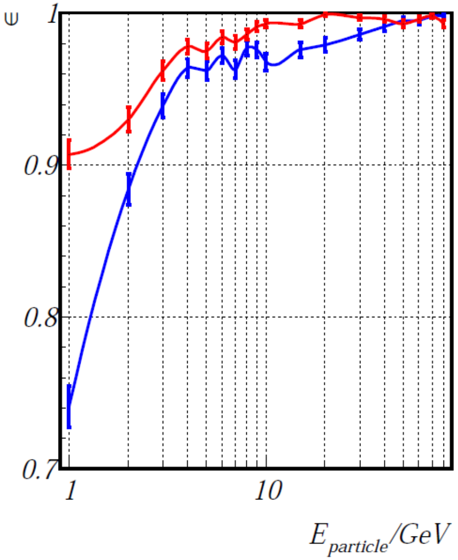
Fractal nature of Shower











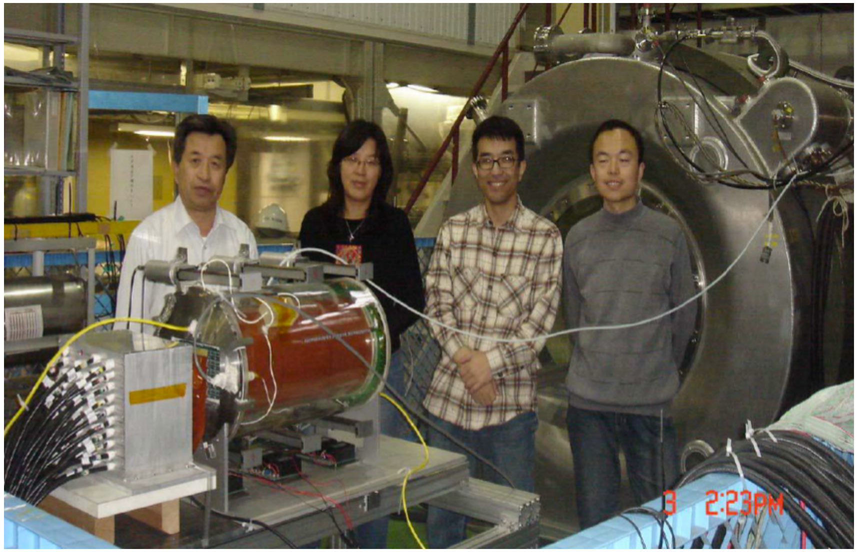
$$FD^{em}_{1\mathrm{mm}}(E) = 1.41 + 0.21 \times \log_{10}(E/\mathrm{GeV})$$
$$FD^{had}_{1\mathrm{mm}}(E) = 1.24 + 0.15 \times \log_{10}(E/\mathrm{GeV})$$
$$FD^{mip}_{1\mathrm{mm}}(E) = 1.2$$

Efficient PID over the full energy range

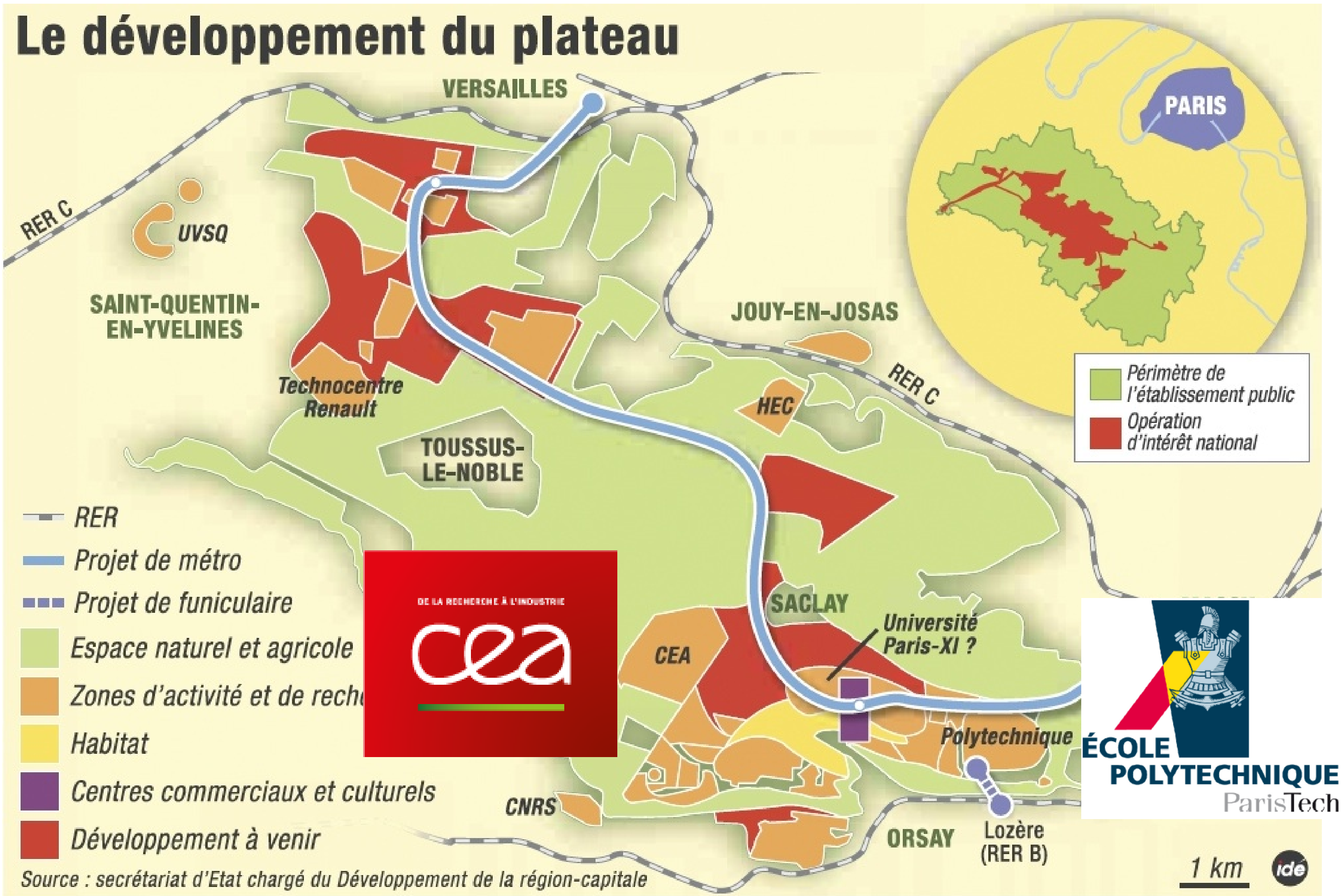
P.R.L 112 012001 (2014)

Detector R&D

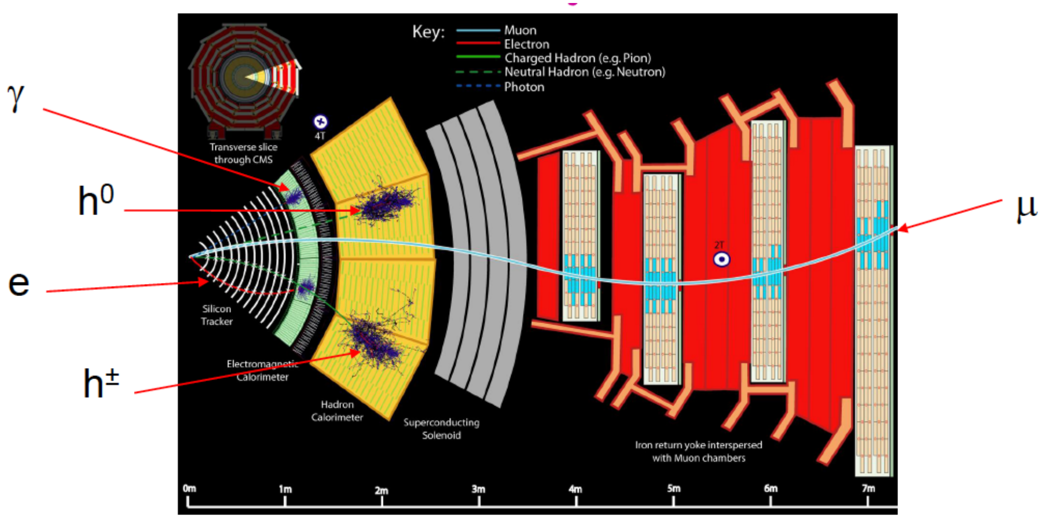
- Status:
  - TPC: Tsinghua & IHEP have participated in LCTPC
  - VTX: Investigating into the technology Market, lots of related projects
  - Calorimeter: cooperation with CALICE collaboration
- *Long termly: prototype design, construction, test, integration...*

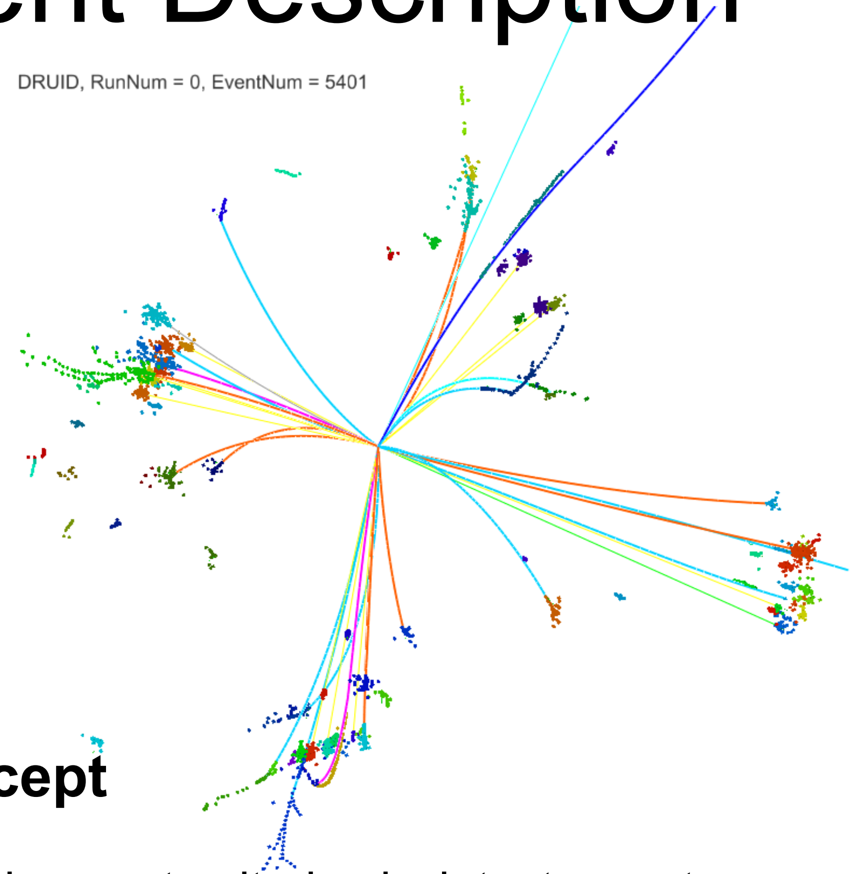


Franco-Chine Cooperations: with LLR & Saclay



PFA: General Event Description





PFA, the concept

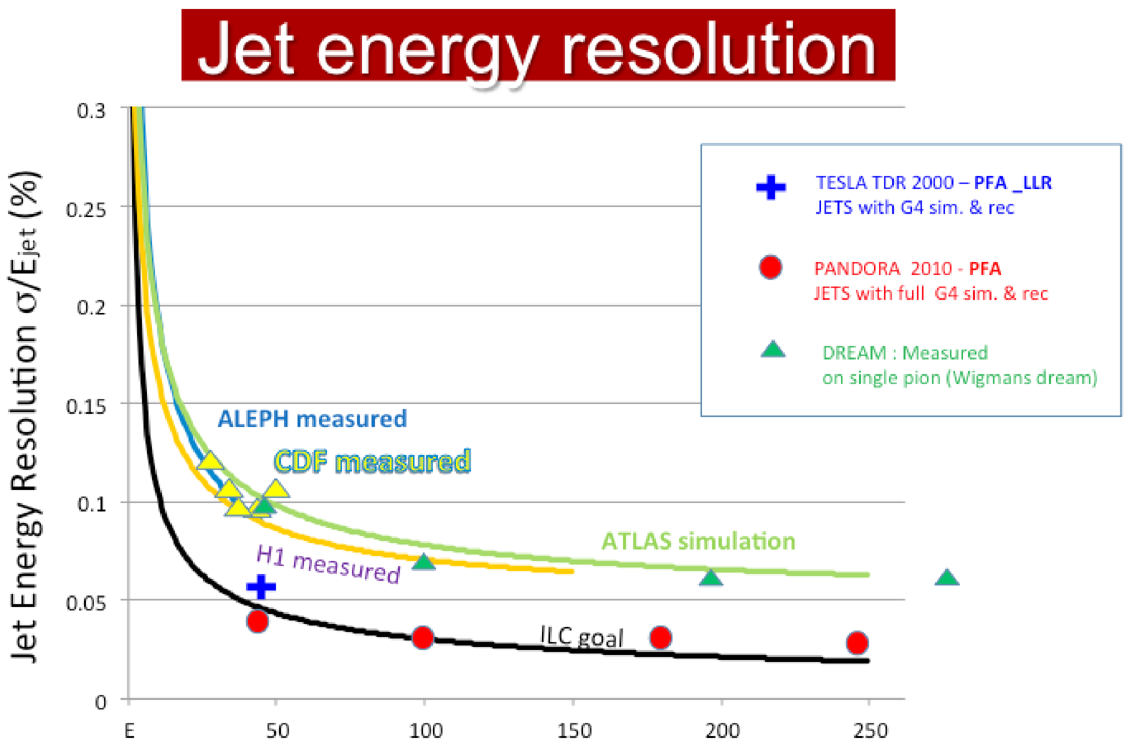
Follow each particle, and reconstruct them with the most suited sub-detector system

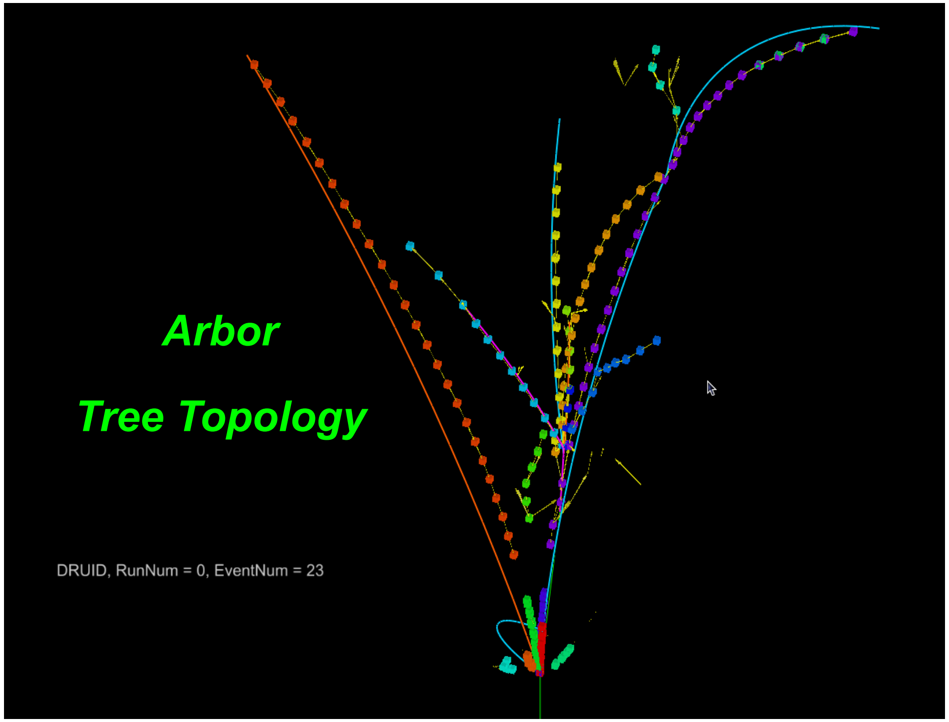
Fully appreciate all the detector-recorded signal, ultimate reconstruction - analysis

Pattern recognition: an algorithm as smart as the trained human eyes

Natural trend with the Detector, electronic/AI development

PFA, from principle to reality





ILD ECAL

Octagonal barrel + 2 endcaps

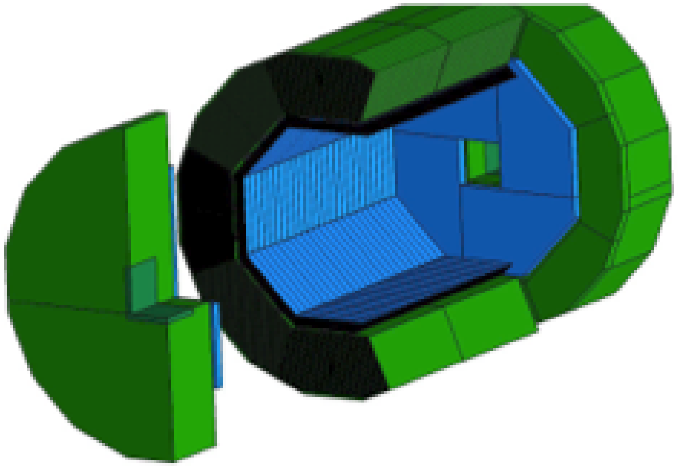
Barrel: 8 (phi) x 5 (z) identical modules

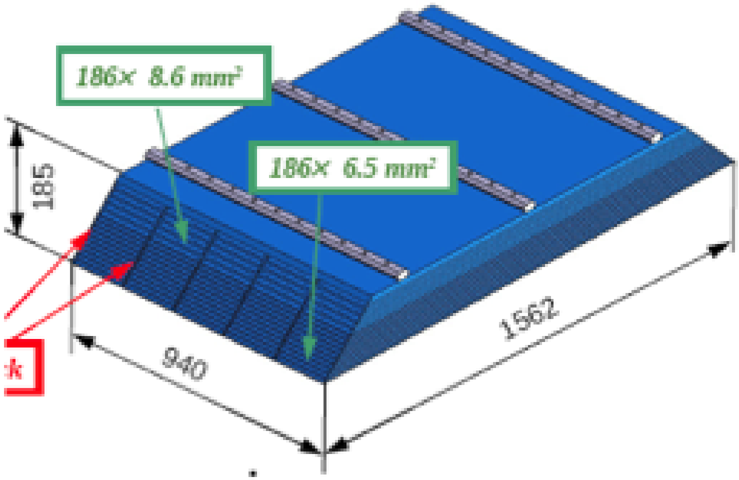
Endcap: 12 modules; 3 types

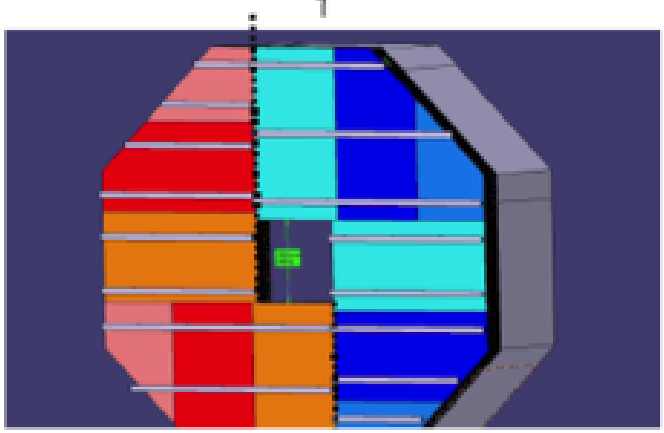
Gaps between modules non-projective

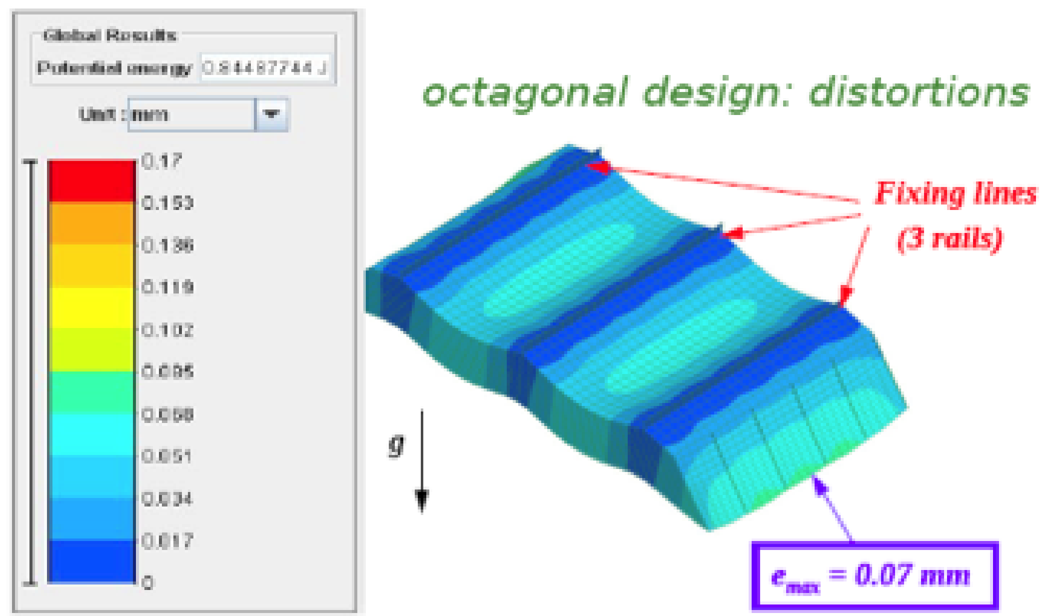
Total mass ~ 80 T (barrel), 32 T (endcaps)
Each module ~ 2-3 T

Modules are attached to inner HCAL face with rails

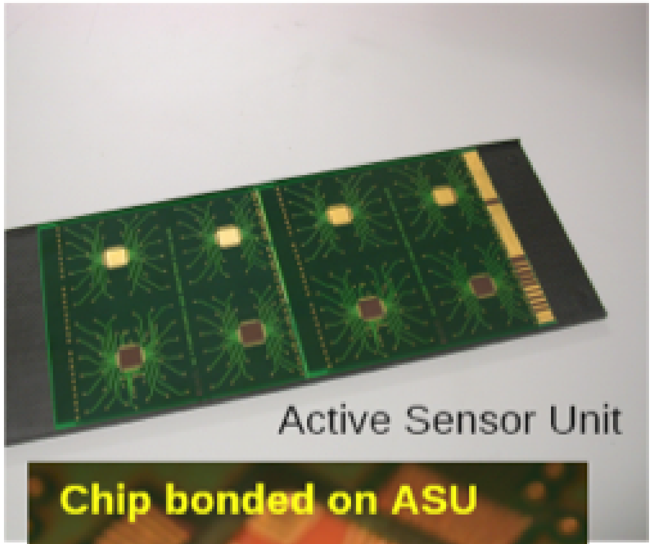








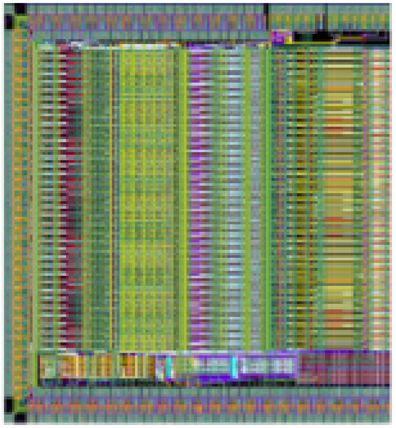
Front-end electronics/DAQ integration



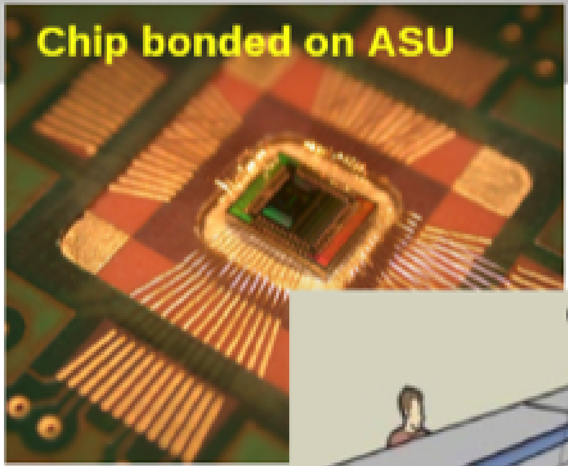
Active Sensor Unit

Si sensors mounted on PCB with front-end electronics (SKIROC chip), electrical services, sensors

Several ASU connected into one slab, read out by a single DIF card

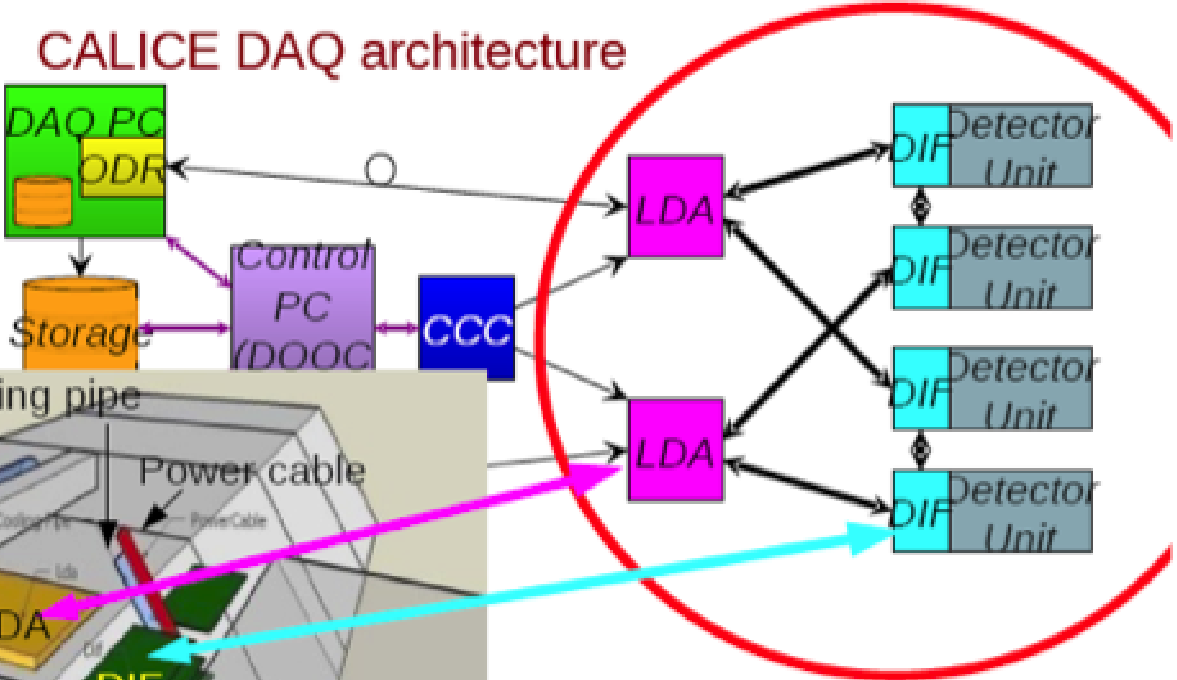


SKIROC

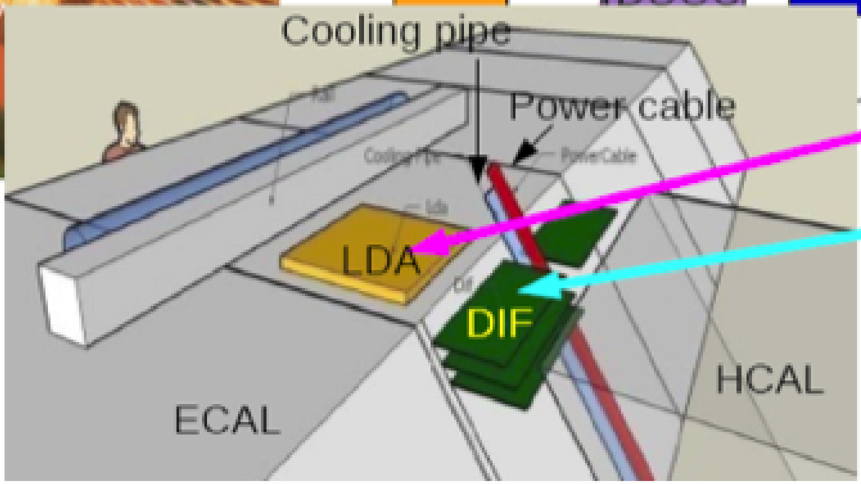


Chip bonded on ASU

CALICE DAQ architecture

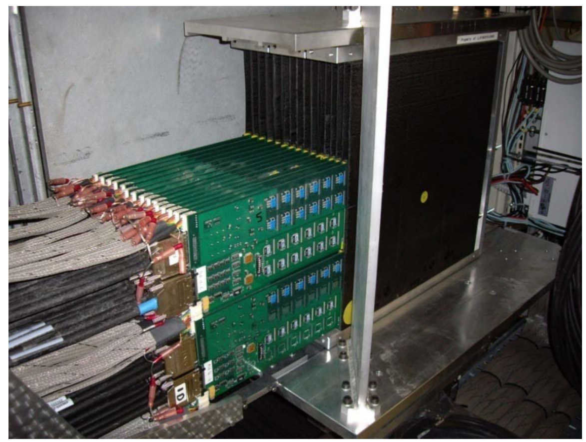


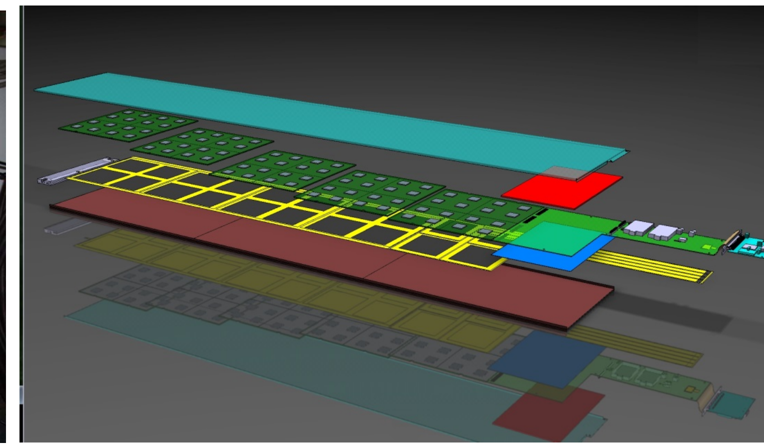
These sit in ECAL/HCAL gap



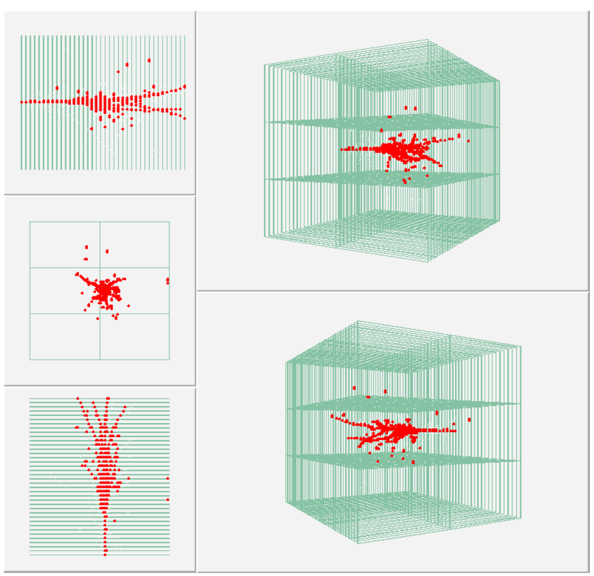
Prototype construction and performance studies

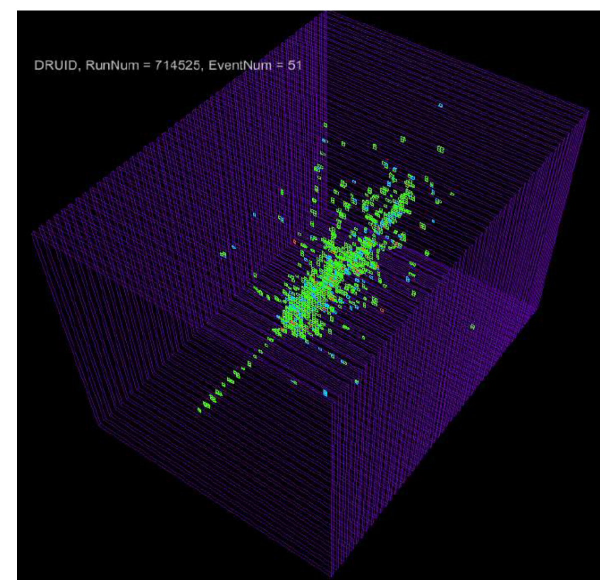
LLR: Expertise in Mechanics, Electronics, DAQ system, Off-line data reconstruction, Data analysis - performance studies, Simulation, …

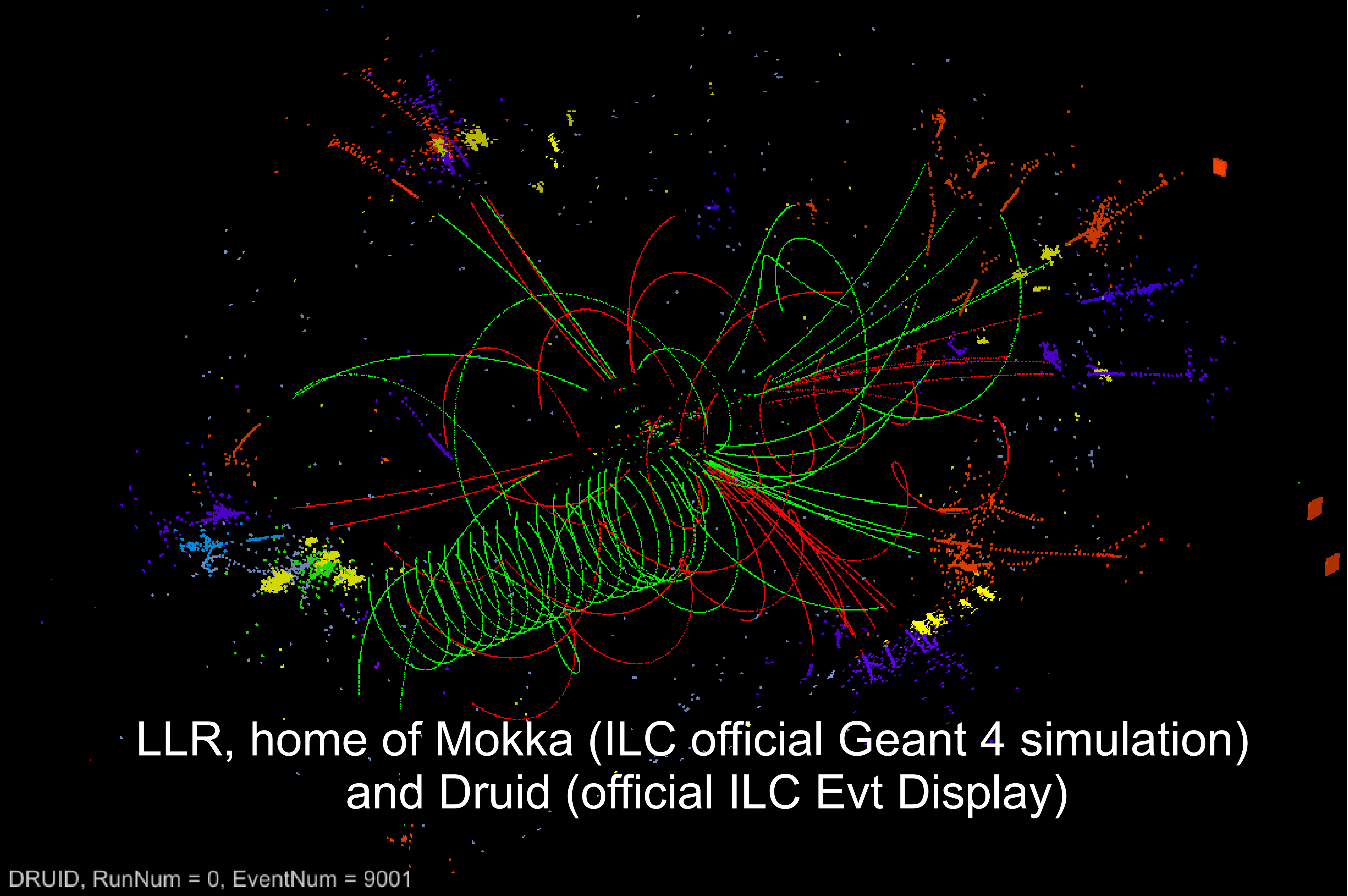




LLR: involved in the CMS Front Calorimeter Upgraded







LLR, home of Mokka (ILC official Geant 4 simulation) and Druid (official ILC Evt Display)

Higgs CP & MI measurements

École polytechnique
Laboratoire Leprince-Ringuet

THÈSE

Pour l'obtention du titre de

DOCTEUR DE L'ÉCOLE POLYTECHNIQUE
SPECIALITÉ PHYSIQUE

présentée

le 16 novembre 2009

par

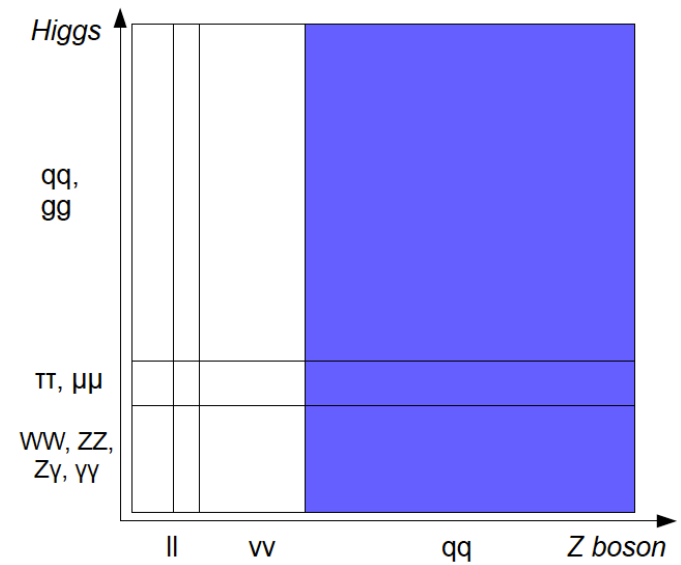
Marcel Reinhard

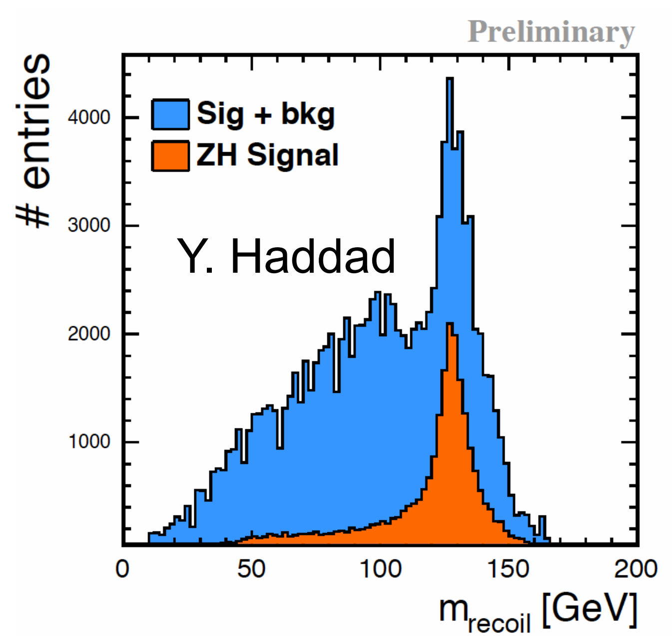
Violation de CP dans le secteur du Higgs avec un détecteur de nouvelle génération à l´ILC

CP violation in the Higgs sector with a next-generation detector at the ILC

Soutenue devant la Commission d'examen composé de :

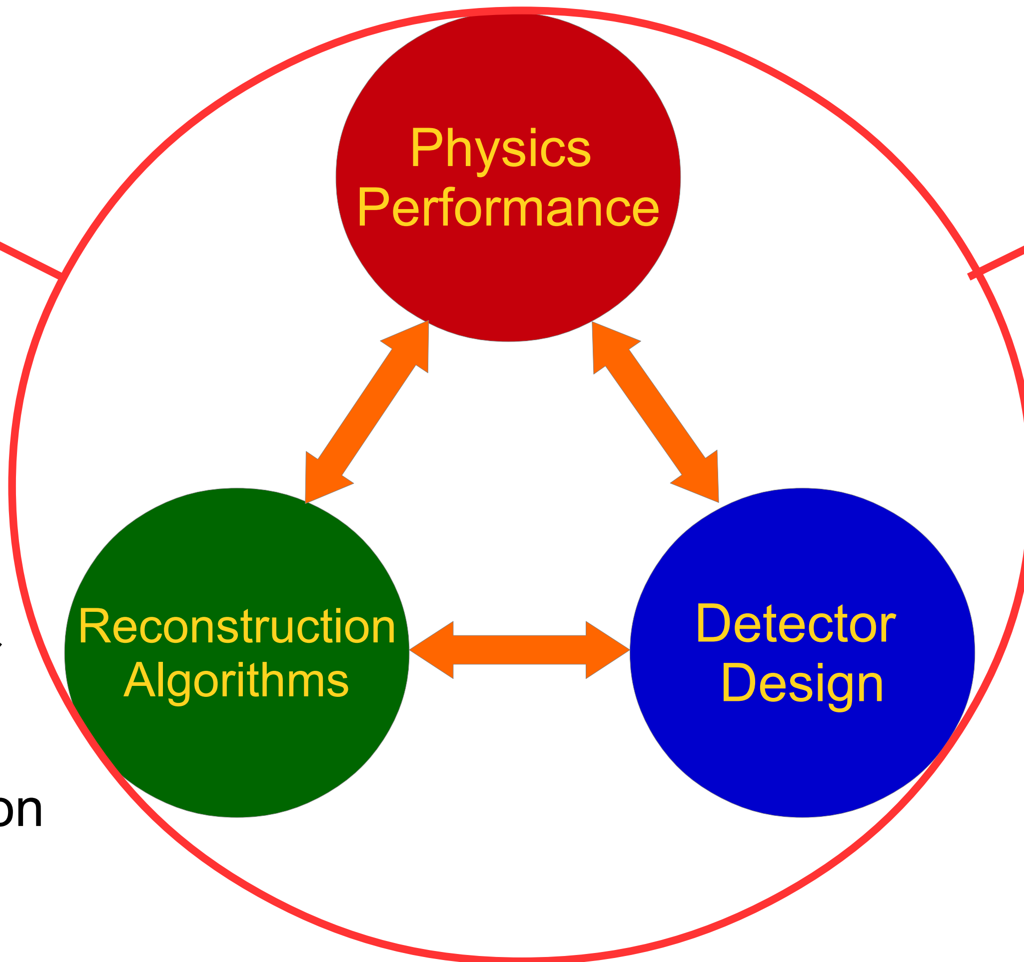
M.	Henri	VIDEAU	Président du jury
M.	Jean-Claude	BRIENT	Directeur de thèse
M.	Hans-Christian	SCHULTZ-COULON	Rapporteur
M.	Fabian	ZOMER	Rapporteur
M.	Imad	LAKTINEH	Examinateur
M.	Wolf-Dieter	SCHLATTER	Examinateur





Model independent Higgs measurements though HZ, Z->2j events

Br(H→2γ) measurements, Higgs CP measurements, etc.



Arbor PFA

Performance study & Optimization

Framework optimization

Dedicated algorithm development

G4 Simulation: Maintenance & development

Silicon technology

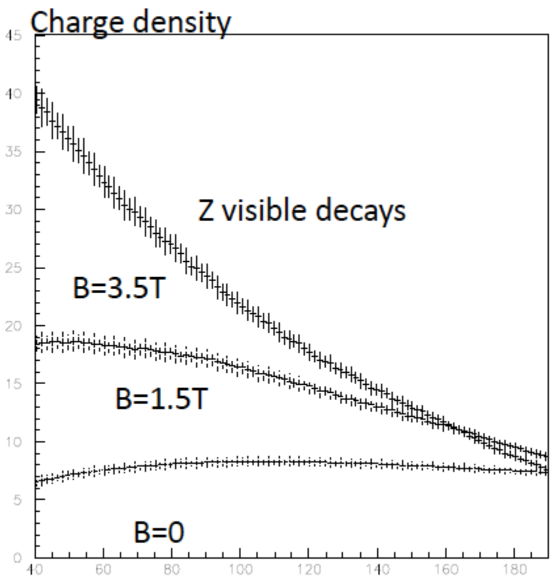
Calorimeter design, Performance study & optimization

Man power

- Wang Feng: Fresh PostDoc
  - Ph.D on theoretical Particle Physics
  - Investigating: ECAL performance studies & geometry optimization
  - H->2 photon decay branching ratio measurement
  - Arbor: performance study and optimization
  - Will short termly visit LLR
- Yu Dan: Joint Ph.D Program between LLR and IHEP
  - Master student from Ecole polytechnique, accomplished an internship at LLR on GRPC SDHCAL performance
  - Calorimeter performance studies and Higgs measurements
- Emilia Becheva: Geant 4 – Mokka expert
  - Short term visit to IHEP
  - Support & Training

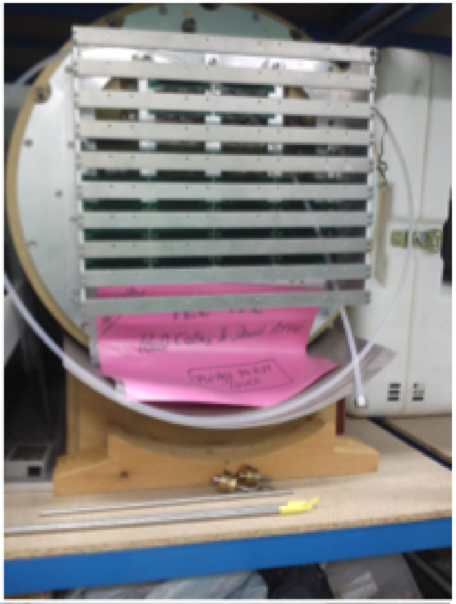
TPC @ FCC/CEPC

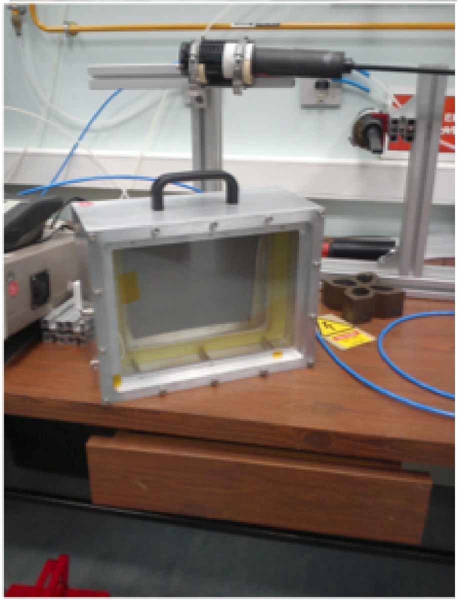
- Nature choice
  - Excellent momentum resolution with extremely low material
  - Fulfills the requirement of Higgs measurements
- Key questions: to Z pole measurements
  - Maximal acceptable event rate
    - 19.2 k Hz Visible Z decays + 33.6 k Hz Bhabha events;
  - How much Charge?
    - Disturbing from ions (1 billion ion for a FCCee)
    - Field Stabilities/Homogeneity
  - Optimized Design
    - B-Field
    - Size
    - Readout electronics & Cage design, ...



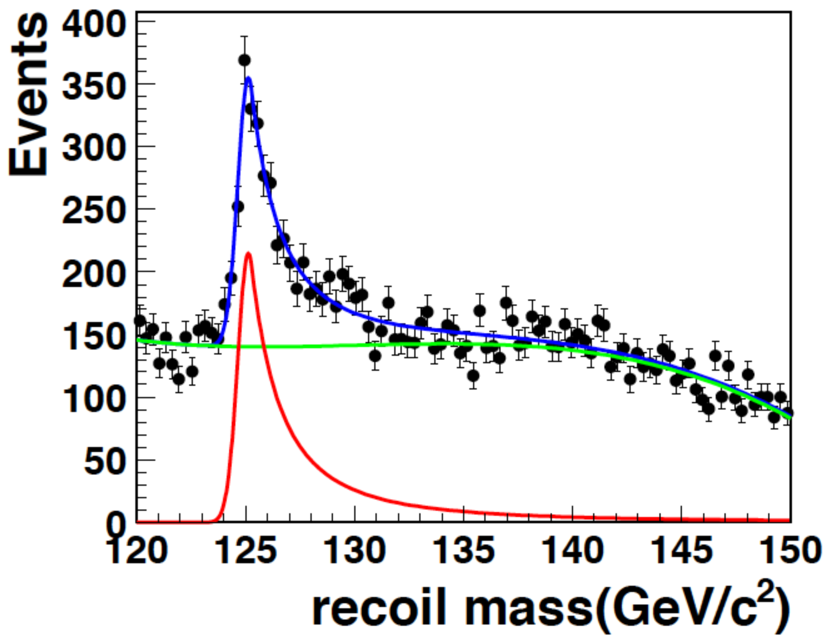
TPC @ Saclay

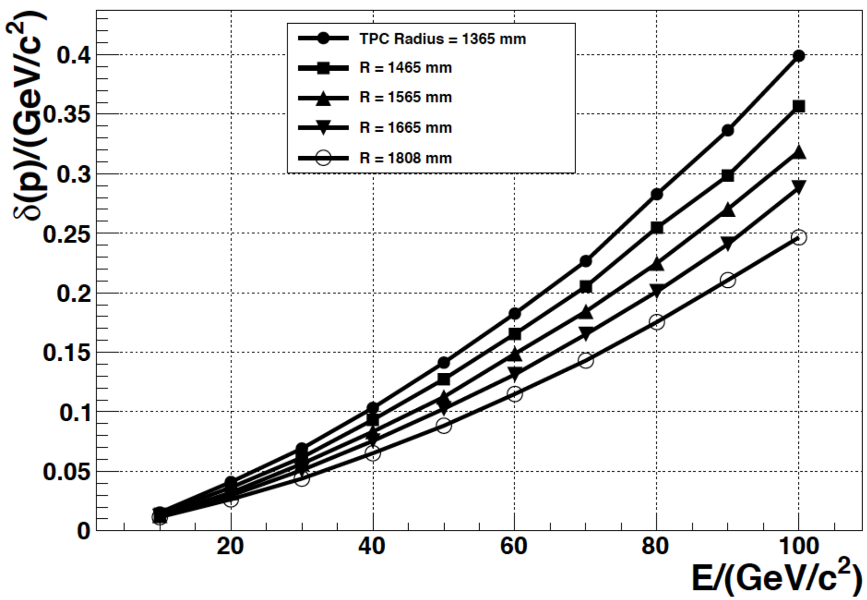
- Short – middle term
  - Use a small TPC in the lab, with cosmic rays: end 2014
  - Inject controlled amount of charge with UV flashes: end 2014
  - Develop simulation code (Garfield)
  - medium term : join ILC test-beam at DESY: 2015
  - Test setup with B field at Saclay: 2015 (?)
- Long term:
  - Study integration and combined perf. of the TPC with a Si tracker/Interaction with physics and software group.
  - Material amount in the end-plate ?
  - Cooling/low power electronics design
  - Low material assembly techniques ?
  - Reconstruction algorithms, interface with calorimetry ?





Higgs total/invisible cross section





Higgs total cross section: highly rely on tracker – TPC performance.

Good momentum resolution & lepton tagging/identification

Higgs invisible decay: A direct Signal Beyond SM. Can be analyzed using the same framework for the mass/total cross section

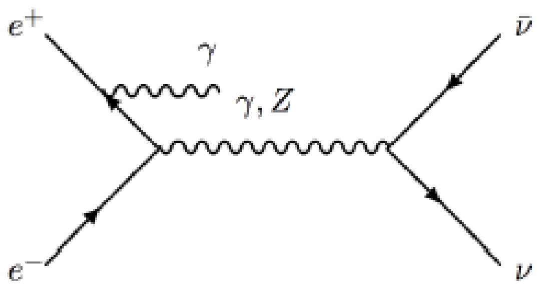
Neutrino generation measurement

- Motivation:
  - 1st: 2-sigma derivation at LEP

    ☞ At the end of LEP: [Phys.Rept.427:257-454,2006]

    $$\mathbf{N_\nu = 2.984 \pm 0.008}$$

    (Remark: indication of 2σ **deficit** in N_ν)
  - 2nd: a solution to Dark Matter (sterile neutrino), Neutrino mixing
- Methods:
  - Line Shape
  - ZZ/ZH events
  - Z(gammas) events



$$N_\nu = \frac{N(\gamma Z_{inv})}{N(\gamma Z_{ee,\mu\mu})} / \left(\frac{\Gamma_{\nu_l}}{\Gamma_l}\right)_{SM}$$

➠ $\left(\frac{\Gamma_{\nu_l}}{\Gamma_l}\right)_{SM}$ uncertainty is small

Neutrino generation measurement: Strategy

- Free lunch: ZZ/ZH events & Z(gammas) events at Higgs Runs

Assume 5 years $\sqrt{s} = 240$ and 350 GeV running with 4 experiments

☞ **650000 (120000)** $e^+e^- \to ZZ$ events per year in 1 experiment at 240 (350) GeV

➠ $\mathcal{B}[\mathrm{Z(ll)Z(inv)}] = 3\%,\ l = e, \mu$

➠ $\mathcal{B}[\mathrm{Z(bb)Z(inv)}] = 6\%$

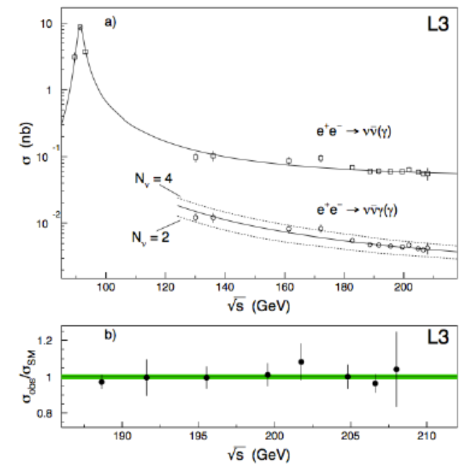
☞ **57870** $e^+e^- \to ZH(b\bar{b})$ events per year in 1 experiment

Expected statistical precision on δN_ν

Mode	$N_{inv}(240)$	$N_{inv}(350)$	δN_ν	Efficiency
Z(ll)Z(inv)	$1.6 \cdot 10^5$	$0.3 \cdot 10^5$	0.014	CMS LEP3 [arXiv:1208.1662]
Z(bb)Z(inv)	$1.7 \cdot 10^5$	$0.3 \cdot 10^5$	0.014	21%, CMS LEP3 [arXiv:1208.1662]
H(bb)Z(inv)	$0.5 \cdot 10^5$	$0.1 \cdot 10^5$	0.024	21%, same as for Z(bb)Z(inv)
Total	$\mathbf{3.8 \cdot 10^5}$	$\mathbf{0.7 \cdot 10^5}$	**0.0089**	
γZ(inv)	$3 \cdot 10^7$		0.0011	100% eff., no bkg.

☞ Inclusion of the dijet channel $\mathcal{B}[\mathrm{Z(qq)Z(inv)}] = 28\%$ deserves dedicated MC studies

Combined (ZZ, ZH) precision can be pinned down to **0.006**



Special run at 105 GeV
($\sigma(\gamma Z_{inv})$ ~20 pb and x3.5 luminosity)
may allow remarkable improvement

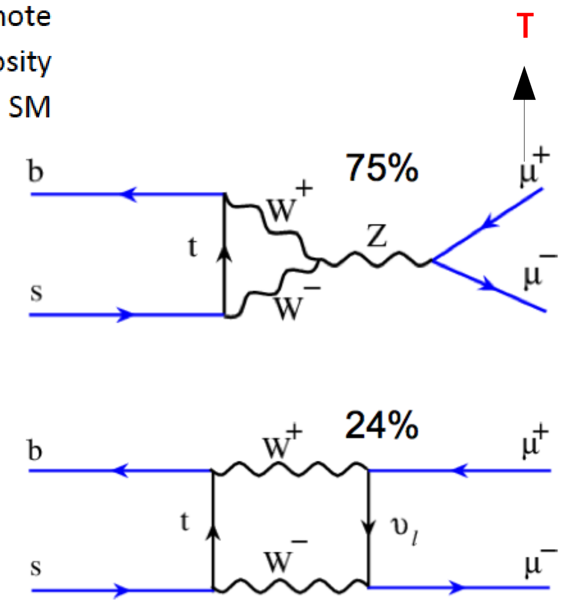
Disclaimer: possible interference with background has to be estimated (dedicated generator is needed)

- Together with WW events:
  - 30 M/y γZ(inv) event at 161 GeV c.m.s
- Specialized run at 105 GeV...

Rare decay: Bs → tau tau

physics. Amongst these rare processes, rare B decays are considered as good candidates. In particular, B decays to lepton pairs are interesting. Recently LHC experiments have observed the decay $B_s \rightarrow \mu^+\mu^-$ and estimated is a branching fraction of $(2.9 \pm 0{,}7) \times 10^{-9}$ (average of CMS and LHCb) compatible within errors to the expectation in the SM of $(3.57 \pm 0{,}30) \times 10^{-9}$. In this note we propose to investigate the possibility to measure the decay $B_s \rightarrow \tau^+\tau^-$ at high luminosity e^+e^-collider running at the Z-pole. Such a measurement would enable to confront the SM predictions for processes involving 3rd generation particles both in the initial and final state.

Physical quantity	unit	value
Cross section $\sigma(Z \rightarrow anything)$	nanobarns	43
Fraction $Z \rightarrow \overline{B}_s$ or $Z \rightarrow B_s$	%	3.2
Luminosity	nb^{-1}	560
1 year operation	second	10^7
Nb of $\overline{B}_s$ or B_s produced		$7.7\ 10^9$



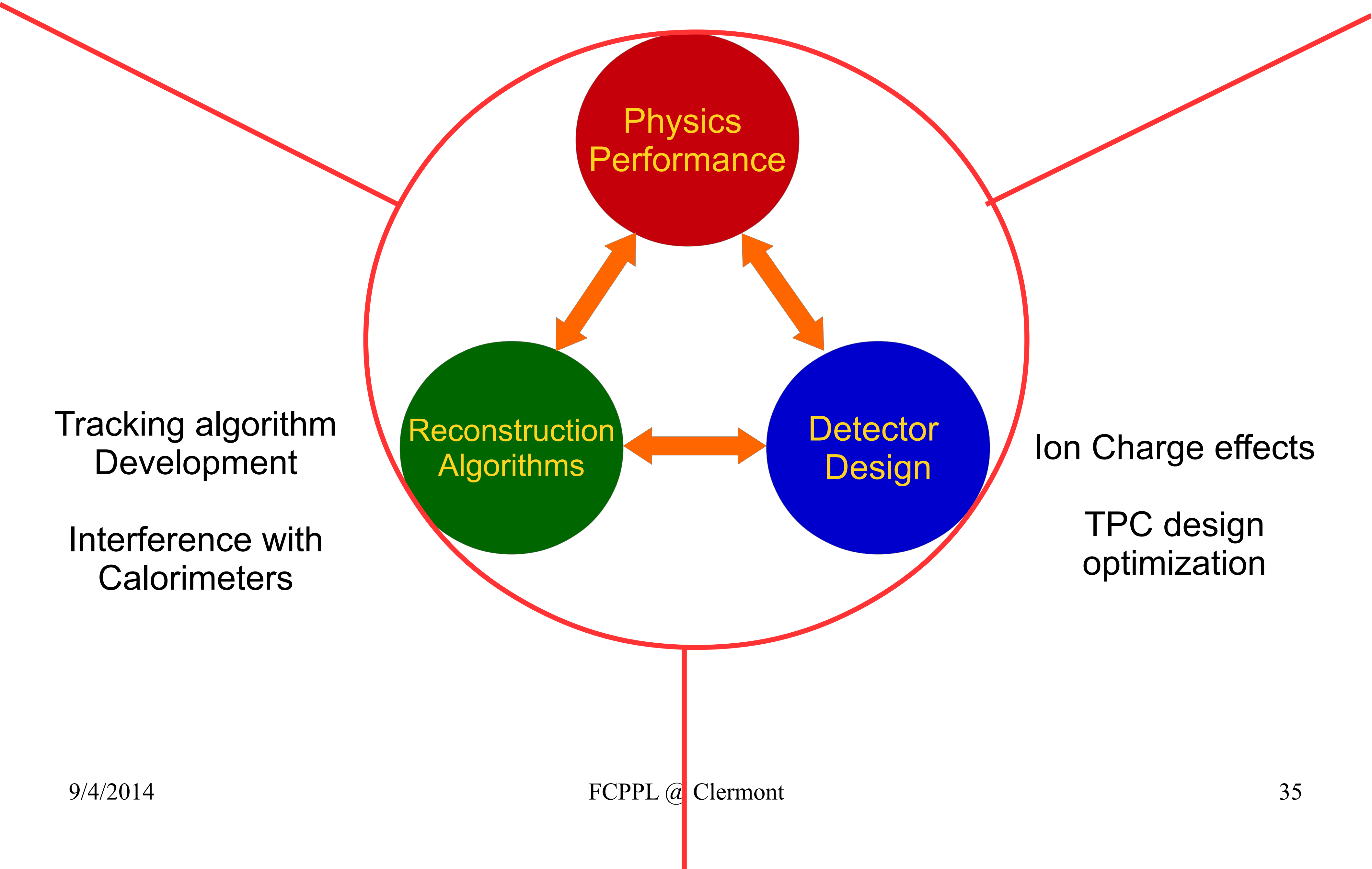
Extremely difficult measurement at existing facilities

FCC: 1000 evt/IP

A Z factory ~ a factory of many, many…particles...

Open question: what's the best B-Field Value/TPC Radius?

Higgs Invisible Decay Branching ratio, Neutrino Generation, Rare decay of Z



Summary

- CEPC detector: lots of ongoing activities at China
  - CEPC project is strongly supported from the Chinese HEP community
  - Good understanding to the physics requirements & working hard towards the pre-CDR and future
- International cooperations, key ingredient
  - Joyful, fruitful … harmonic :)
  - Franco-Chine cooperation is essential for the CEPC detector R&D and Physics analysis
- Lots of interesting/crucial tasks, needs lots of efforts, communication, managements
  - Already some operational plans, certainly needs to go much further

Thank you!

Internal | Events | Contact Us

CEPC

Circular Electron Positron Collider

HOME ABOUT CEPC ORGANIZATION RESULTS WHY SCIENCE JOIN US

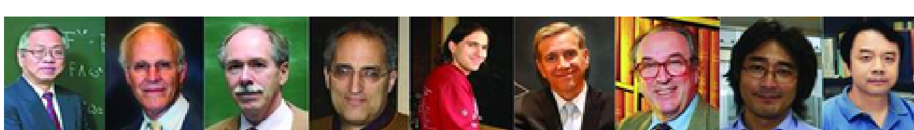
Future High Energy Circular Colliders

The Standard Model (SM) of particle physics can describe the strong, weak and electromagnetic interactions under the framework of quantum gauge field theory. The theoretical predictions of SM are in excellent agreement with the past experimental measurements. Especially the 2013 Nobel Prize in physics was awarded to F. Englert and P. Higgs "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".

After the discovery of the Higgs particle, it is natural to measure its properties as precise as possible, including mass, spin, CP nature, couplings, and etc., at the current running Large Hadron Collider (LHC) and future electron positron colliders, e.g. the International Linear Collider (ILC). The low Higgs mass of ~125 GeV makes possible a Circular Electron Positron Collider (CEPC) as a Higgs Factory, which has the advantage of higher luminosity to cost ratio and the potential to be upgraded to a proton-proton collider to reach unprecedented high energy and discover New Physics.

http://cepc.ihep.ac.cn/

Panel Discussion on Fundamental Physics



What's new After the Higgs discovery: Where is the Fundamental Physics going?

* End of 20'th Century

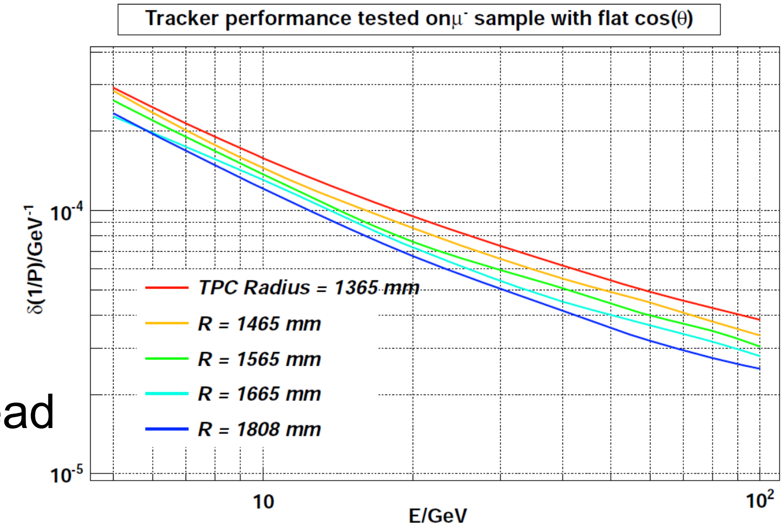
[1895 — 2012]

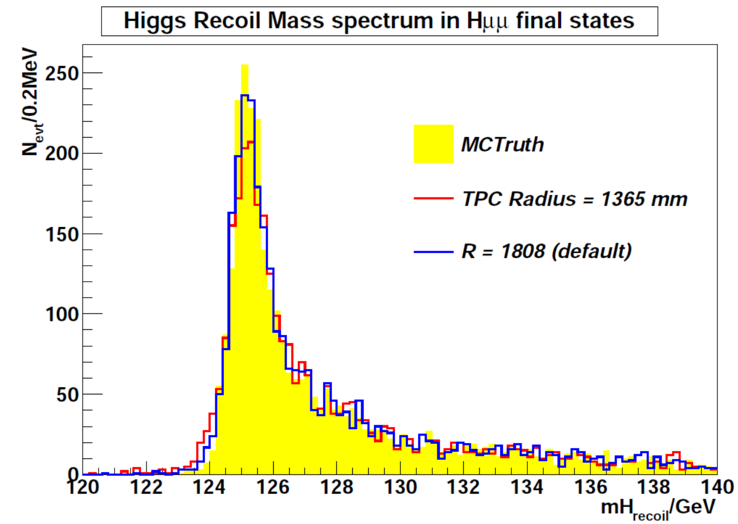
* Dawn of a New Era in Fundamental Physics

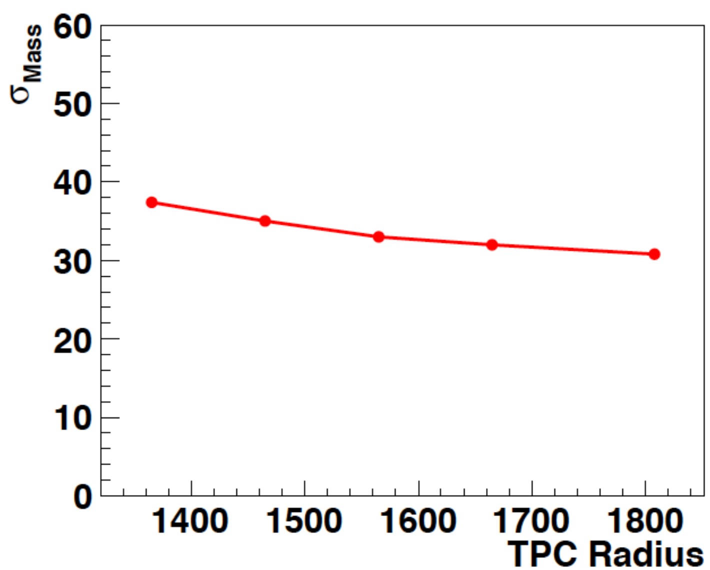
Spared slides

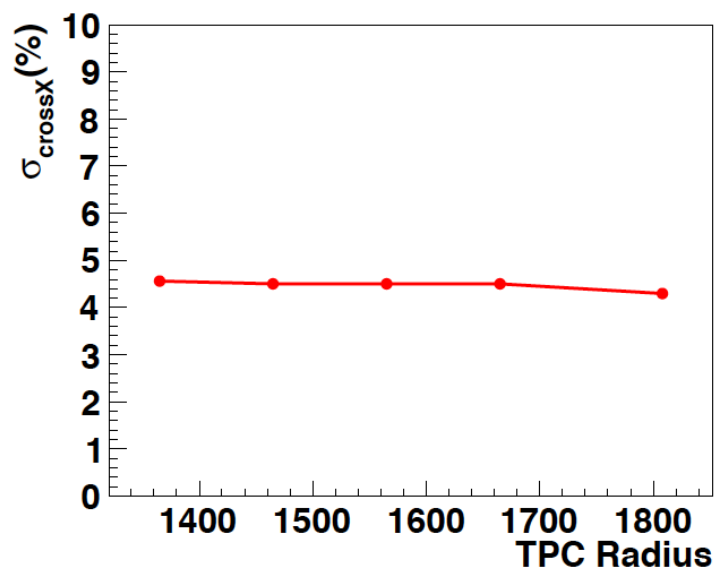
Fast simulation of recoil mass spectrum

Large intrinsic width:
from beam energy spread
& radiation effects
(Beamstrahlung, etc)



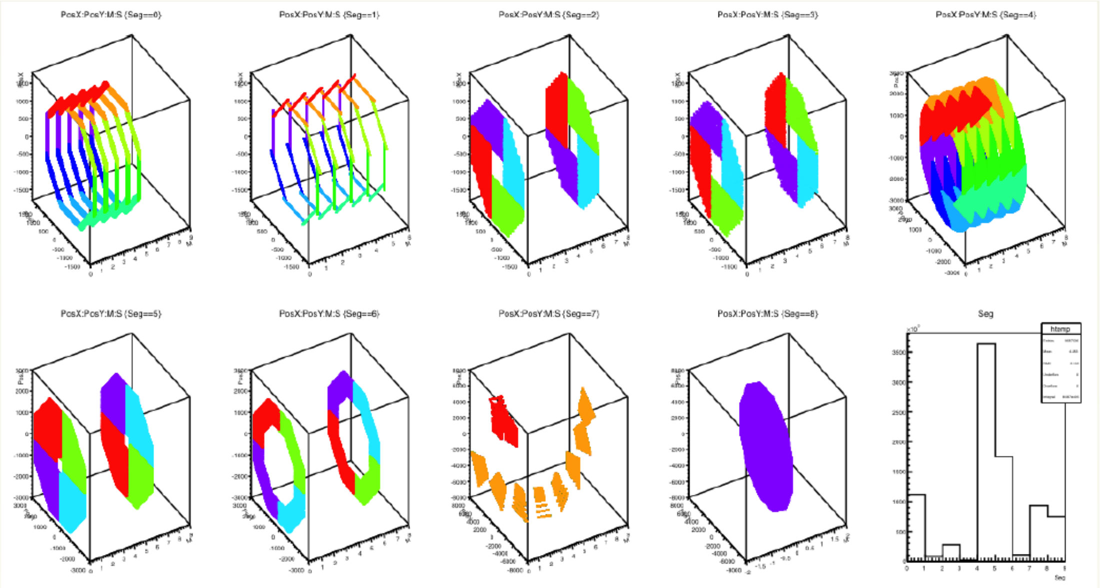


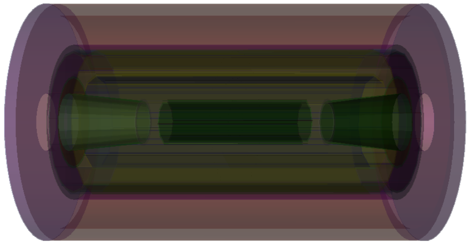


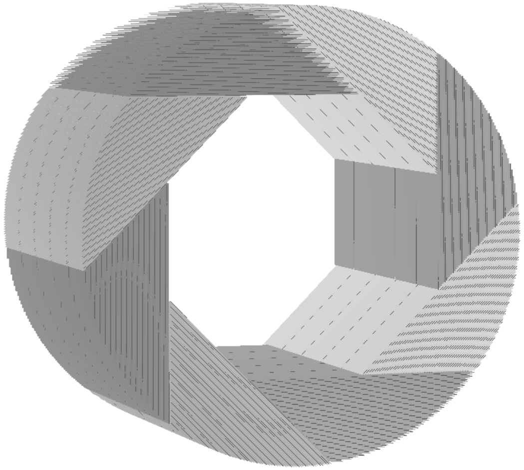


Detector simulation studies

- Center simulation support: Nankai U
  - Validation of New geometry
  - Cooperating with Ecole polytechnique (France)
- Sub detector simulation
  - TPC: UCAS (binglong Wang)
  - VTX: SDU (Qingyuan Liu)
  - Calo: SJTU
- Sub detector performance studies
  - Charged particle: IHEP (finished)
  - Neutron hadron: SJTU
  - Photons: WhU & IHEP (Feng Wang)

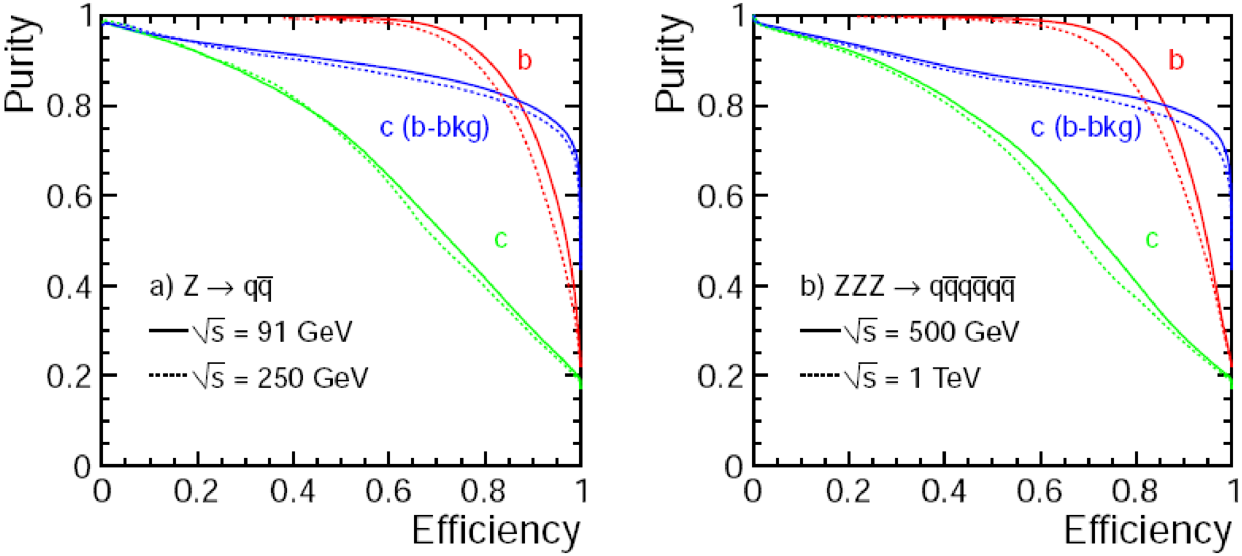


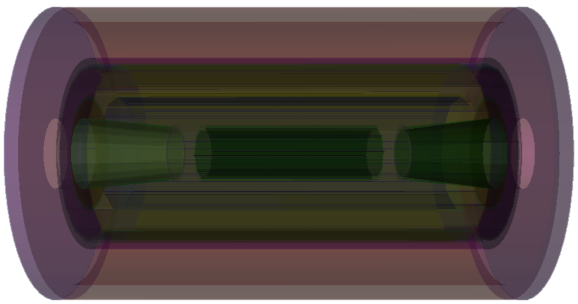




Sub detector & performance: VTX

b Vs udsc; c Vs b; c Vs udsb





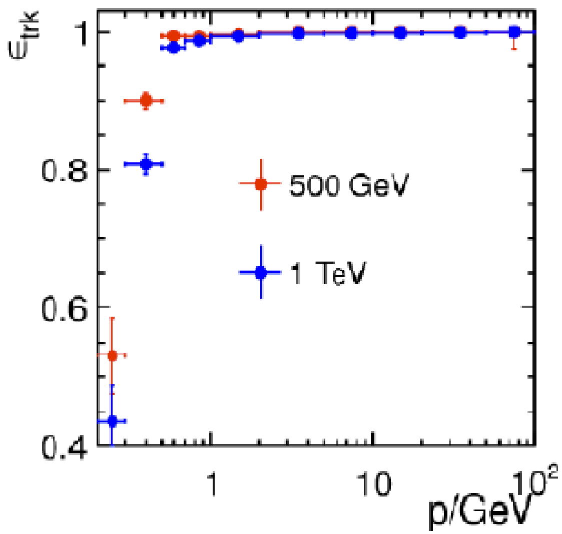
VTX detector: spatial resolution ~ 5 μm, located with inner radius of 15 mm

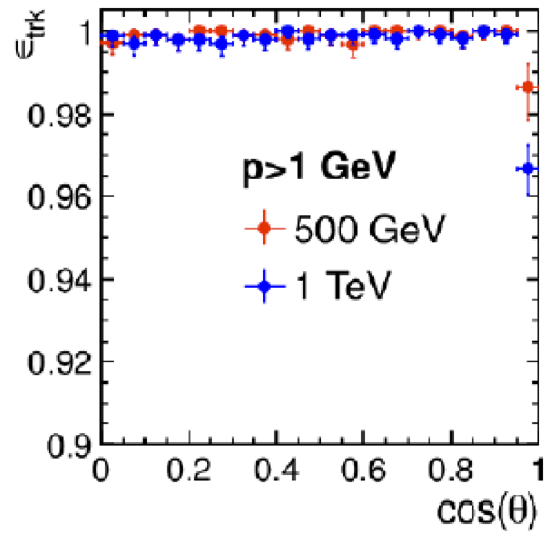
Flavor tagging performance:

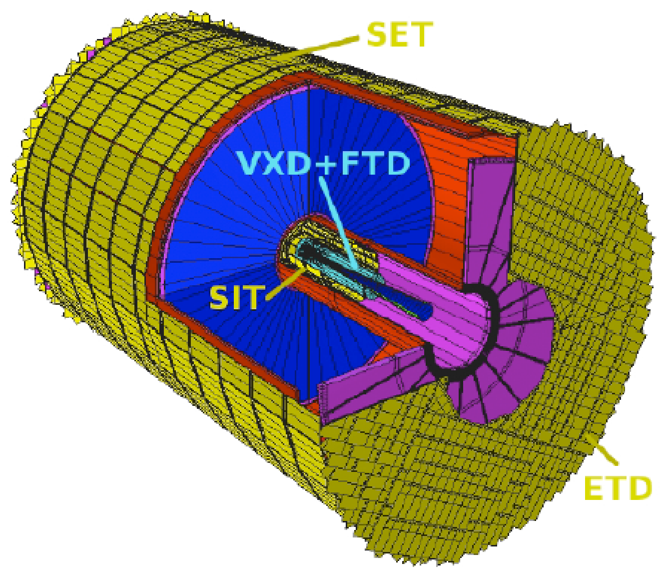
- Eff = 80%, purity > 90% for b-tagging
- Capability for c tagging

Algorithm: LCFIPlus, Tokyo University (Tomohiko Tanabe. etc)

Tracker





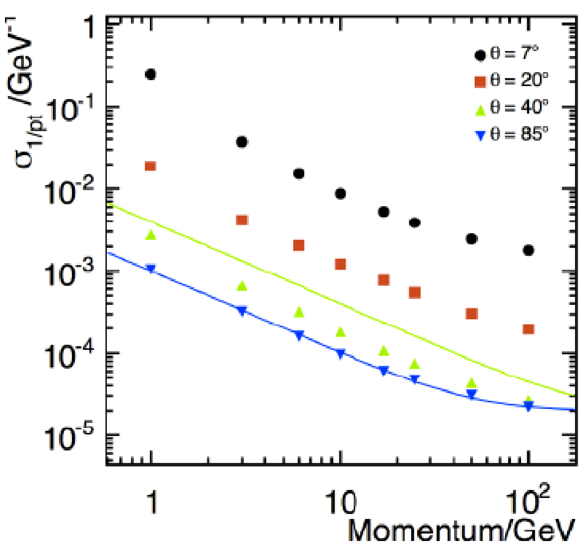


Tracking:

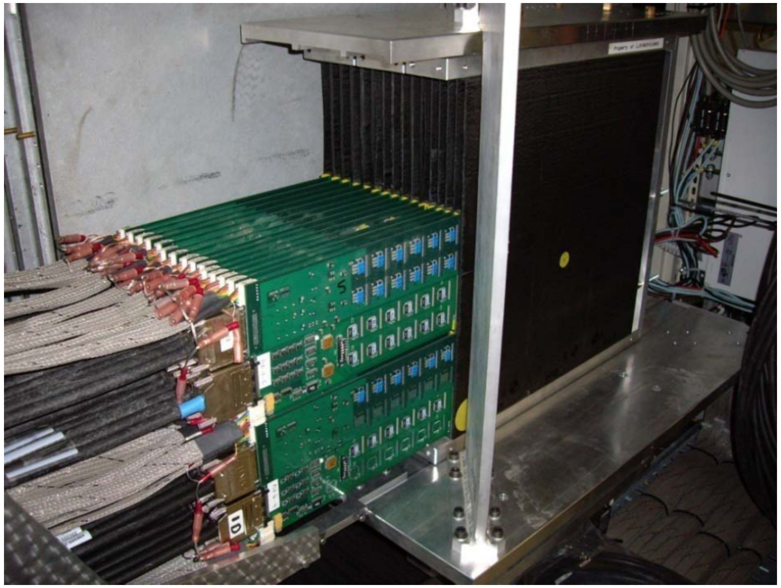
- Barrel: TPC + Inner Silicon (VTX, SIT)
- Forward: Front Tracking Disks;
- Optional: External Silicon Tracker

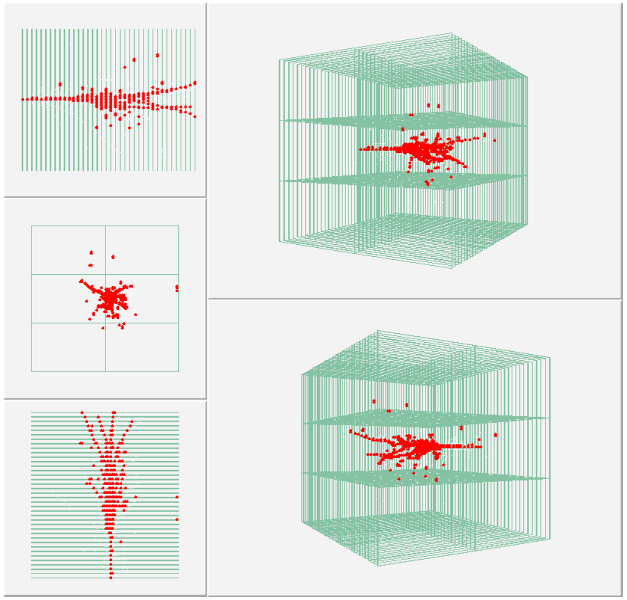
Performance: $\delta(1/P_T) \sim 2\text{-}5 * 10^{-5} (1/\text{GeV})$

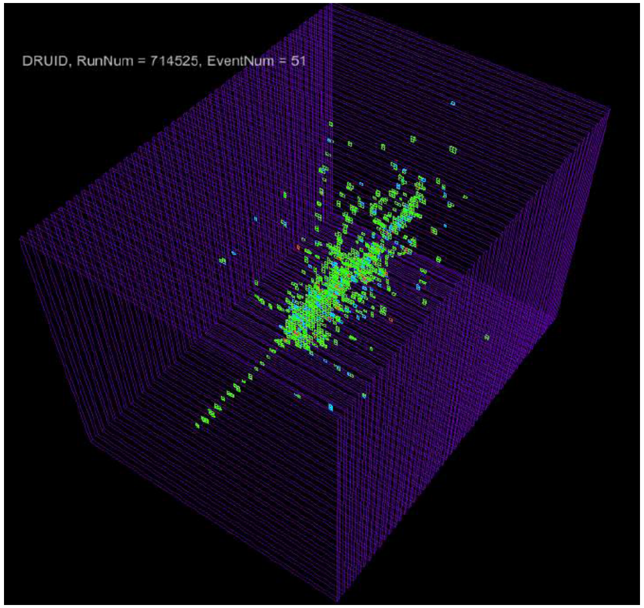
Algorithm: Clupatra, DESY (F. Gaede);
KalTest, KEK (K. Fujii), Tsinghua (B. Li)



Imagine Calorimeter

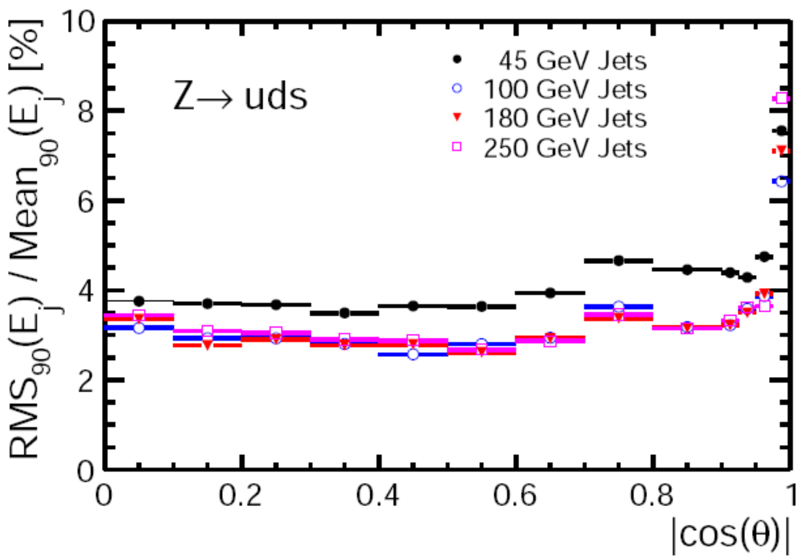






Ultra high granularity ~ 1 channel cm^{-3}.
3d, 4d or 5d image...

PFA： δEJ/E = 3 - 4%
Algorithms:
PandoraPFA, Cambridge (M. Thomson);
Arbor, LLR & IHEP(Manqi, Henri)



Higgs Measurement at ILD

ILC Higgs Measurement:

Well understood,

But for sure potential

to improve

	$\Delta(\sigma \cdot BR)/(\sigma \cdot BR)$				
$\sqrt{s}$ and $\mathcal{L}$	$250\,\text{fb}^{-1}$ at $250\,\text{GeV}$		$500\,\text{fb}^{-1}$ at $500\,\text{GeV}$		$1\,\text{ab}^{-1}$ at $1\,\text{TeV}$
(P_{e^-}, P_{e^+})	(-0.8,+0.3)		(-0.8,+0.3)		(-0.8,+0.2)
mode	ZH	$\nu\bar{\nu}H$	ZH	$\nu\bar{\nu}H$	$\nu\bar{\nu}H$
$H \to b\bar{b}$	1.2%	10.5%	1.8%	0.66%	0.32%
$H \to c\bar{c}$	8.3%	-	13%	6.2%	3.1%
$H \to gg$	7.0%	-	11%	4.1%	2.3%
$H \to WW^*$	6.4%	-	9.2%	2.4%	1.6%
$H \to \tau^+\tau^-$	4.2%	-	5.4%	9.0%	3.1%
$H \to ZZ^*$	19%	-	25%	8.2%	4.1%
$H \to \gamma\gamma$	29-38%	-	29-38%	20-26%	7-10%
$H \to \mu^+\mu^-$	-	-	-	-	31%
$H \to$ Inv.(95%C.L.)	$< 0.95\%$		-		-
$t\bar{t}H, H \to b\bar{b}$	-		28%		6.0%

TABLE I: Expected accuracies for cross section times branching ratio measurements for the 125 GeV H boson by the canonical scenario.

couplings	250 GeV	250 GeV + 500 GeV	250 GeV + 500 GeV + 1 TeV
g_{HZZ}	1.3%	1.3%	1.3%
g_{HWW}	4.8%	1.4%	1.4%
g_{Hbb}	5.3%	1.8%	1.5%
g_{Hcc}	6.8%	2.9%	2.0%
g_{Hgg}	6.4%	2.4%	1.8%
$g_{H\tau\tau}$	5.7%	2.4%	1.9%
$g_{H\gamma\gamma}$	18%	8.4%	4.1%
$g_{H\mu\mu}$	-	-	16%
g_{Htt}	-	14%	3.2%
Γ_0	11%	5.9%	5.6%

TABLE II: Expected accuracies of Higgs couplings and total Higgs width by the canonical scenario.

J. Tian & K. Fujii
LC-REP-2013-021

Higgs Measurement at ILD: Luminosity Upgrade scenario

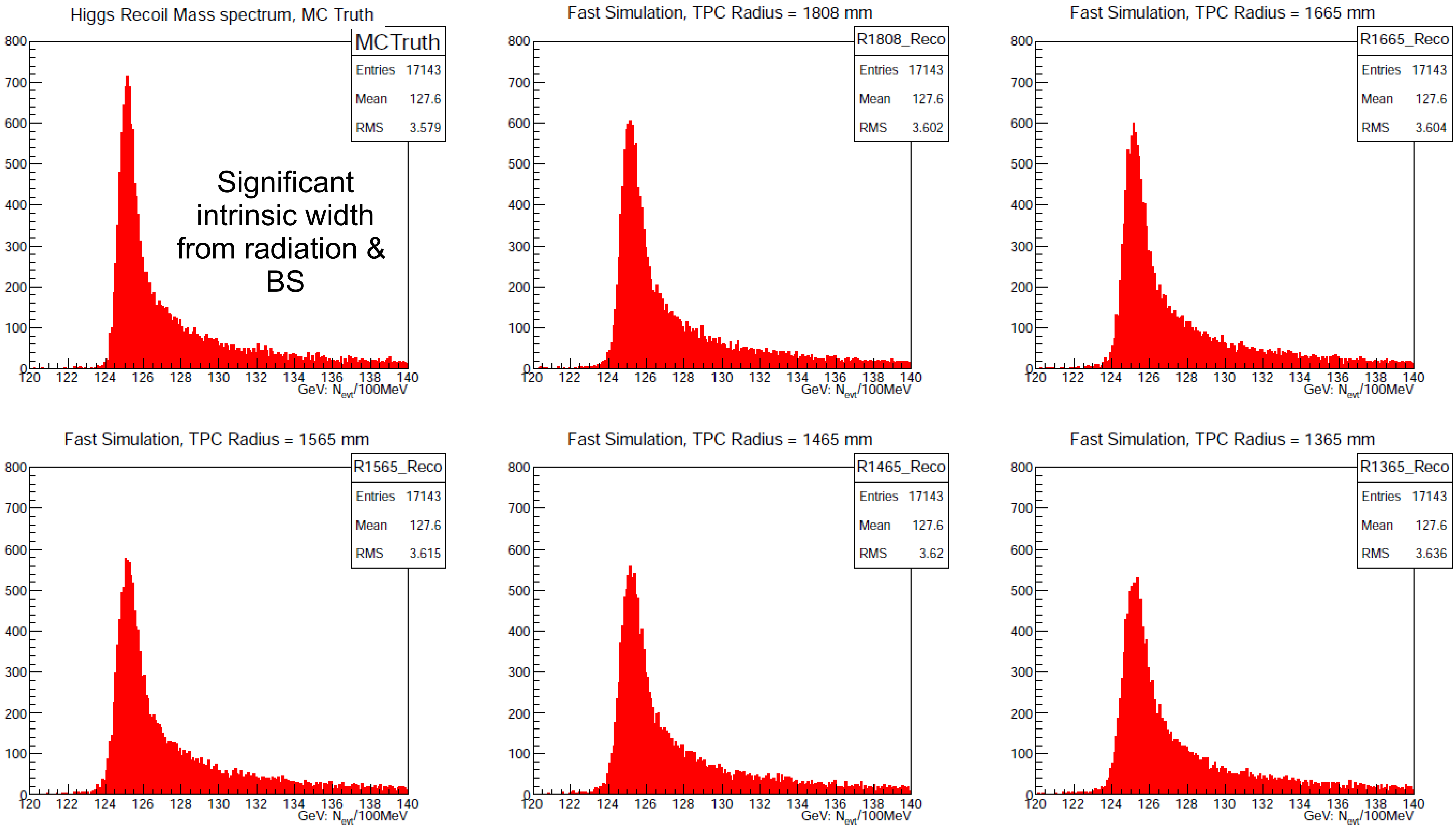
	$\Delta(\sigma \cdot BR)/(\sigma \cdot BR)$				
$\sqrt{s}$ and $\mathcal{L}$	1150 fb^{-1} at 250 GeV		1.6 ab^{-1} at 500 GeV		2.5 ab^{-1} at 1 TeV
(P_{e^-}, P_{e^+})	(-0.8,+0.3)		(-0.8,+0.3)		(-0.8,+0.2)
mode	ZH	$\nu\bar{\nu}H$	ZH	$\nu\bar{\nu}H$	$\nu\bar{\nu}H$
$H \to b\bar{b}$	0.56%	4.9%	1.0%	0.37%	0.20%
$H \to c\bar{c}$	3.9%	-	7.2%	3.5%	2.0%
$H \to gg$	3.3%	-	6.0%	2.3%	1.4%
$H \to WW^*$	3.0%	-	5.1%	1.3%	1.0%
$H \to \tau^+\tau^-$	2.0%	-	3.0%	5.0%	2.0%
$H \to ZZ^*$	8.8%	-	14%	4.6%	2.6%
$H \to \gamma\gamma$	16%	-	19%	13%	5.4%
$H \to \mu^+\mu^-$	-	-	-	-	20%
$H \to$ Inv.$(95\% C.L.)$	$< 0.37\%$		-		-
$t\bar{t}H, H \to b\bar{b}$	-		16%		3.8%

TABLE IV: Expected accuracies for cross section times branching ratio measurements for the 125 GeV H boson by the luminosity upgrade scenario.

couplings	250 GeV	250 GeV + 500 GeV	250 GeV + 500 GeV + 1 TeV
g_{HZZ}	0.61%	0.61%	0.61%
g_{HWW}	2.3%	0.67%	0.65%
g_{Hbb}	2.5%	0.90%	0.74%
g_{Hcc}	3.2%	1.5%	1.1%
g_{Hgg}	3.0%	1.3%	0.93%
$g_{H\tau\tau}$	2.7%	1.2%	0.99%
$g_{H\gamma\gamma}$	8.2%	4.5%	2.4%
$g_{H\mu\mu}$	-	-	10%
g_{Htt}	-	7.8%	2.0%
Γ_0	5.4%	2.8%	2.7%

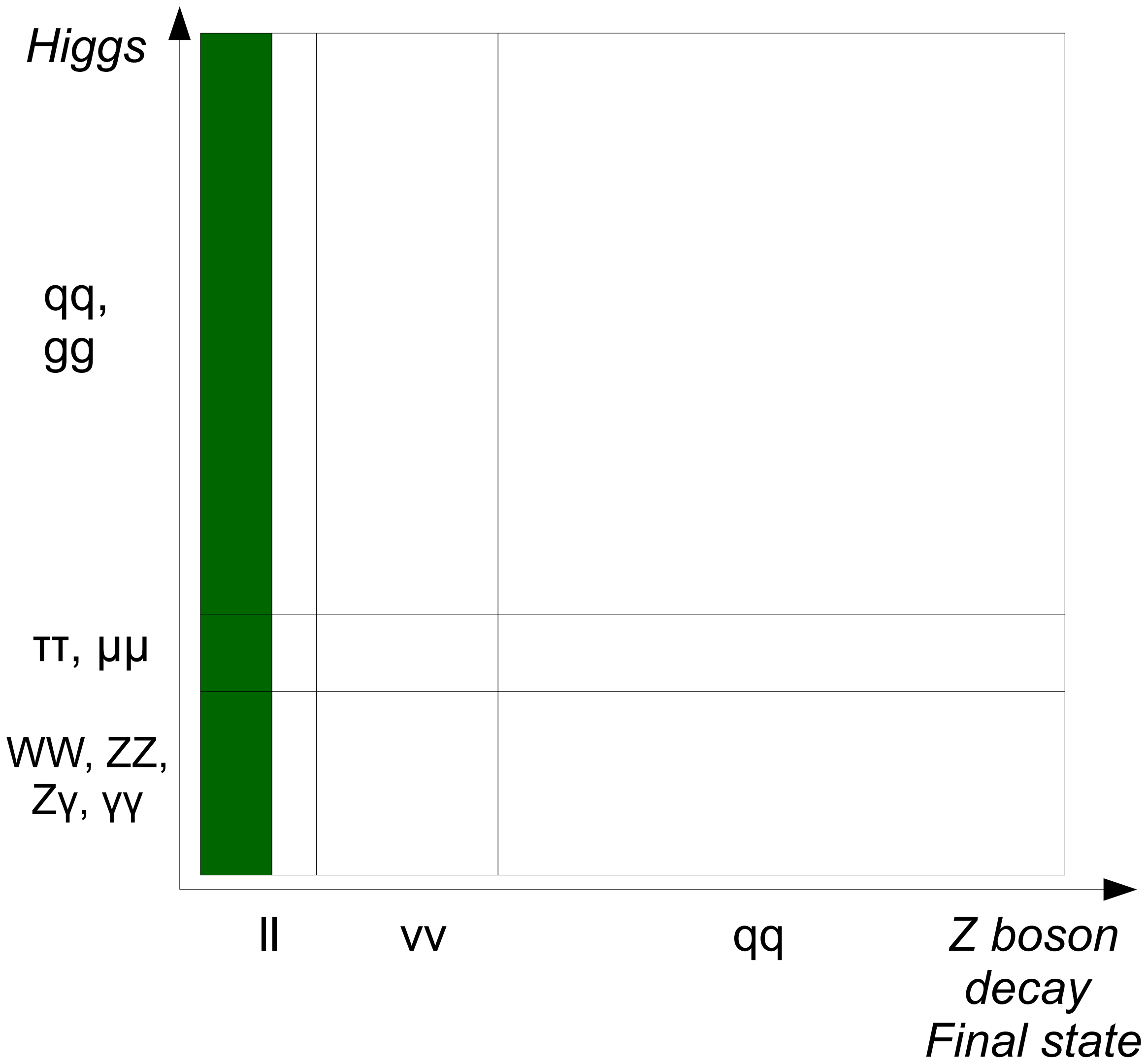
TABLE V: Expected accuracies of Higgs couplings and total Higgs width by the luminosity upgrade scenario.

Recoil mass at different TPC Radius



Nevts scaled by a factor of ~ 5

Measurements at different final states: ZH, $Z \rightarrow 2l$ (l = ee, μμ), $H \rightarrow X$



Model independent tagging of ZH events from recoil mass spectrum to di-lepton system. Statistic ~ 6.7k evts

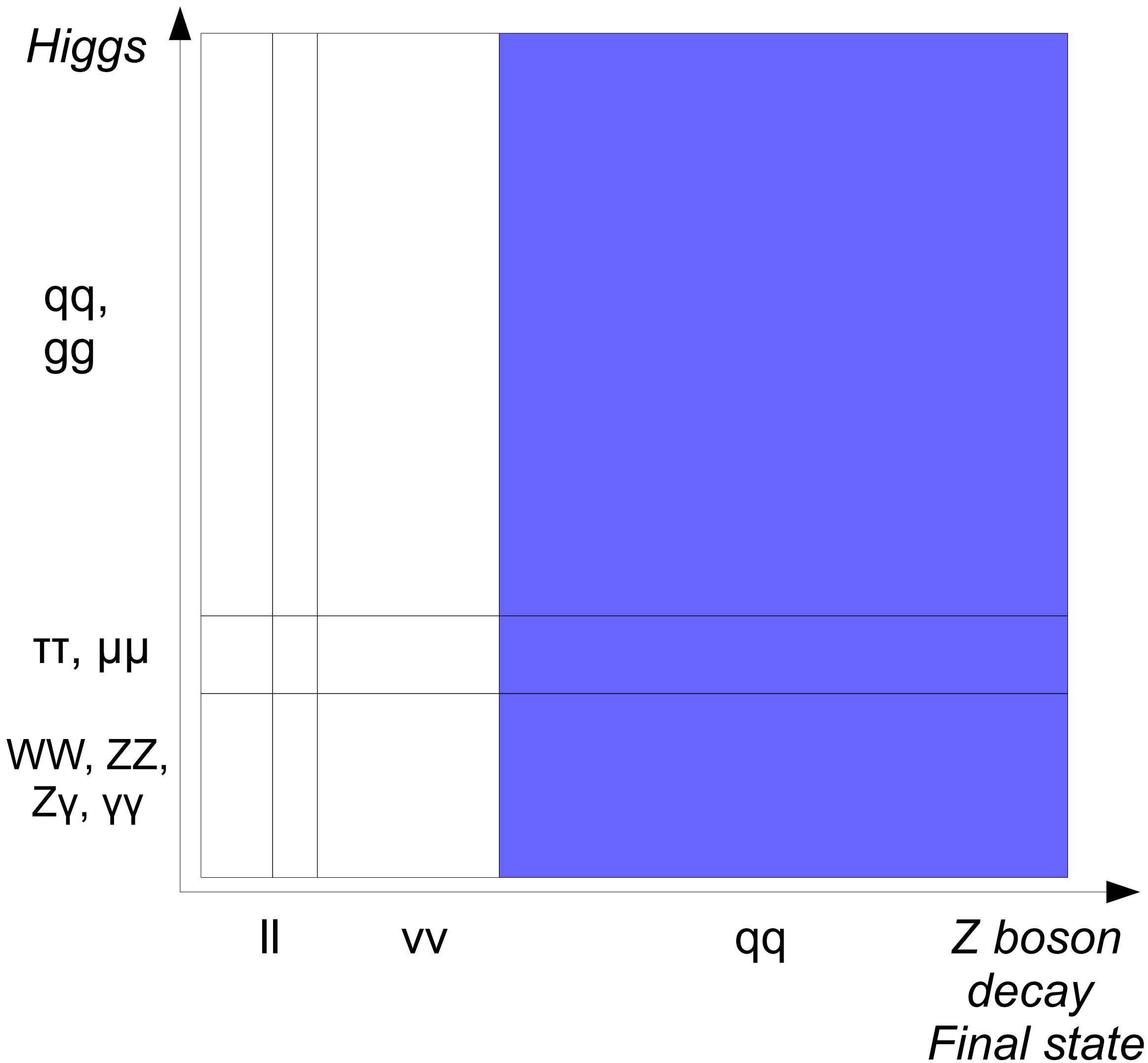
Objective Observables:

Recoil mass spectrum:
Higgs mass, σ(HZ)

Tagged ZH events + Higgs final states classification:
Br(H→X)*σ(HZ)

Critical performance/algorithms:
Tracking & final states Classification (Tagging of Tau, WW*/ZZ*, jet flavor):

ZH, $Z \to 2q$, $H \to X$



Model independent tagging of ZH events from recoil mass spectrum to di-jet system. Statistic ~ 70k evts

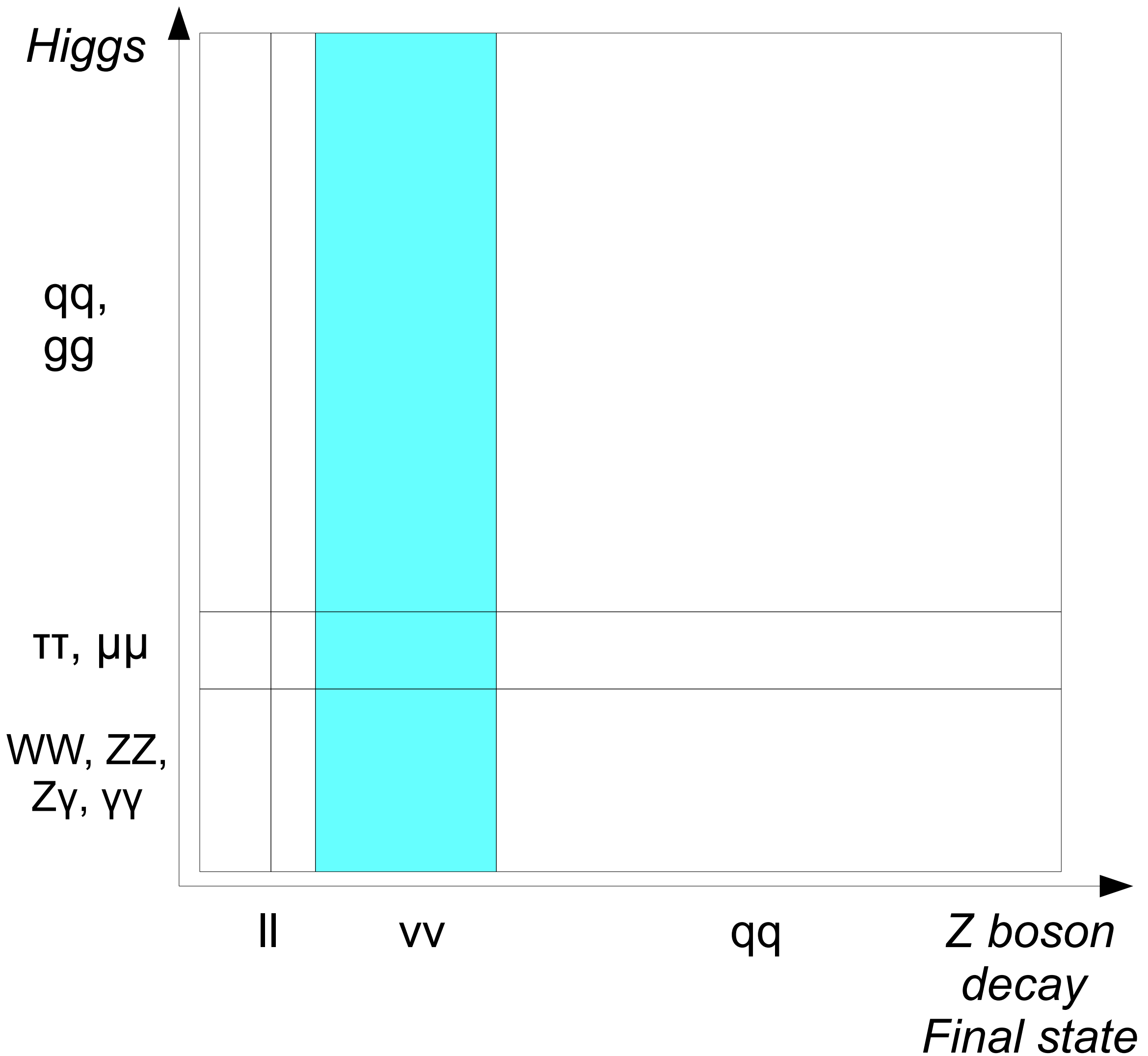
Objective Observables:

Recoil mass spectrum:
Higgs mass, $\sigma(HZ)$

Tagged ZH events + Higgs final states classification:
$Br(H \to X)^{*}\sigma(HZ)$

Critical performance/algorithms:
PFA (jet energy resolution),
Jet clustering &
final states classification:

ZH, Z→2ν, H→X



Tag the ZH events from di-jet
Invariant mass. Statistic ~ 20k evts

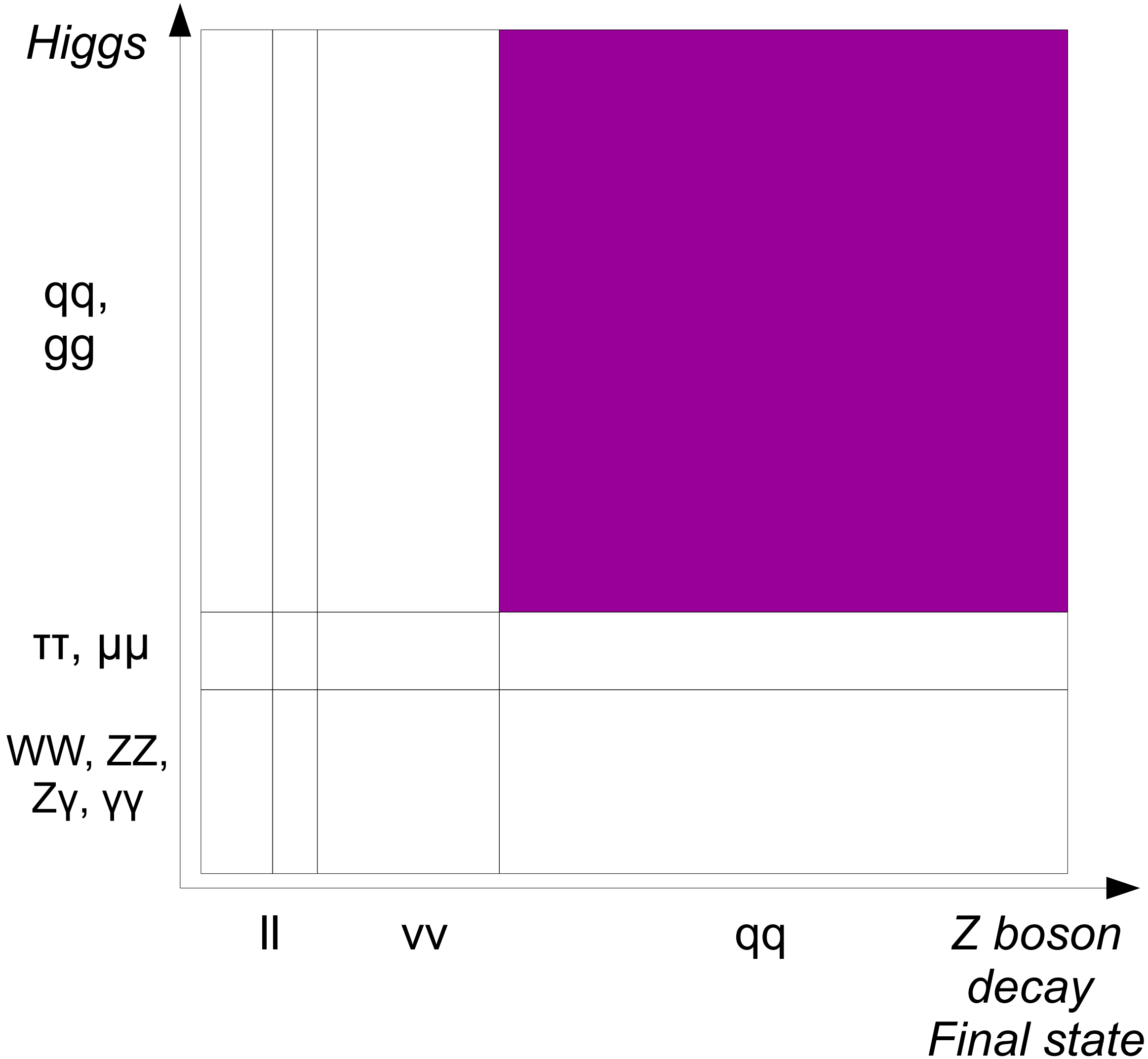
Objective Observables:

Higgs mass, σ(HZ)*Br(H→X)

Critical performances/algorithms:

Jet clustering,
PFA (Jet energy resolution,
Missing energy reconstruction)
Final states classification

ZH, Z→2q, H→2q



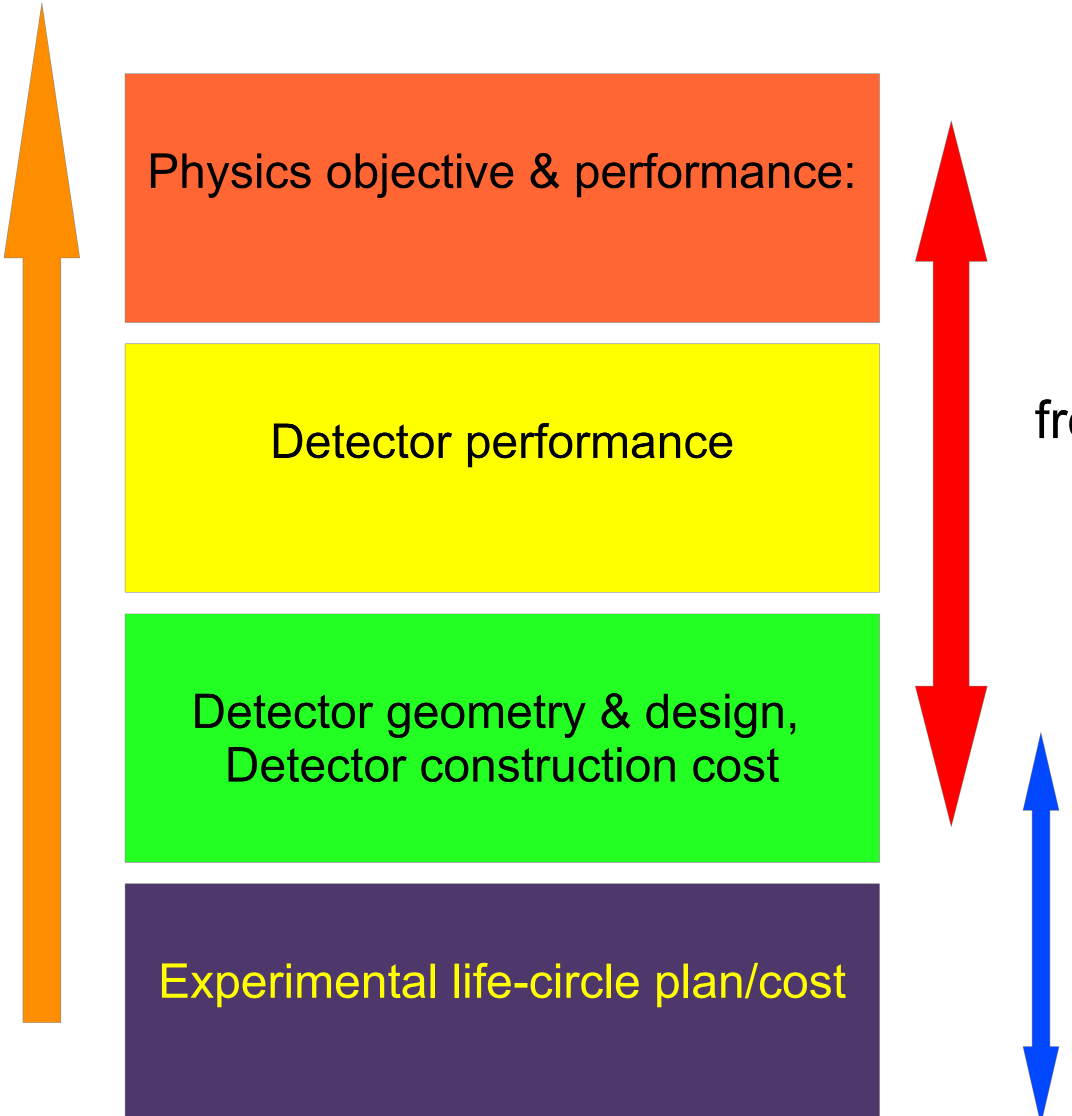
Tag the ZH events from invariant Mass of all 2-jets combinations.
Statistics ~ 50k evts

Objective Observables:

Higgs mass, σ(HZ)*Br(H→2j), σ(HZ)*Br(H→2b, 2c, 2g),

Critical performances:
Jet clustering,
Jet energy resolution (PFA),
Flavor tagging

Detector optimization: objective

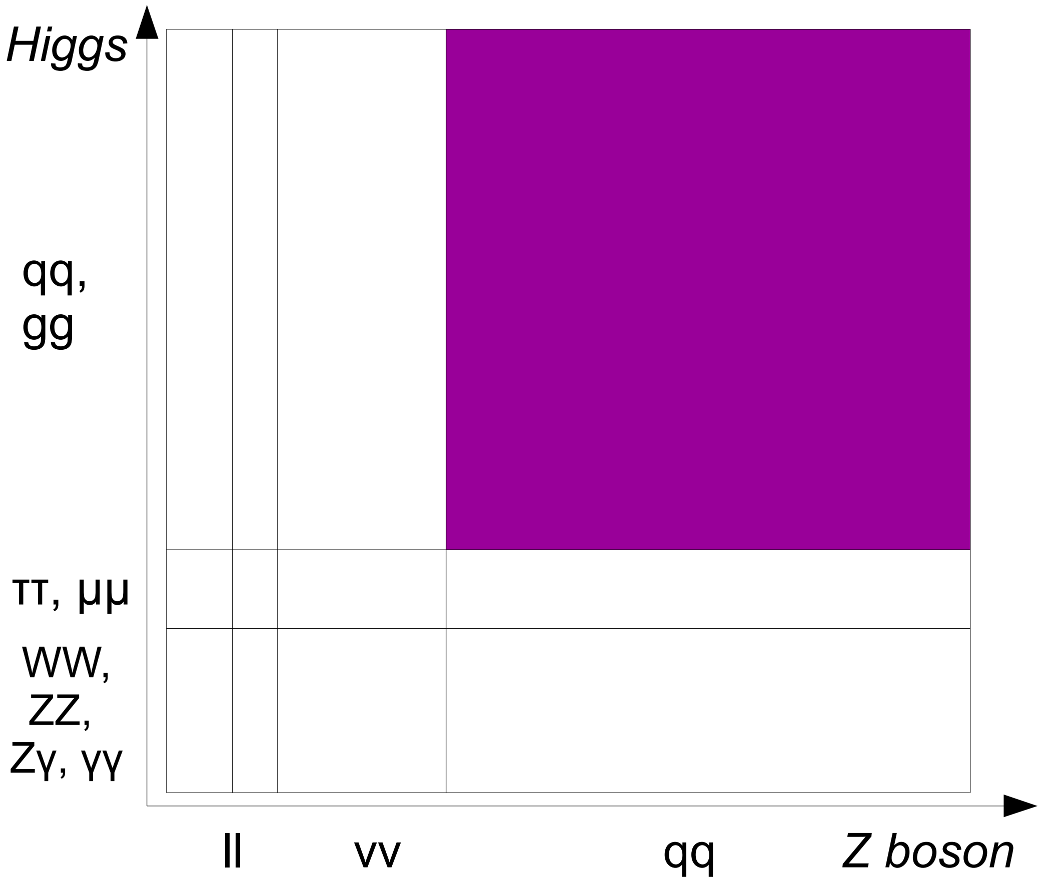


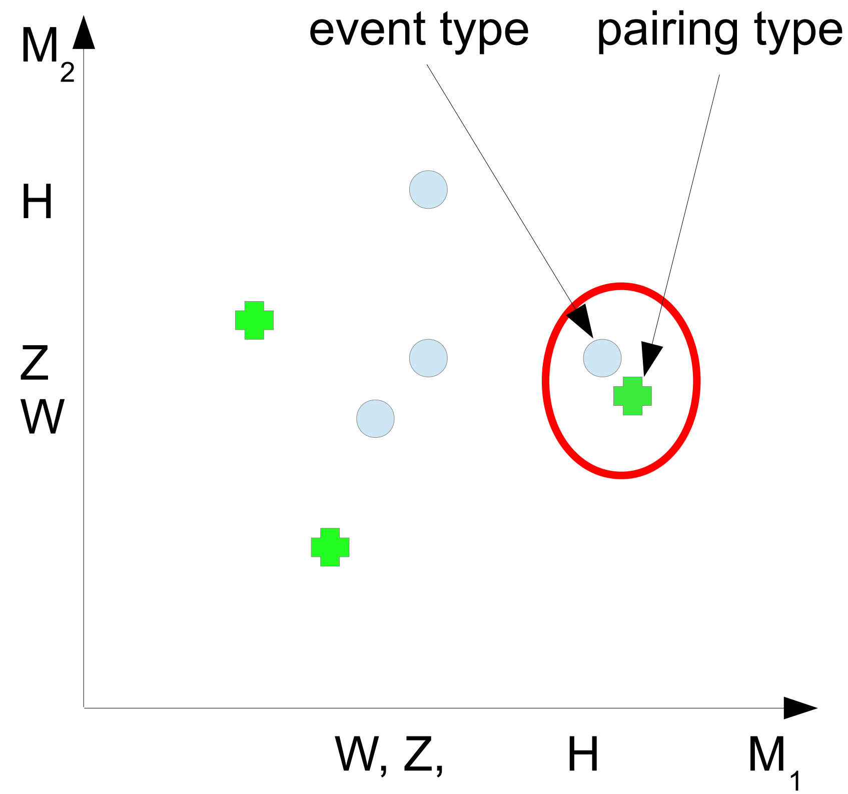
Full & Fast simulation:

from generator to physics performance, parametrized the performance to detector design/cost...

Profound understanding, reliable reference, Communication, PR, decision making...

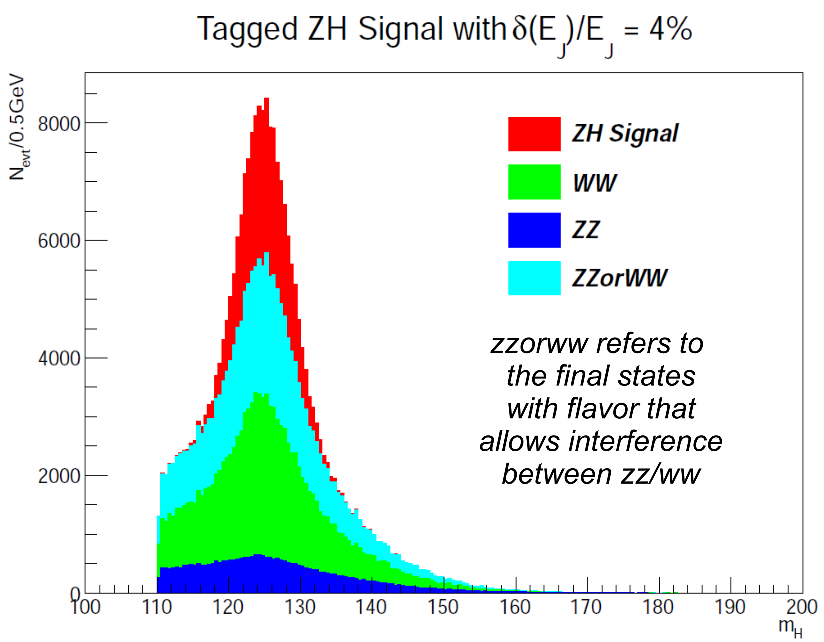
Measurement of σ(HZ)*Br(H→2j)

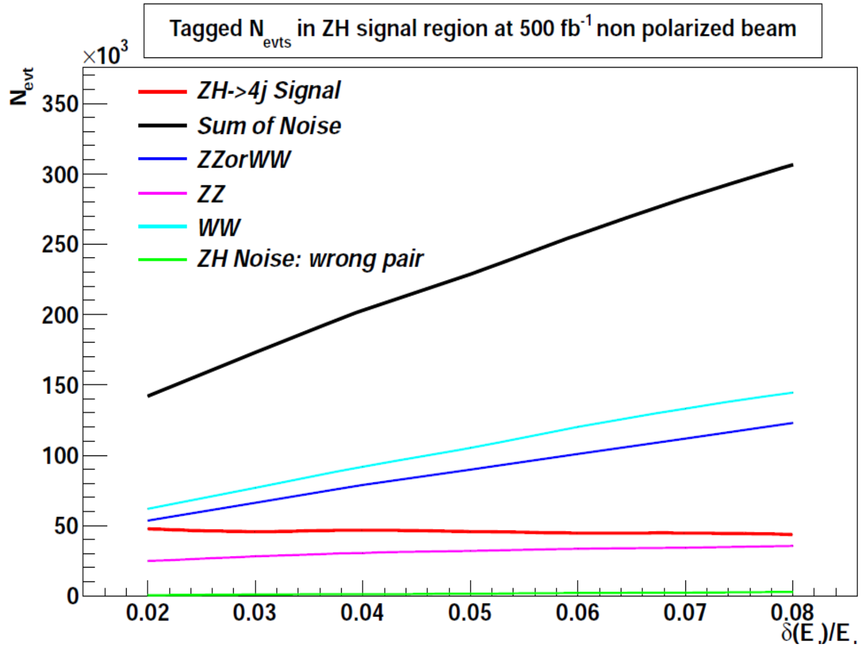


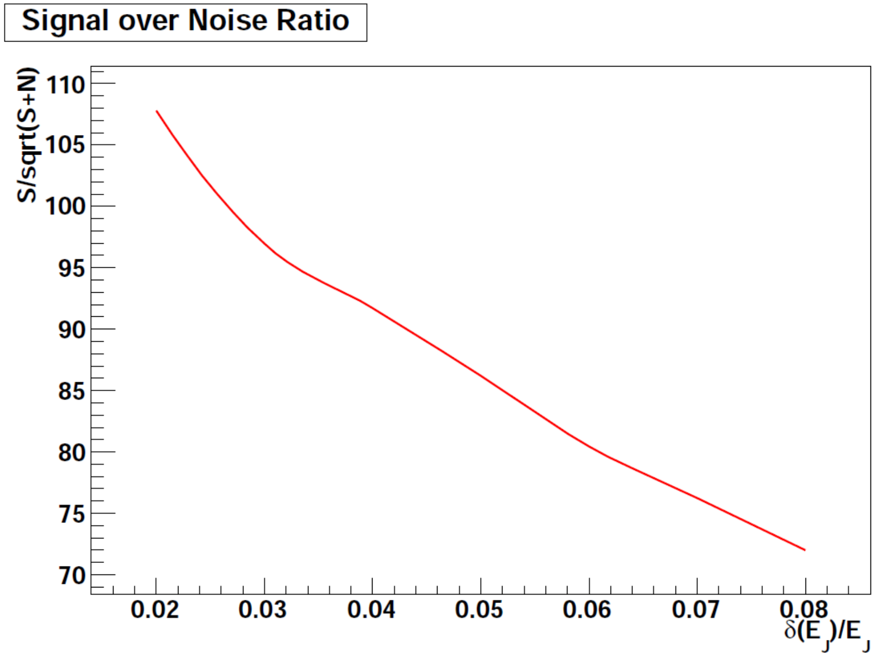


- Represent reconstructed jets by MC Truth quark * percentage energy smearing
- Main backgrounds ZZ, WW events into 4 jets
- Define Chi2 = $((M_{i,j} - MB_1)/\sigma_1)^2 + ((M_{k,l} - MB_2)/\sigma_2)^2$, Ijkl runs over all 3 combinations
- The minimal chi2 indicates both event type and jet pairing

Performance at different Jet E resolution





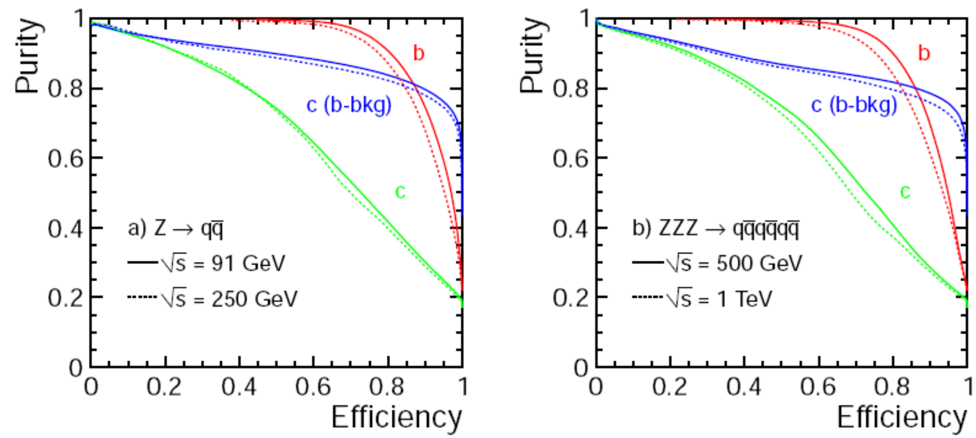


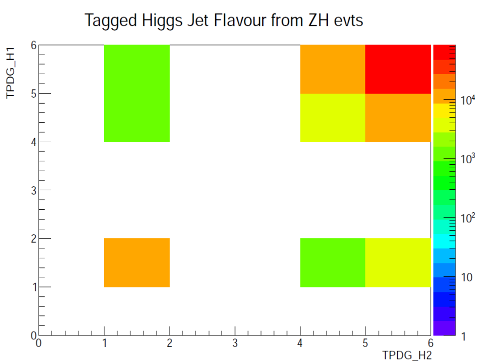
σ(H→2j) measurement easily reaches percentage level accuracy;

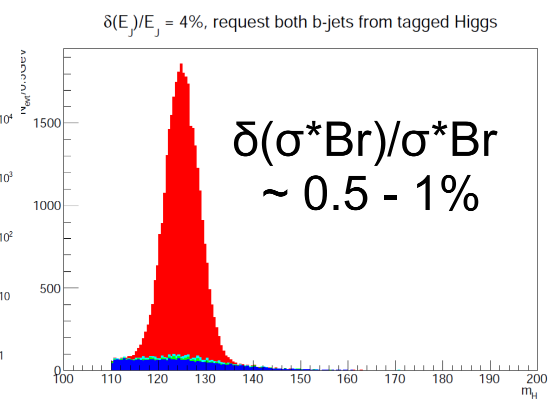
Performance weakly depends on the jet Energy resolution: δσ/σ ~ 1-1.5 %

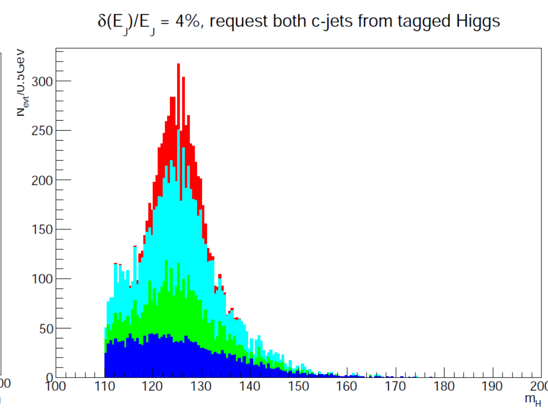
Modeling of Flavor tagging

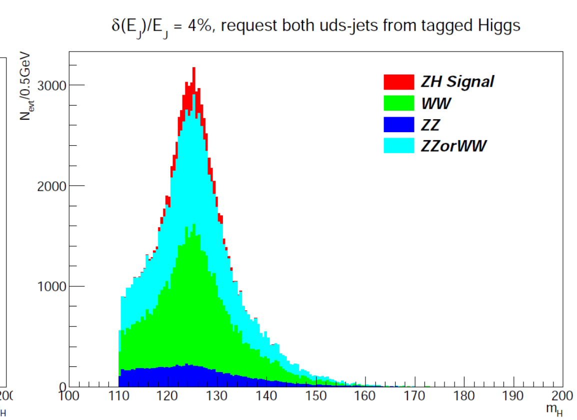
	b	c	uds	undef
b	0.90	0.08	0.02	
c	0.25	0.70	0.05	
uds	0.03	0.06	0.91	





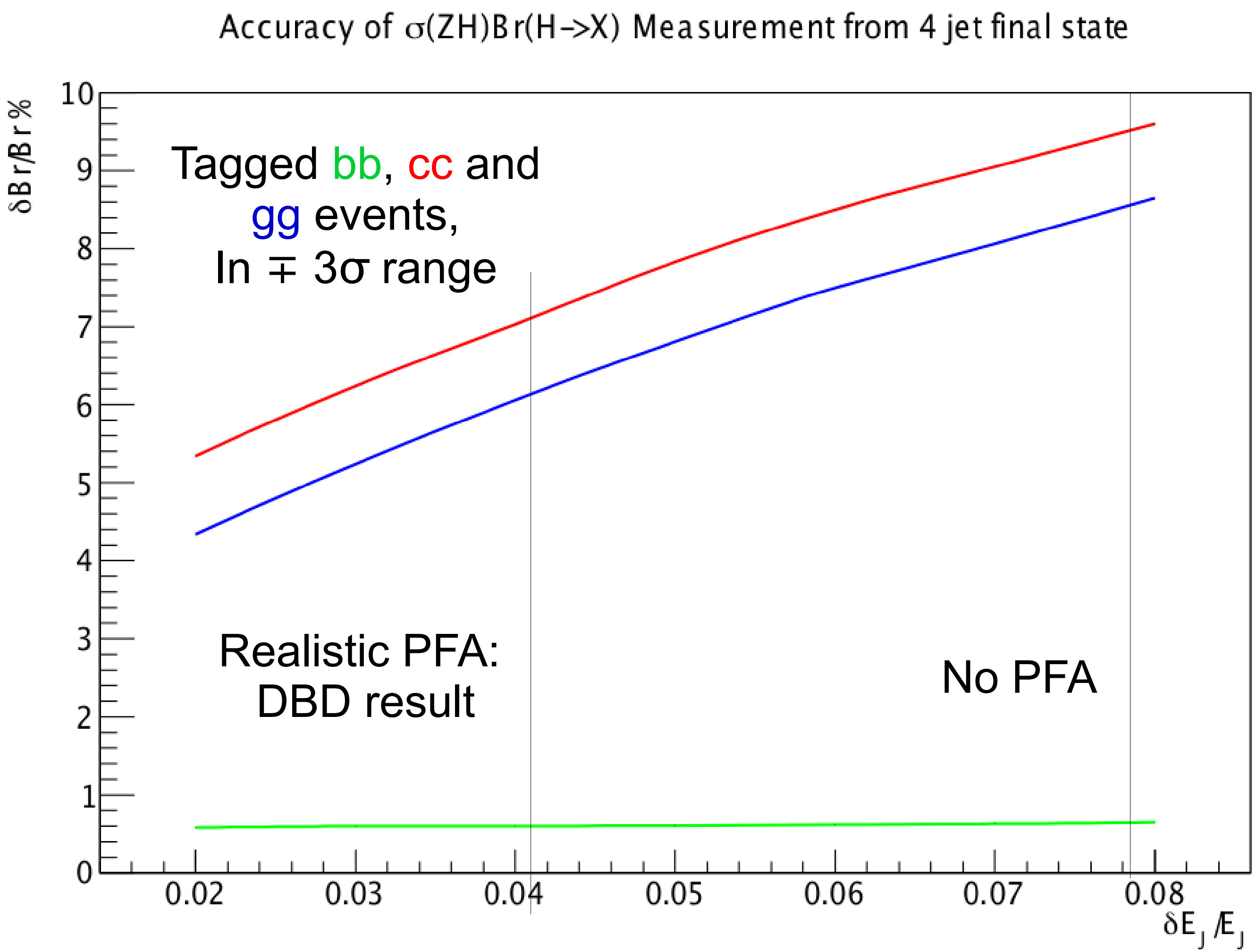






*O = M*T; M, Migration Matrix*
O, T: vector of number of events in each final state, Observed & Truth
T = T(Branching ratios)

Measuring σ(HZ)*Br(H→2j), j = b, c, g



Remarks:

Measurements from HZ, Z→ll, νν Can be combined to Improve the result

Fit range and event Selection can be improved

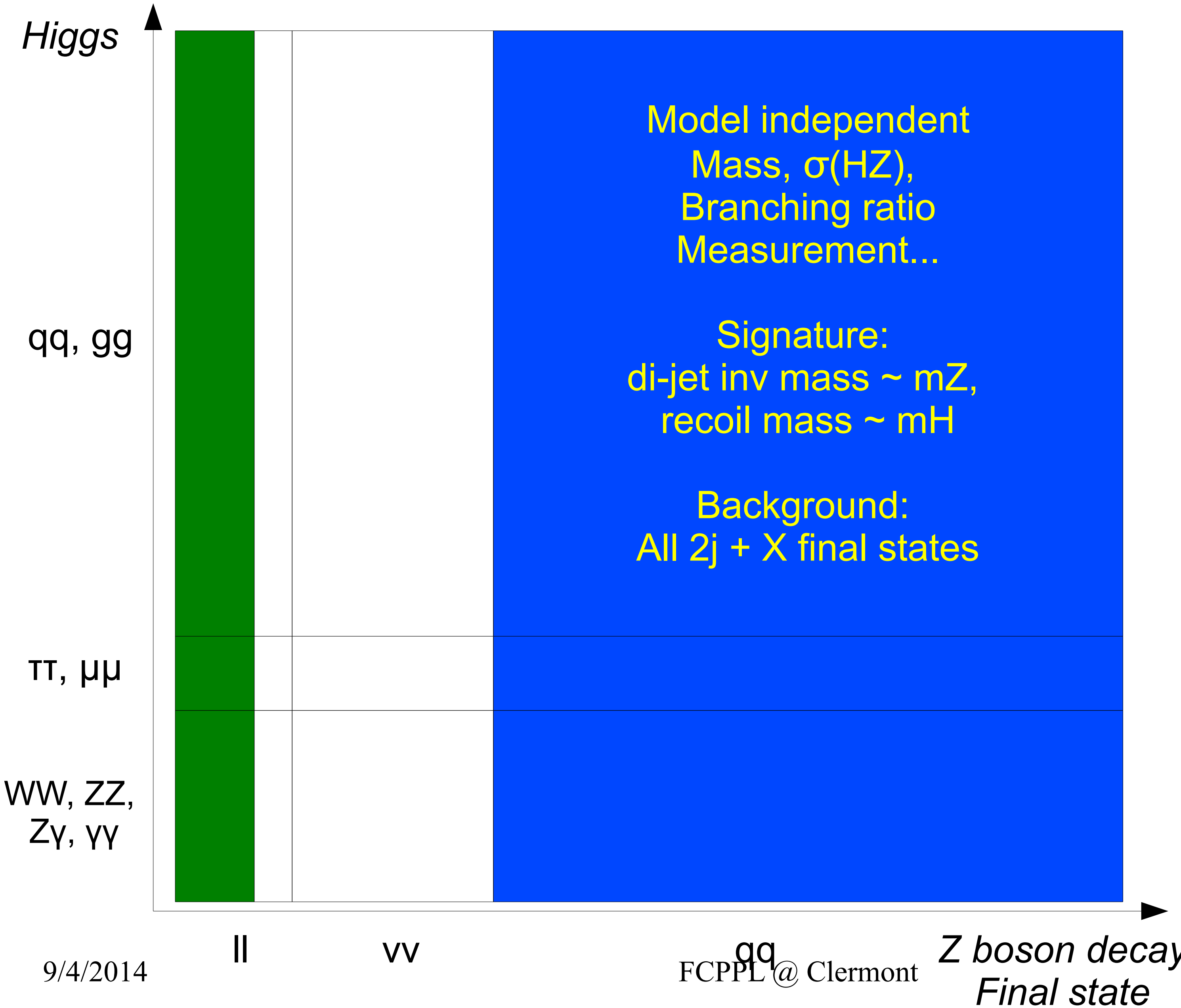
Migration Matrix information Should be used

bb, cc accuracies Should be worse in realistic because of Neutrinos

Trends shall not be Changed after including All above effects

PFA is critical for Br(H→gg, cc) measurement...

Model - independent tagging of ZH

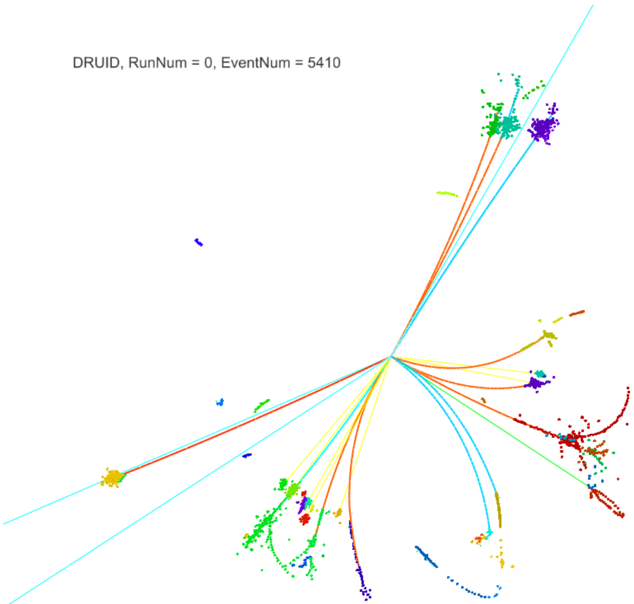


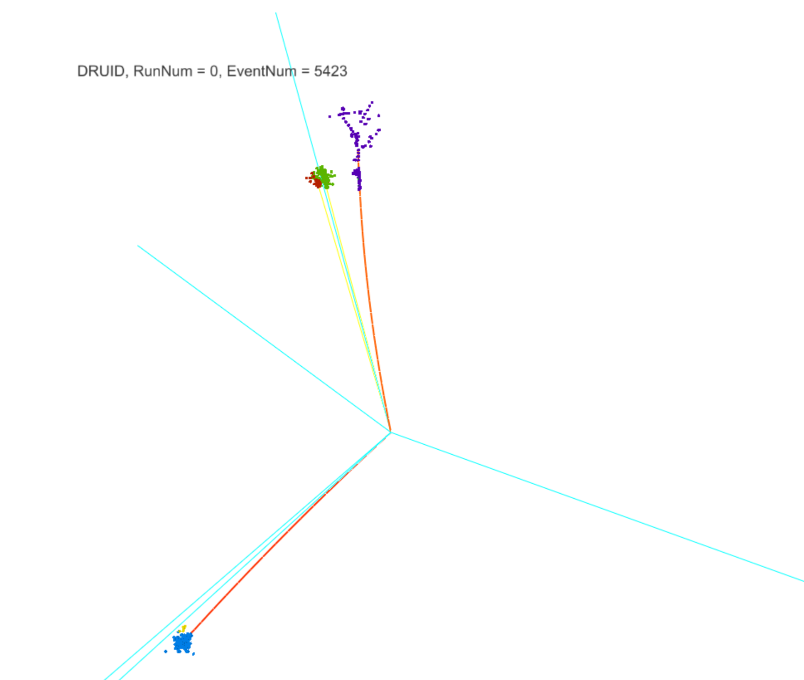
Algorithm:

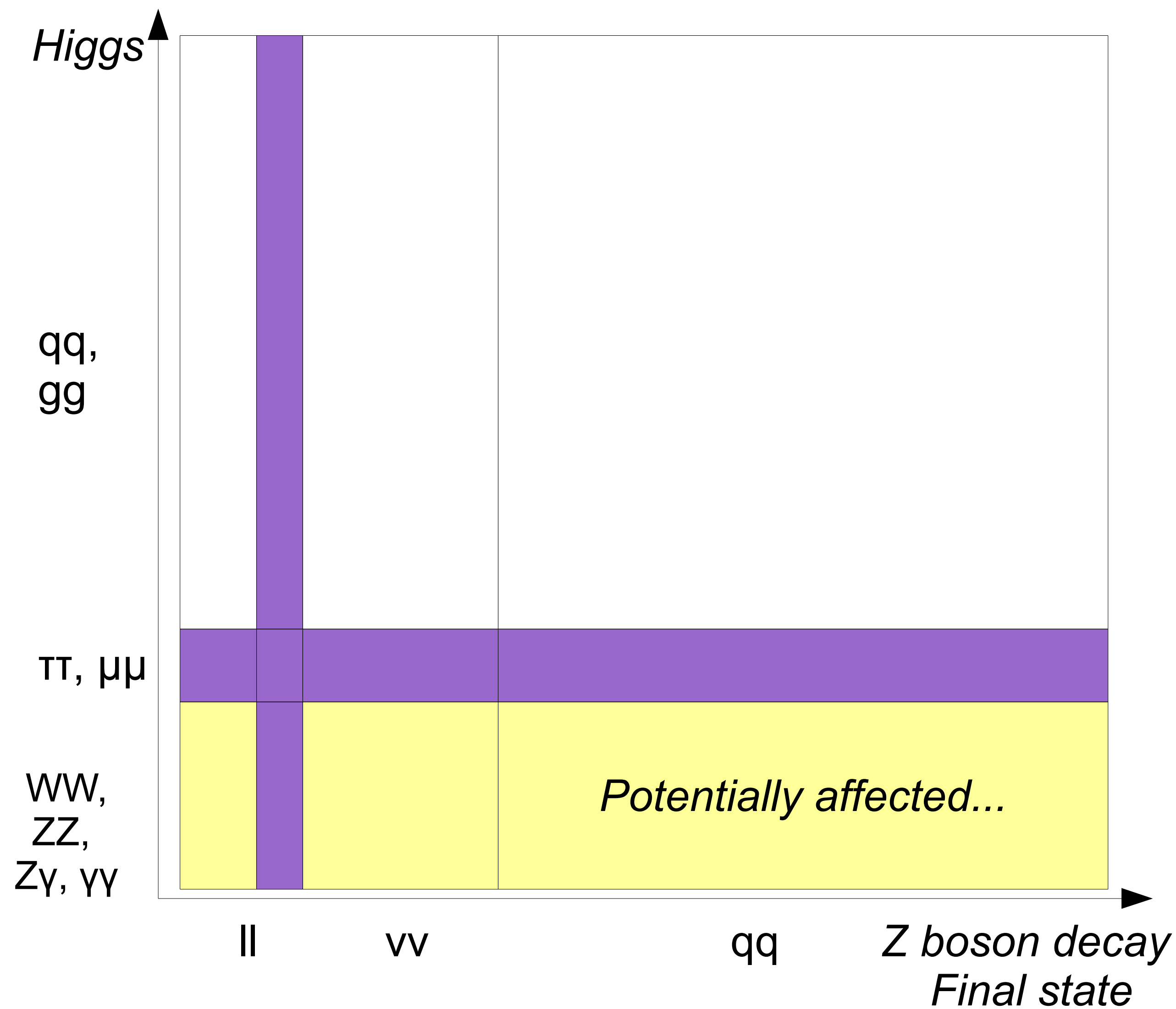
If 2f: calculate
M_inv & M_recoil

If 4f:
Pairing as before,
After pairing,
Define the pair
Closer to mz as Z
pair..

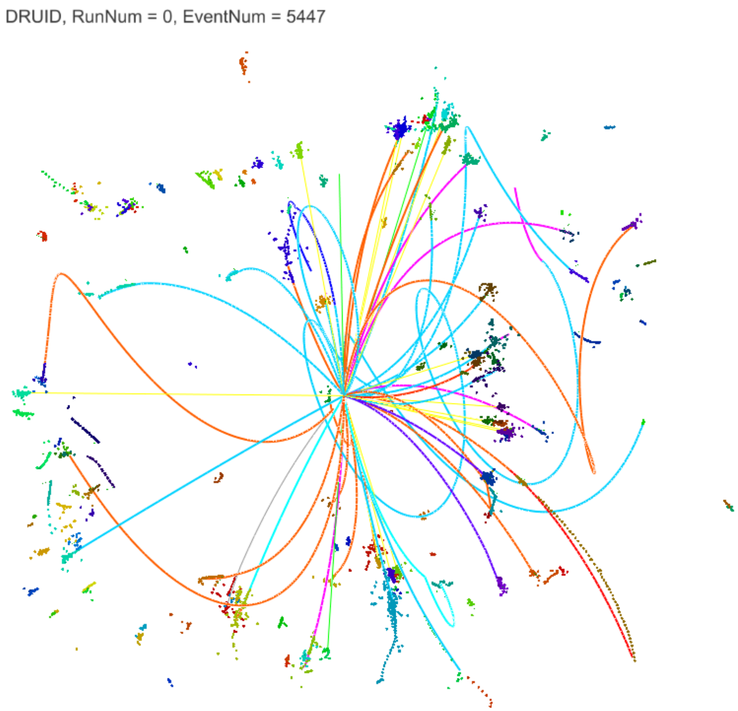
To do: PFA Tau tagging & Reconstruction



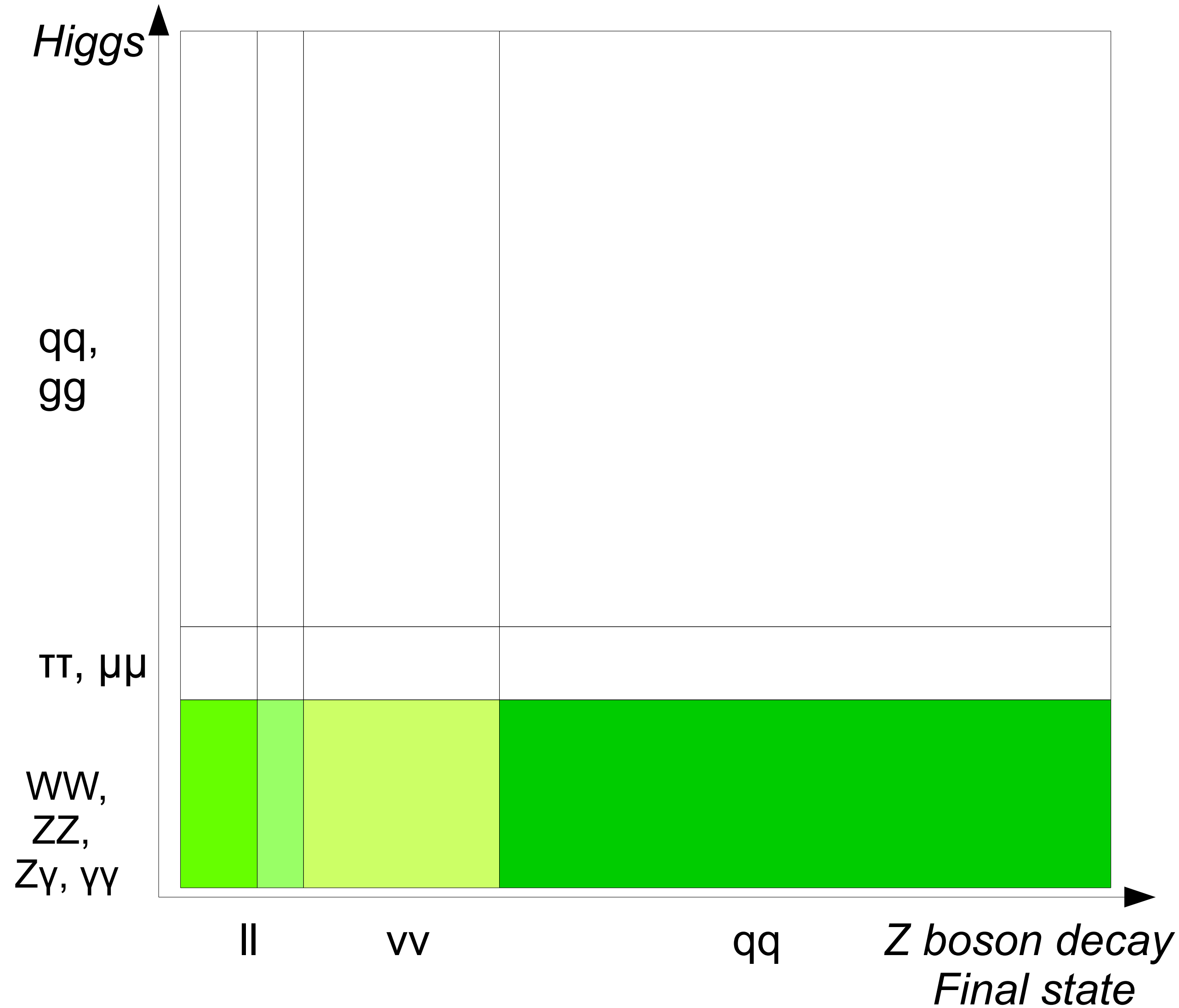




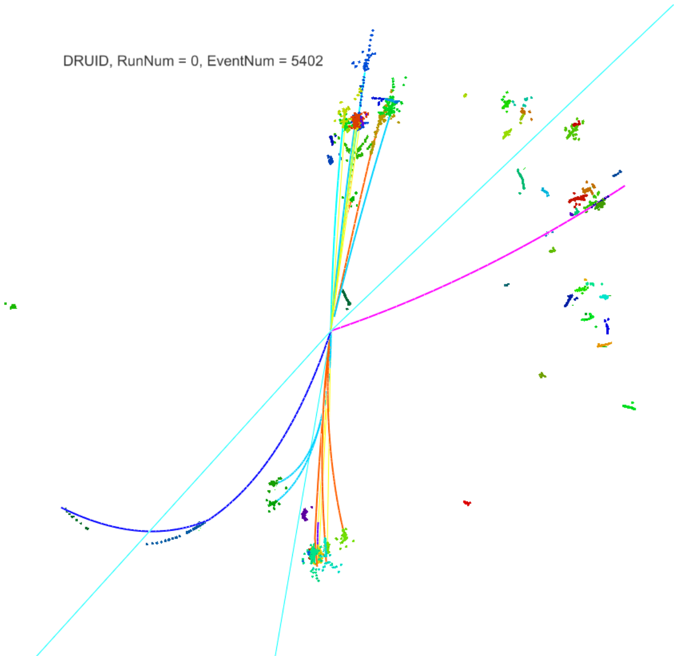
To do: Br(H→WW, ZZ) ~ Width Measurement

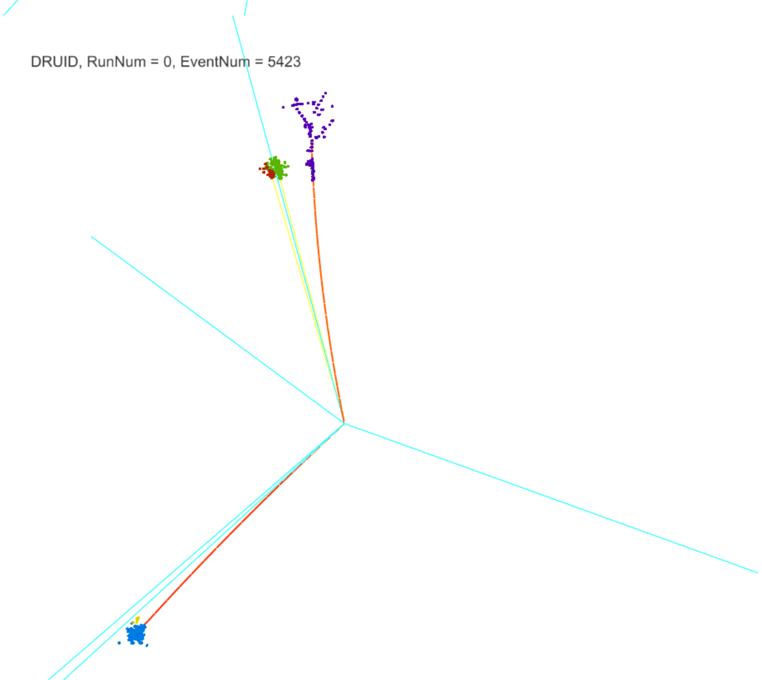


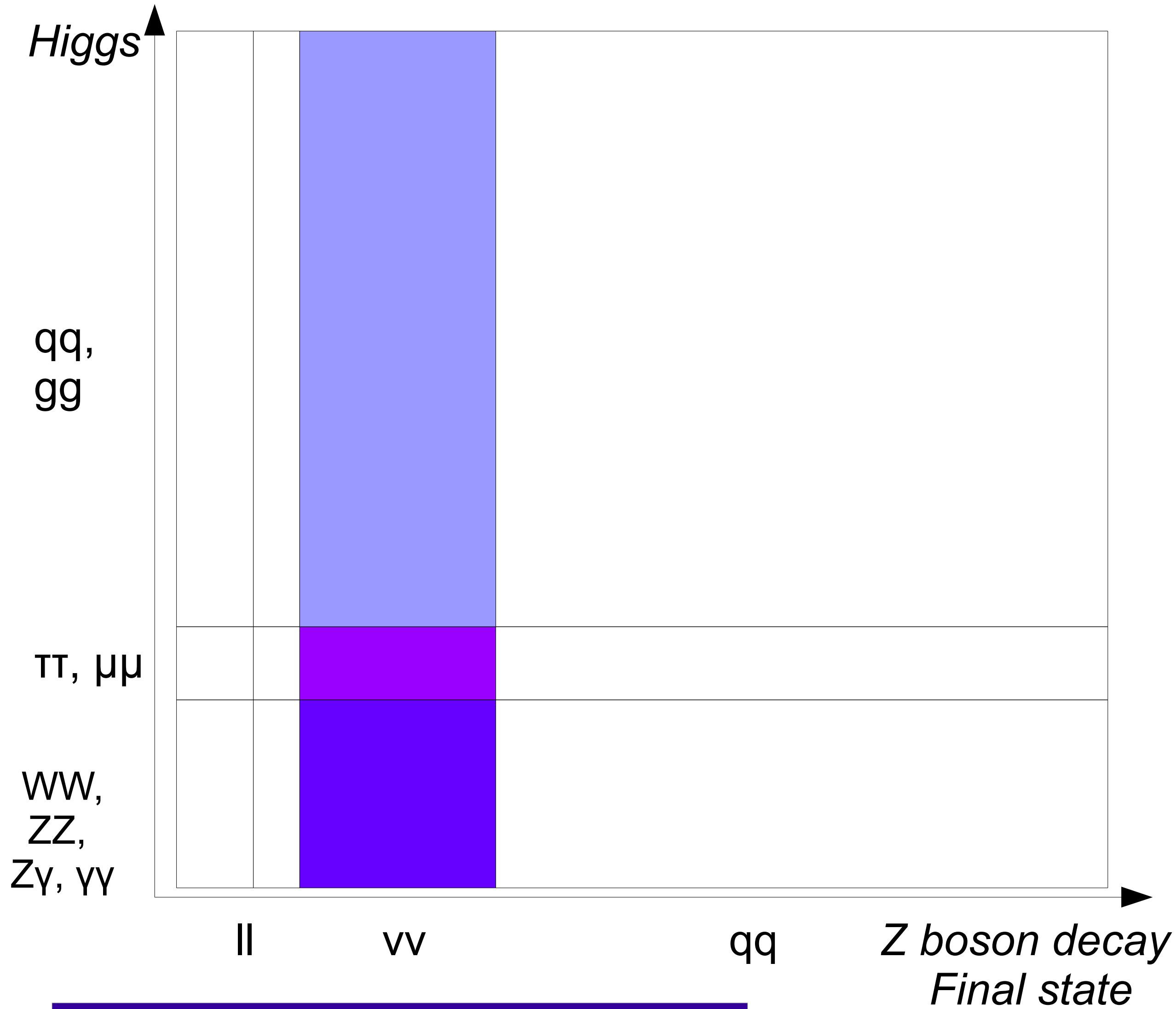
Important,
challenging,
Exciting.



To do: ZH, Z→νν channel

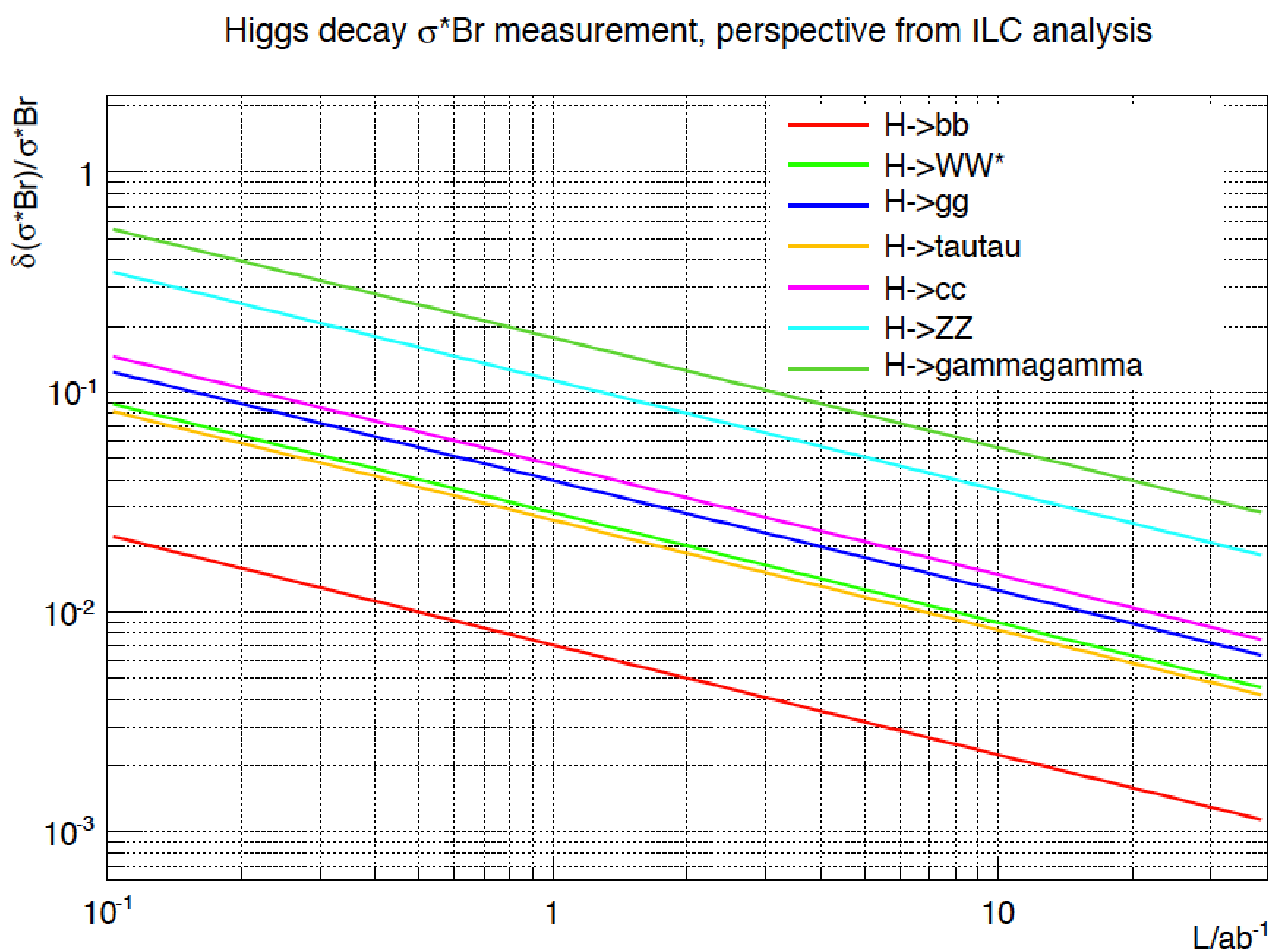






I guess relatively easy...
Test bed for VV event tagging*

Scaled with total luminosity



Frequent communication
With machine group
On beam parameter,
Power consumption
Achievable luminosity

Beam condition:

Luminosity & Beam quality
Machine constrains,
MDI design...