Higgs Measurement at CEPC & its detector

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SM Lagrangian

$$
\begin{aligned}
\mathcal{L} = & -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{8}tr(\mathbf{W}_{\mu\nu}\mathbf{W}^{\mu\nu}) - \frac{1}{2}tr(\mathbf{G}_{\mu\nu}\mathbf{G}^{\mu\nu}) && \text{(U(1), SU(2) and SU(3) gauge terms)} \\
& +(\bar{\nu}_L, \bar{e}_L)\,\tilde{\sigma}^\mu iD_\mu \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} + \bar{e}_R\sigma^\mu iD_\mu e_R + \bar{\nu}_R\sigma^\mu iD_\mu \nu_R + \text{(h.c.)} && \text{(lepton dynamical term)} \\
& -\frac{\sqrt{2}}{v}\left[(\bar{\nu}_L, \bar{e}_L)\,\phi M^e e_R + \bar{e}_R \bar{M}^e \bar{\phi}\begin{pmatrix} \nu_L \\ e_L \end{pmatrix}\right] && \text{(electron, muon, tauon mass term)} \\
& -\frac{\sqrt{2}}{v}\left[(-\bar{e}_L, \bar{\nu}_L)\,\phi^* M^\nu \nu_R + \bar{\nu}_R \bar{M}^\nu \phi^T \begin{pmatrix} -e_L \\ \nu_L \end{pmatrix}\right] && \text{(neutrino mass term)} \\
& +(\bar{u}_L, \bar{d}_L)\,\tilde{\sigma}^\mu iD_\mu \begin{pmatrix} u_L \\ d_L \end{pmatrix} + \bar{u}_R\sigma^\mu iD_\mu u_R + \bar{d}_R\sigma^\mu iD_\mu d_R + \text{(h.c.)} && \text{(quark dynamical term)} \\
& -\frac{\sqrt{2}}{v}\left[(\bar{u}_L, \bar{d}_L)\,\phi M^d d_R + \bar{d}_R \bar{M}^d \bar{\phi}\begin{pmatrix} u_L \\ d_L \end{pmatrix}\right] && \text{(down, strange, bottom mass term)} \\
& -\frac{\sqrt{2}}{v}\left[(-\bar{d}_L, \bar{u}_L)\,\phi^* M^u u_R + \bar{u}_R \bar{M}^u \phi^T \begin{pmatrix} -d_L \\ u_L \end{pmatrix}\right] && \text{(up, charmed, top mass term)} \\
& +\overline{(D_\mu\phi)}D^\mu\phi - m_h^2[\bar{\phi}\phi - v^2/2]^2/2v^2. && \text{(Higgs dynamical and mass term)} \quad (1)
\end{aligned}
$$

Higgs

- 9 fermion masses (+ 3 m_ν)
- 3 CKM mixing angles + 1 phase (+ 3+1 for $m_\nu \neq 0$)
- 1 electromagnetic coupling constant α
- 1 strong coupling constant α_s
- 1 weak coupling constant $G_F = 1.16637(1) \times 10^{-5}$ GeV^{-2}
- 1 Z^0 mass $m_Z = 91.1876(21)$ GeV/c^2
- 1 Higgs mass

Only scalar particle in SM

Most free SM parameters

MANY theoretical difficulties

Higgs, the focus, the gate

The KEY: e^+e^- Higgs factory

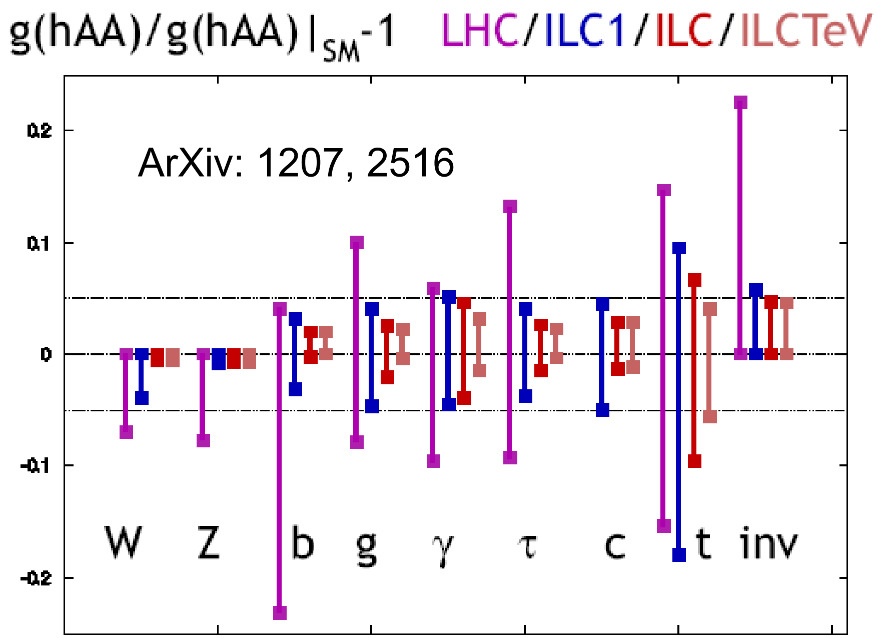
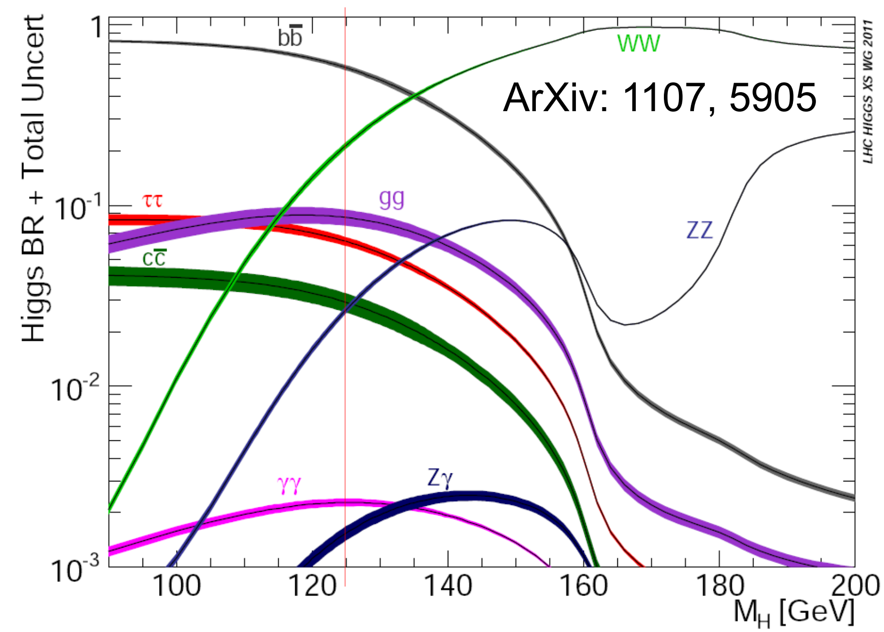


Figure 2: Comparison of the capabilities of LHC and ILC for model-independent measurements of Higgs boson couplings. The plot shows (from left to right in each set of error bars) 1 σ confidence intervals for LHC at 14 TeV with 300 fb^{-1}, for ILC at 250 GeV and 250 fb^{-1} ('ILC1'), for the full ILC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

标准模型 Higgs 衰变分支比



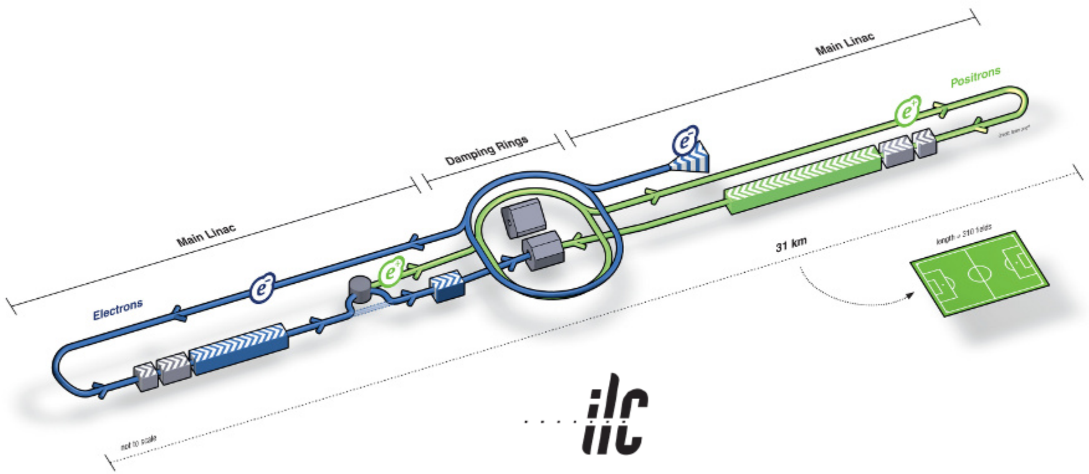
Bb: 58%; WW, 21%; gg, 9%; ττ, 6%; cc, 3%; ZZ + others, 3%

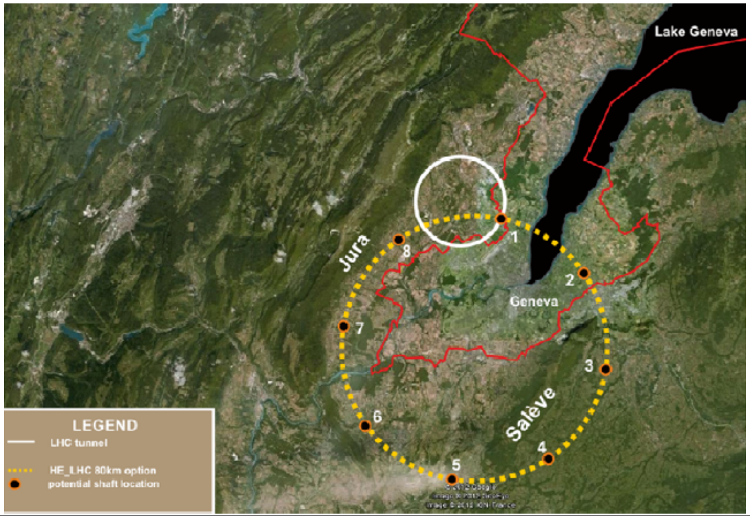
Higgs couplings must be measured to at least 10% to reveal TeV scale new physics

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

LHC: high productivity, no tagging signal, huge backgrounds & systematics.
Ultimate precision in Higgs coupling limited to ~ 10 - 20%
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, LEP3, TLEP..., **CEPC**)

Higgs factory: Linear or Circular





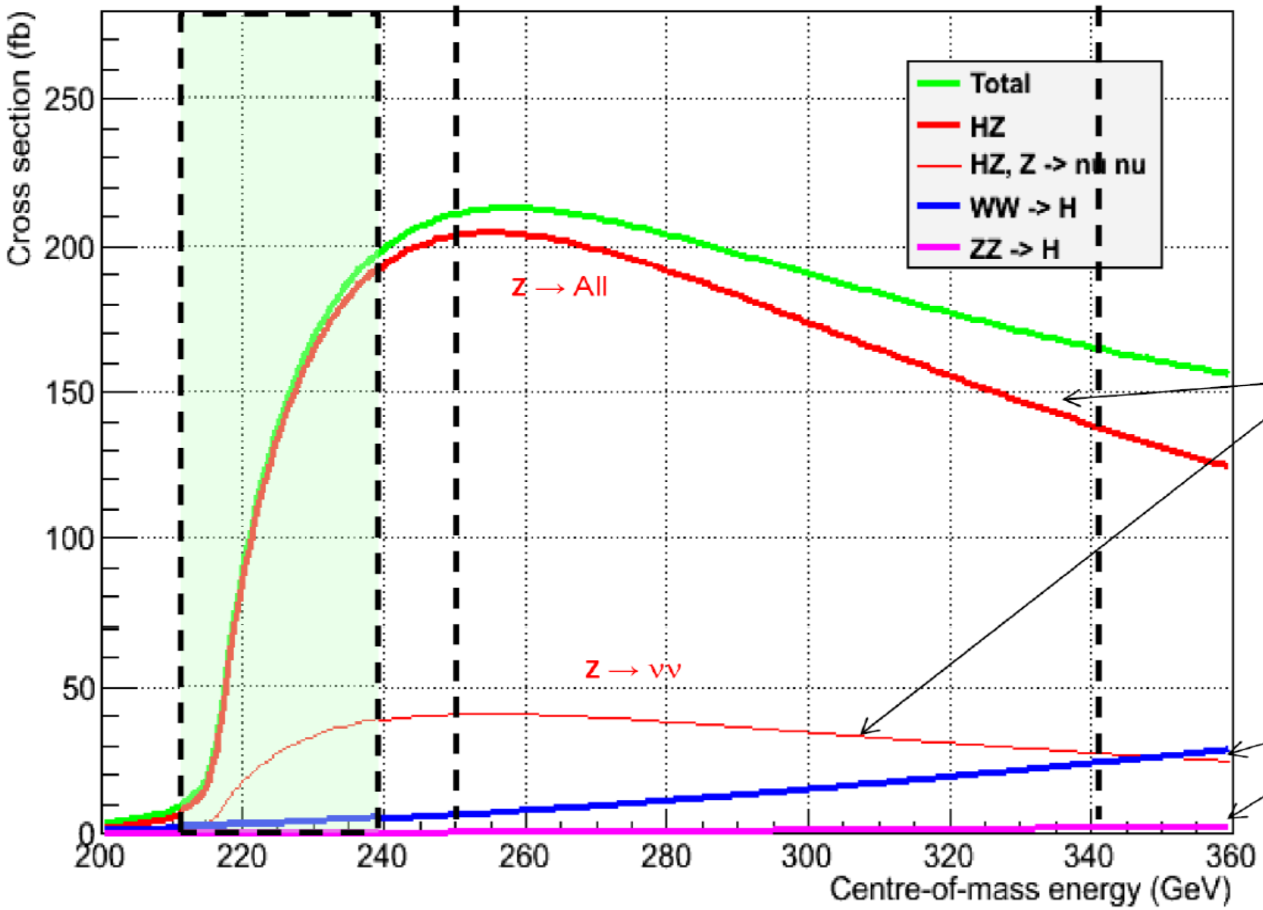
	Linear: ILC, CLIC	Circular: CEPC, TLEP
Pro	Center of mass energy can be upgraded to 1-3 TeV Longitudinal polarized beam Power pulsed detector	Cost-efficient, mature technology Multiple interaction point High luminosity & beam quality
Con	Expensive (∼ 8 – 10 B euros) Single interaction point, might need 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

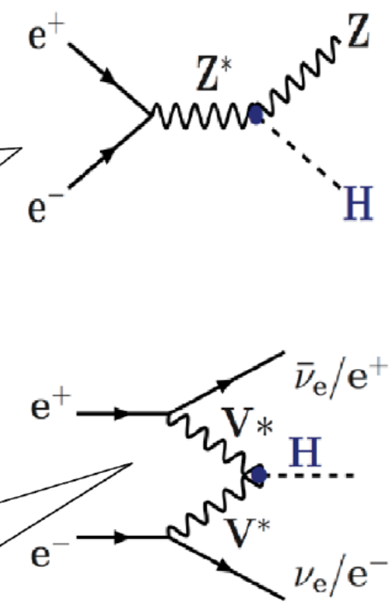
Muon & photon colliders are also possible Higgs factories, but...

CEPC

- Circular machine with total length 50-70 km
- Luminosity: 10^{34} $cm^{-2}s^{-1}$ $\sim$ $100fb^{-1}/y$ at 1 IP
- Site power: ~ o(100) MW
- High beam quality: beam energy spread, low beamstrahlung...
- State of Art

Higgs productivity at e^+e^- machine





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

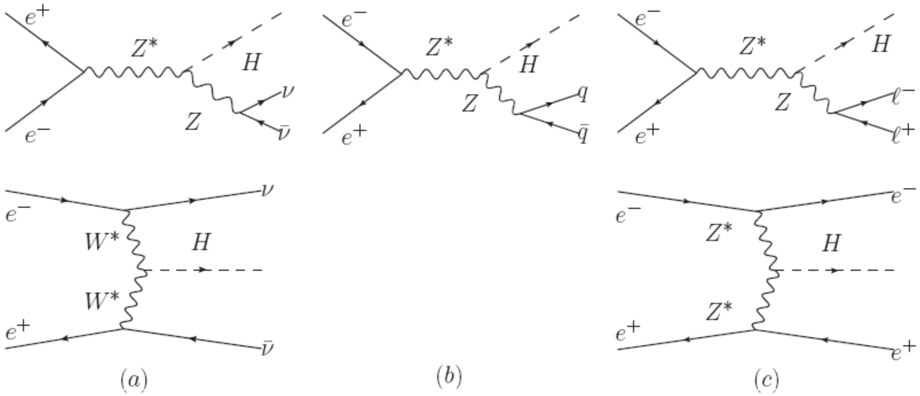
L ～ 10^{34} $cm^{-2}s^{-1}$ ～ $100fb^{-1}$/y： Nominal luminosity $500fb^{-1}$ ~ 10^5 Higgs/IP

Benchmark: 100 k Higgs, but can be (largely) increased

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

CEPC: 8 + 2 measurements for SM higgs

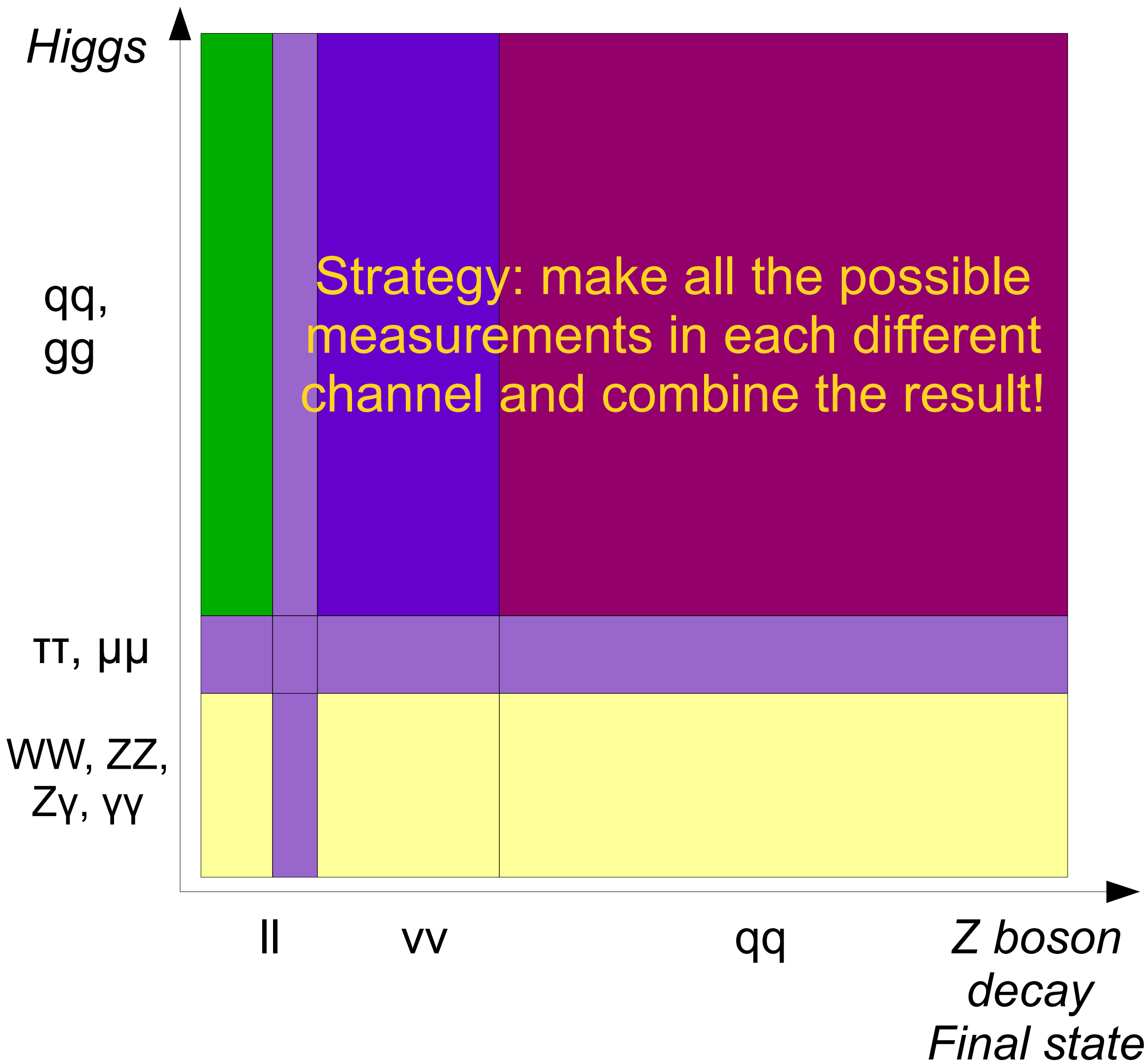
- Mass, spin, total cross section
- Branching ratios (b, c, tau, g, W)
- Branching ratios (gamma, mu)
- Calculate: width – coupling
- Other measurements, SM & exotics...



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)

ZH event: requirement on detector and critical algorithms



Vertex: Flavor tagging, tau tagging;

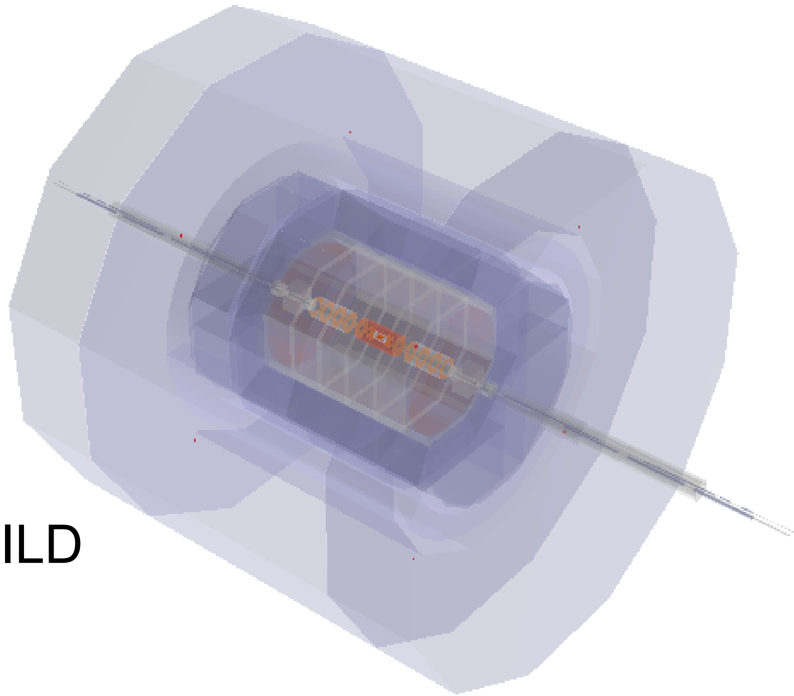
Tracker: momentum measurement of charged particle;

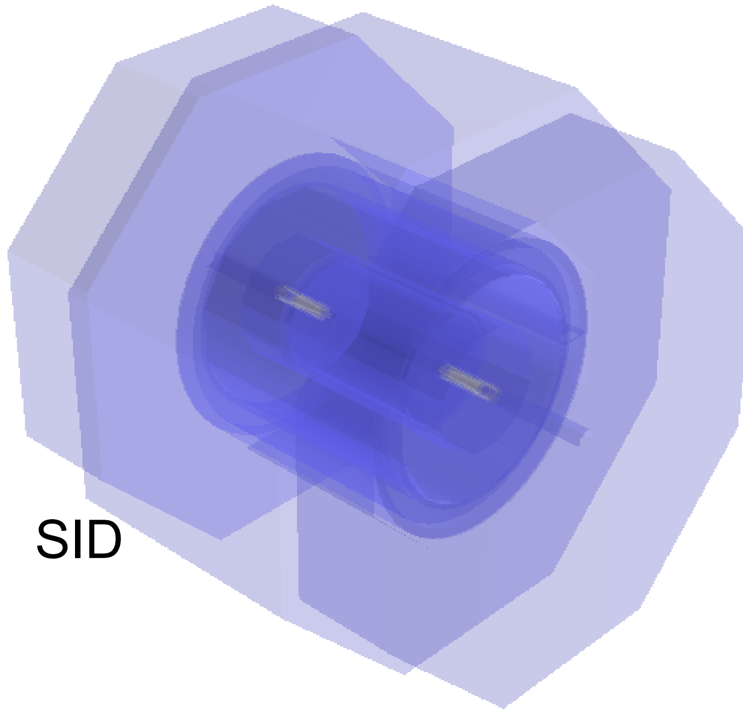
Calorimeter:
Particle Flow Algorithm(PFA): separation/ reconstruction of particle showers,
PID – lepton tagging,
Jet/Missing energy measurements;

Critical algorithms:
H→2 jets: Flavor tagging
H→2 taus: Tau tagging
H→ZZ*, WW*: VV* events tagging

Reference detectors: ILD, CMS,...

PFA Oriented LC detectors





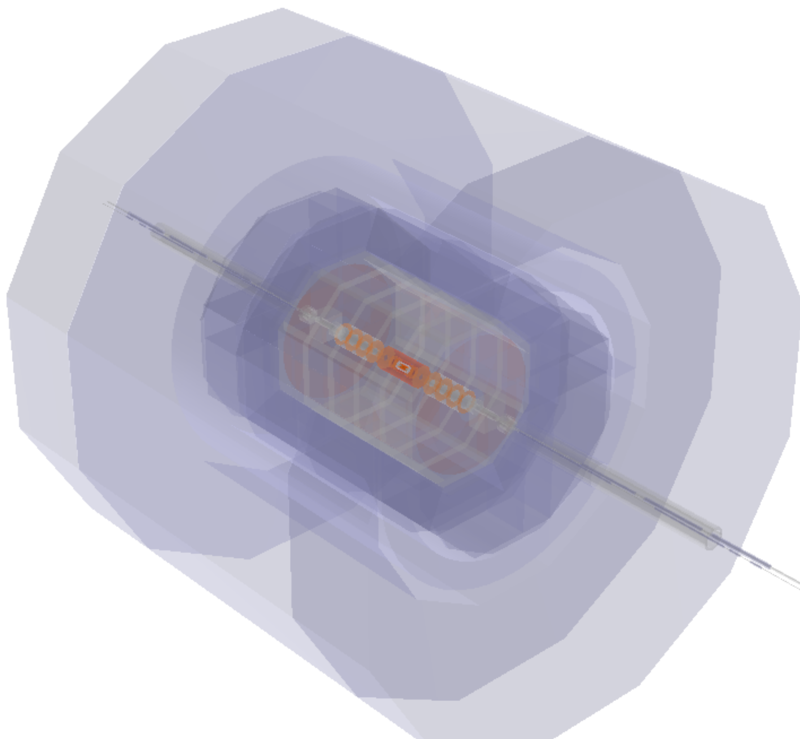
- PFA: Jet energy resolution
  less confusion ~ good separation ~ high granularity
  Granularity > Energy Resolution for the Calorimetry...

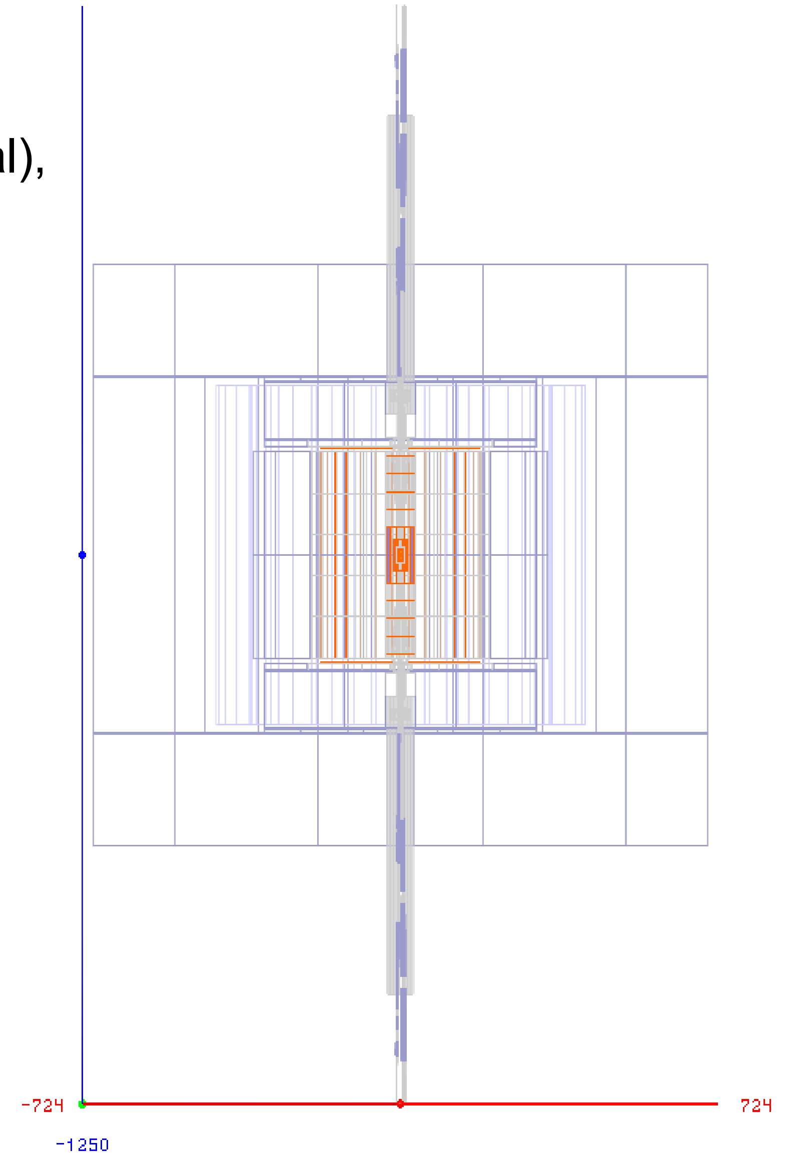
- PFA Oriented detector (both have ILC/CLIC Versions):
  - ILD (European + Asia, International Large Detector): TPC (+ Silicon inner detectors) tracking with B = 3.5T
  - SiD (US, Silicon Detector): Silicon tracking with B = 5T

Reference detector for CEPC: ILD

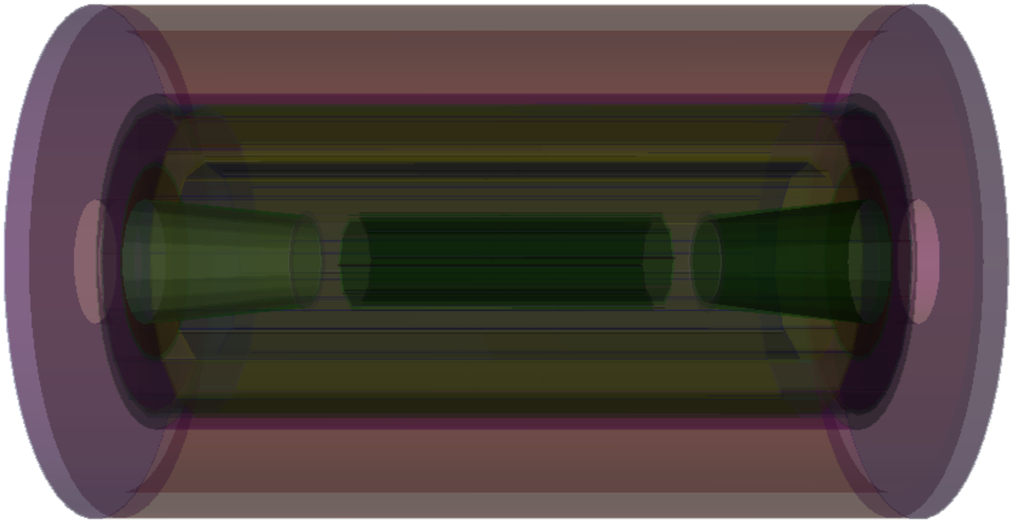
Scale: half_Z: 12.5/6.62 meter, radius 7.24 meter

Sub detectors: VTX, SIT, FTD, TPC, SET/ETD(optional),
Ecal, Hcal, Coil, Muon

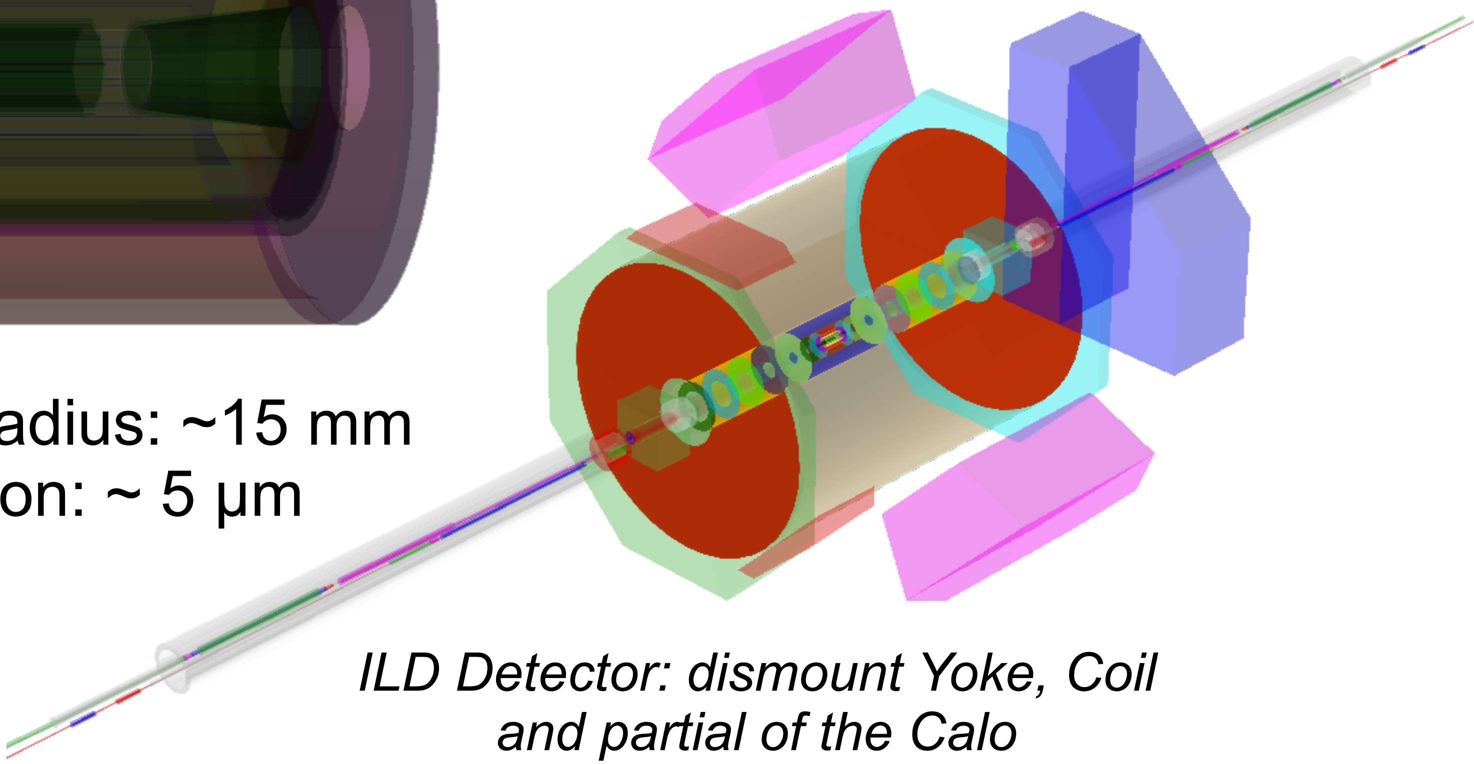




Vertex detector

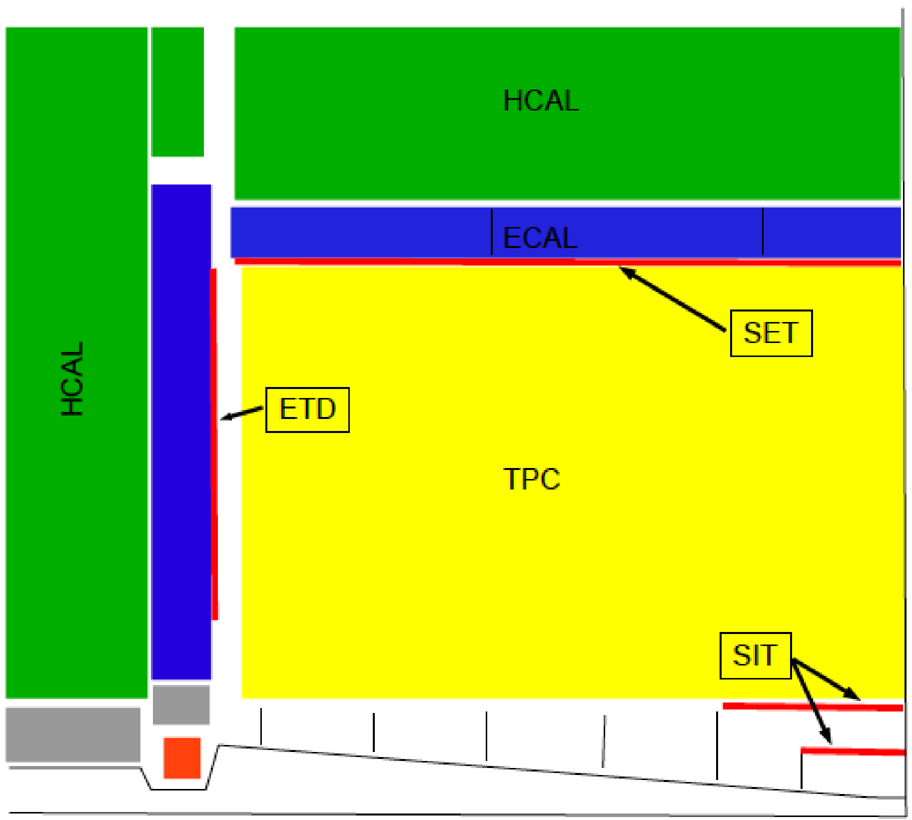


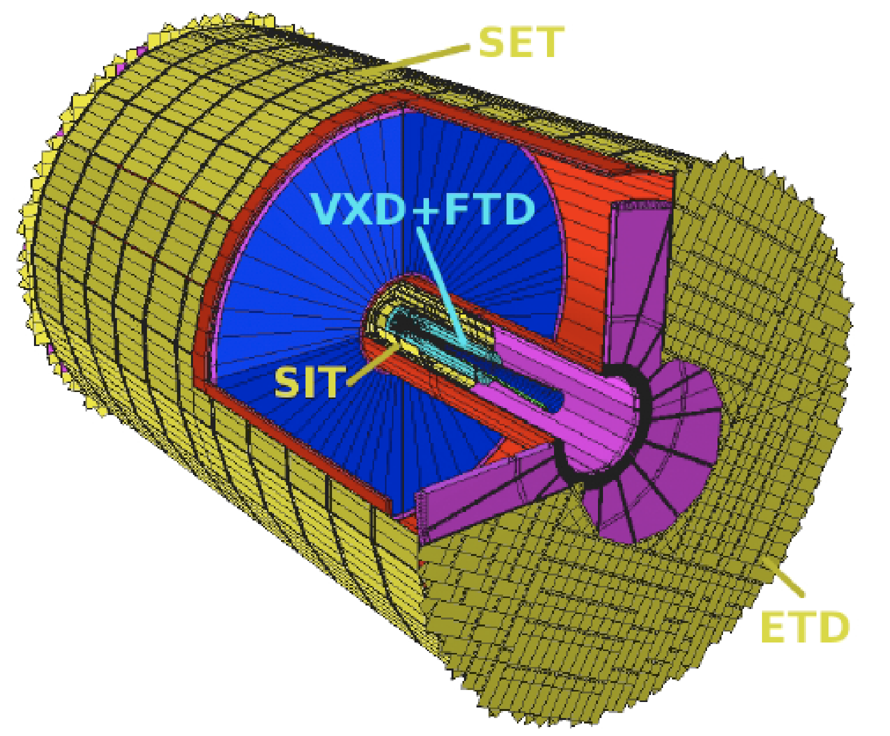
Inner most layer Radius: ~15 mm
Spatial resolution: ~ 5 μm



ILD Detector: dismount Yoke, Coil and partial of the Calo

Silicon Tracking at ILD





- Massive usage of silicon pixel/strips in the tracking system & VTX: ensures good accuracy in Impact parameter & momentum measurement

ILD Main Tracker: TPC

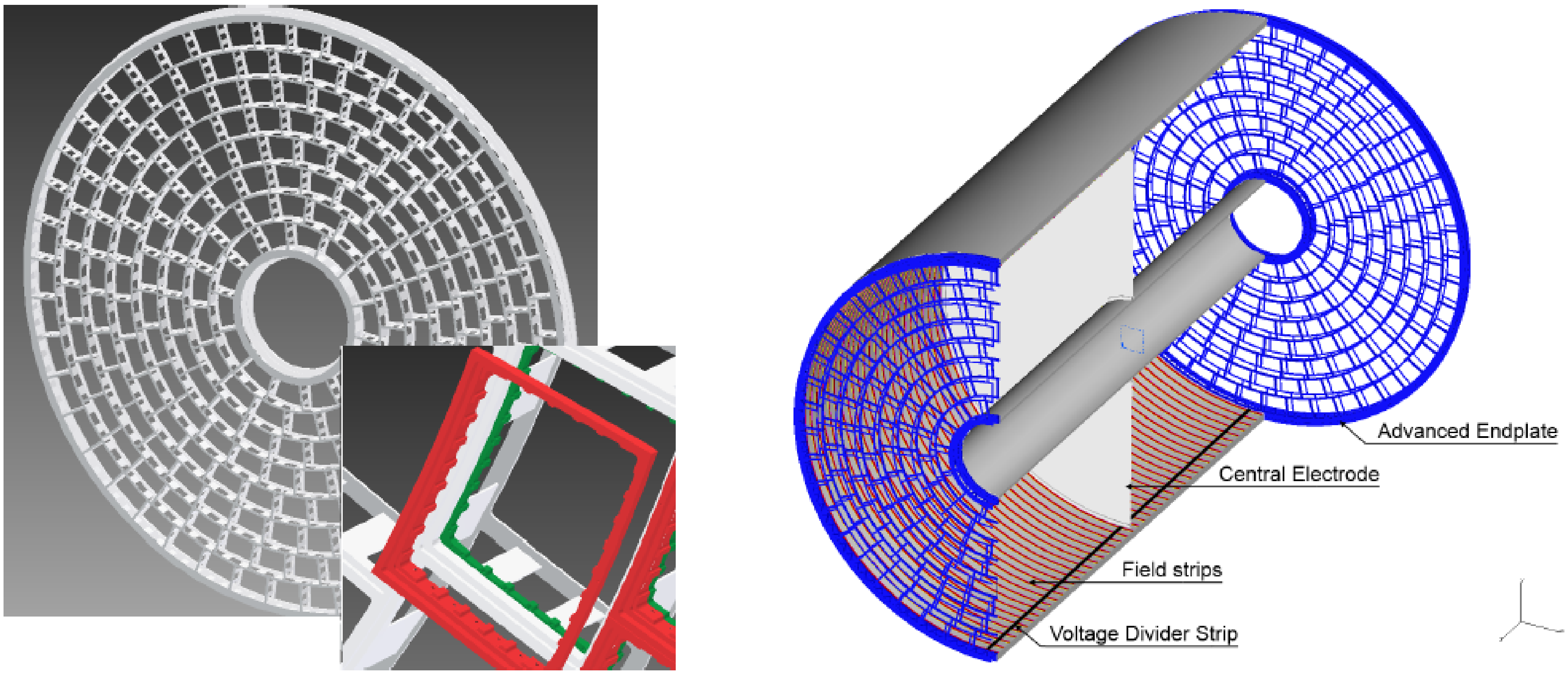
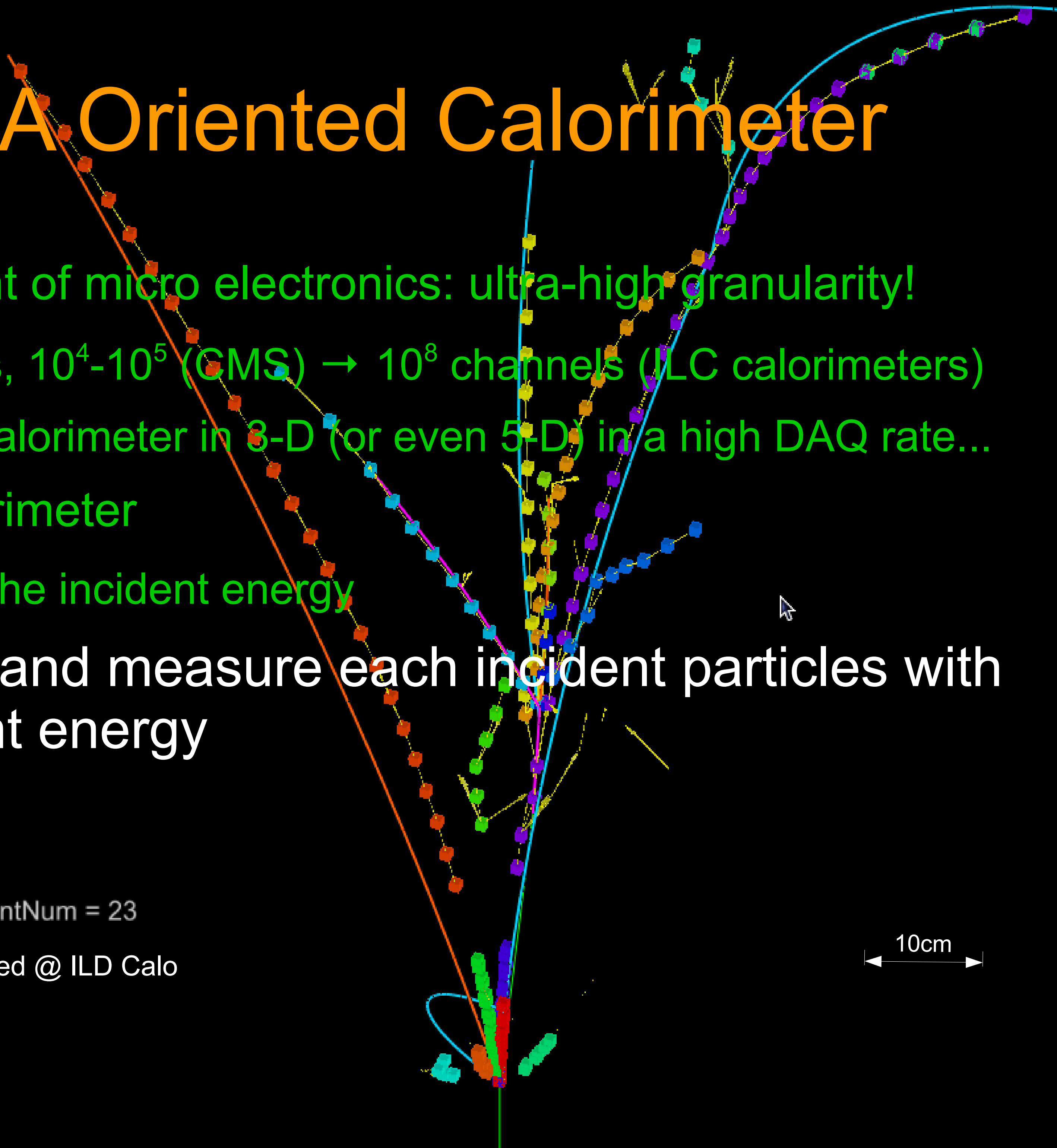


Figure III-2.11. Left: Drawing of the proposed end-plate for the TPC. In the insert a backframe which is supporting the actual readout module, is shown. Right: Conceptual sketch of the TPC system showing the main parts of the TPC (not to scale).

PFA Oriented Calorimeter

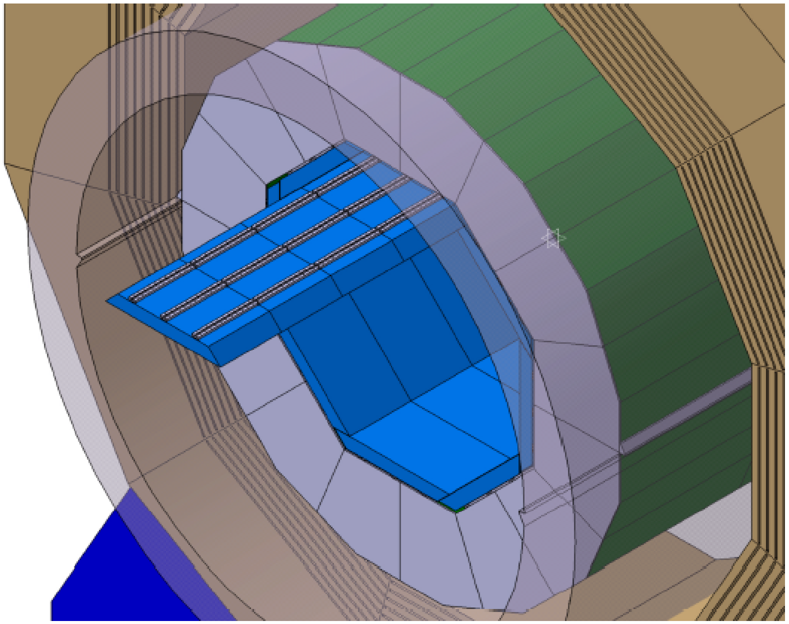
- Development of micro electronics: ultra-high granularity!
  - #channels, 10^4-10^5 (CMS) → 10^8 channels (ILC calorimeters)
  - Imaging calorimeter in 3-D (or even 5-D) in a high DAQ rate...
- Role of calorimeter
  - Measure the incident energy
  - Identify and measure each incident particles with sufficient energy

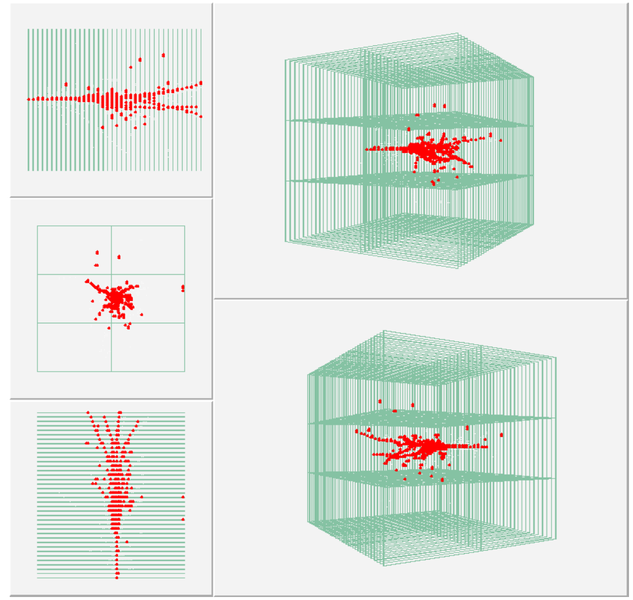


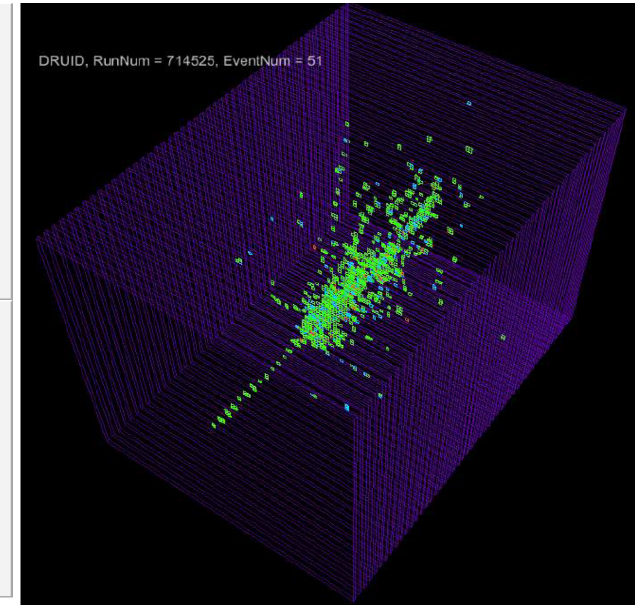
DRUID, RunNum = 0, EventNum = 23

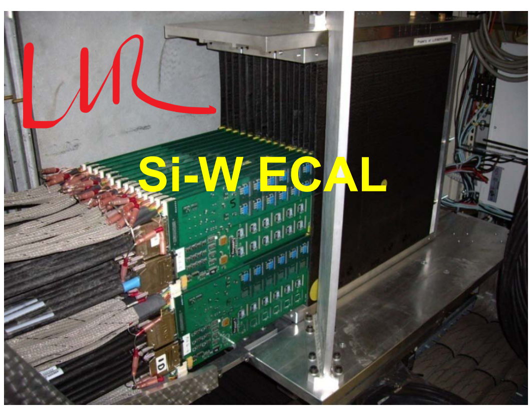
20 GeV Klong reconstructed @ ILD Calo

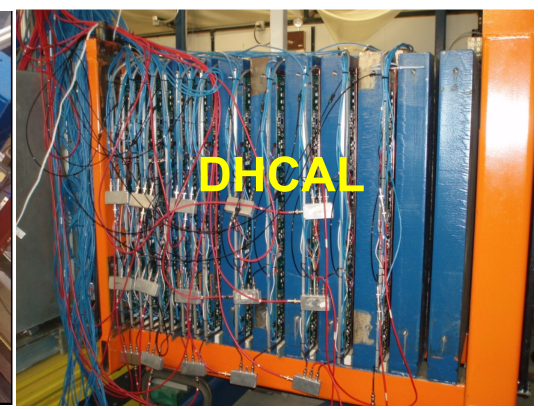
Calorimeter R&D for ILD







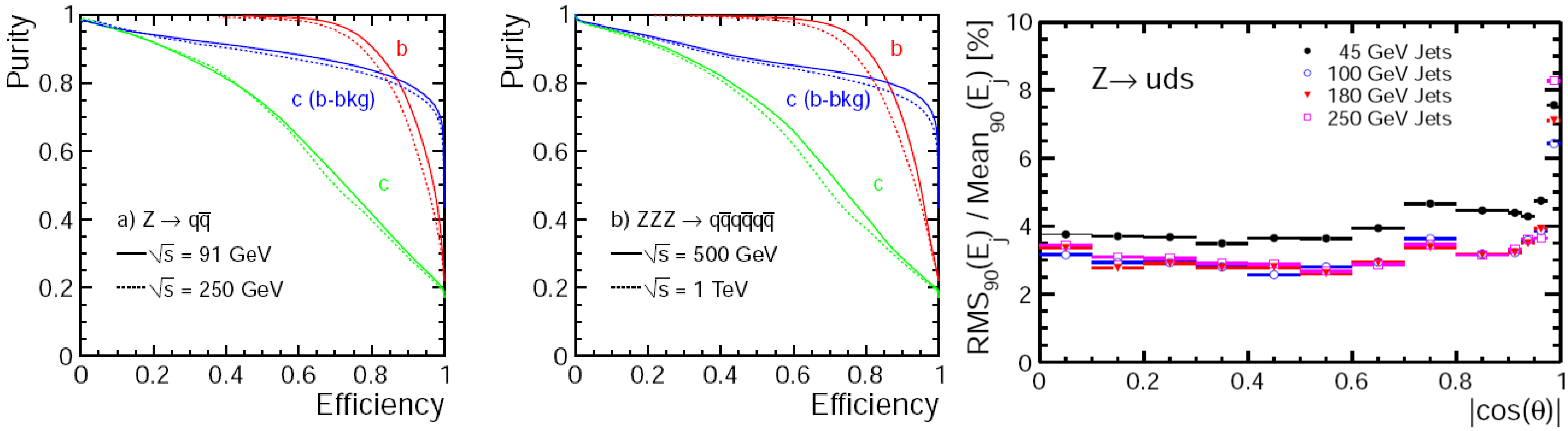




Ultra high granularity ~ 1 channel cm^{-3}. 3d, 4d or 5d image...

ILD Performance

b Vs udsc; c Vs b; c Vs udsb

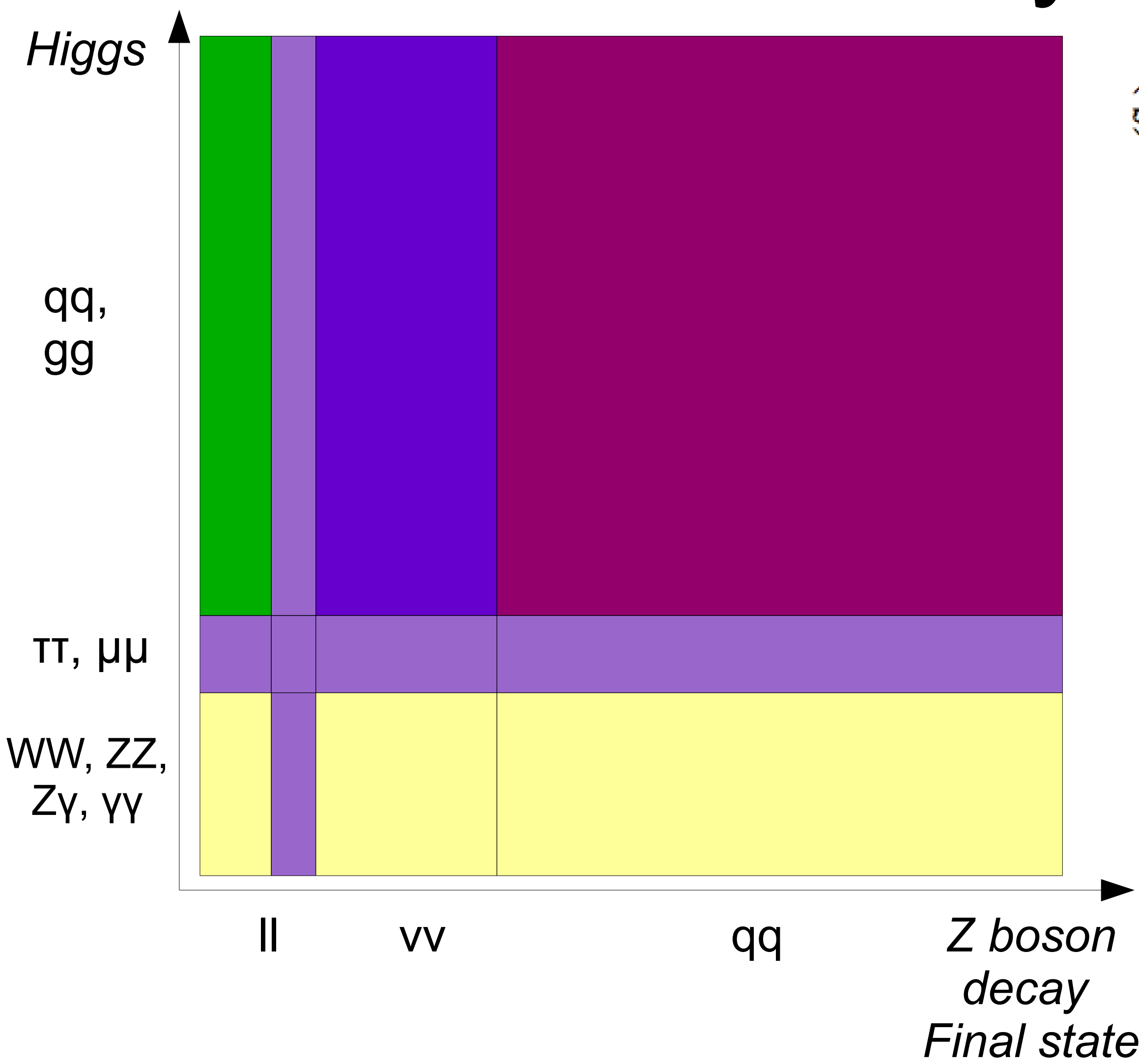


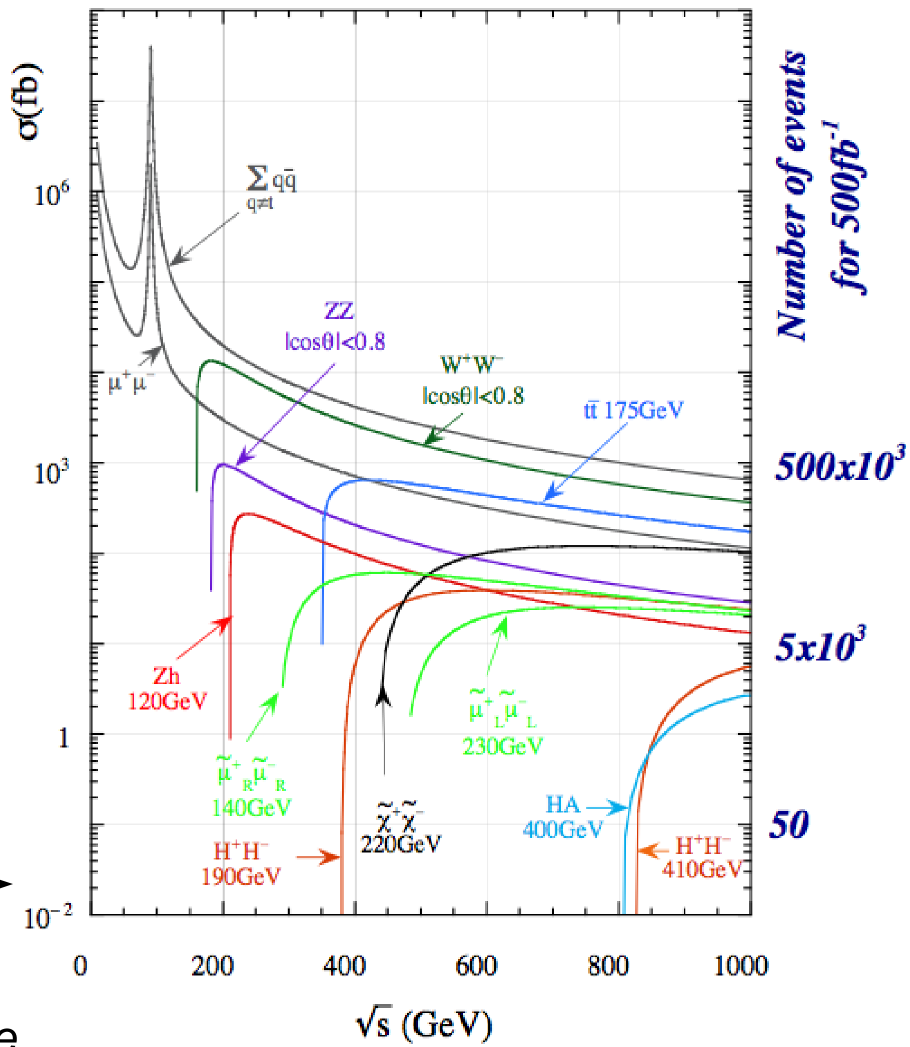
Flavor tagging: eff = 80%, purity > 90% for b-tagging (Impact parameter resolution ~ 5 μm)
Algorithm: LCFIPlus, Tokyo University (Tomohiko Tanabe)

Tracking: $\delta(1/P_T) \sim 2\text{-}5 \times 10^{-5}$(1/GeV)
Algorithm: Clupatra, DESY (Frank Gaede); KalTest, KEK (Keisuke Fujii), etc

PFA： $\delta E_J/E$ = 3 - 4%
Algorithm: PandoraPFA, Cambridge (Mark Thomson); Arbor, LLR & IHEP(Manqi, Henri)

Higgs Measurement: Physics Analysis



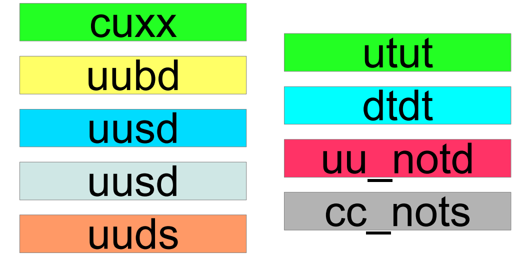


Main background: WW, **ZZ**, qq/ll, Single W, Single Z...

All 4-fermion back grounds

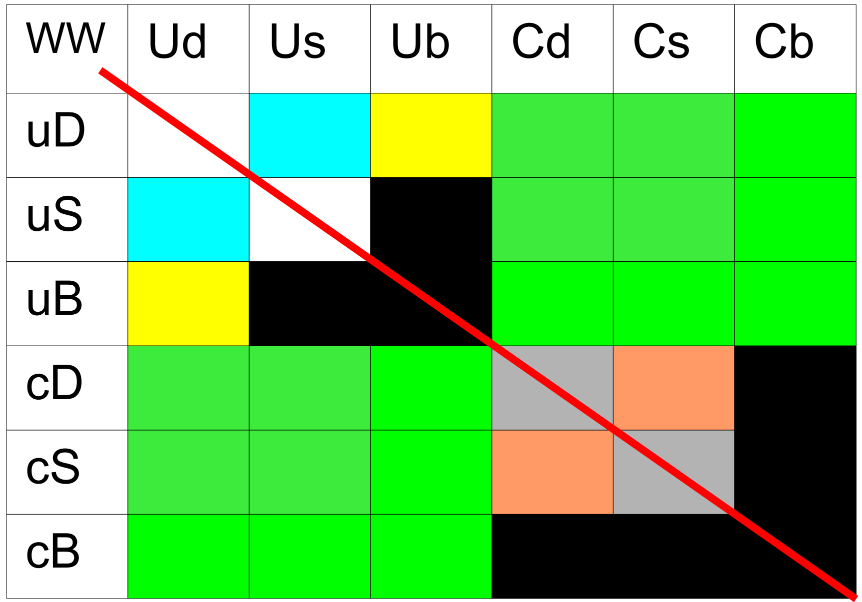
Type	ID	LL (n)	LR (n+1)	RL (n + 3)	RR (n+2)	non-pol	Final states
sw_l	6585-88	40	3335	29.1	40	861	$\nu_e e \nu_l l$ (l:μ,τ)
sw_sl	6563-66	119.7	10000	85.6	119.3	2581.2	ν_eeUD
sze_l	6555-58	1009.6	1084.1	1019.5	1008.4	1030.4	eell(l:μ,τ) ee$\nu_l\nu_l$
sze_sl	6559-62	259.8	459.1	316.5	259.0	323.6	eeUU, DD
szeorsw_l	6567-70	27.7	922.1	21.6	27.6	249.8	ee$\nu_e\nu_e$
sznu_l	6589(LR)-90		192.8	39.3		58.0	$\nu_e\nu_e$ll, (l:μ,τ)
sznu_sl	6571-72		456.8	130.8		146.9	$\nu_e\nu_e$UU, DD
ww_h	6551-52		14874.3	136.4		3752.7	
ww_l	6581-82		1564.2	14.7		394.7	$\nu_\mu \mu \nu_\tau \tau$
ww_sl	6577-78		18781.0	172.7		4738.4	UDν_ll (l:μ,τ)
zz_h	6573-74		1402.1	605.0		501.8	
zz_l	6579-80		158.0	99.5		64.4	2l2l (l:μ,τ) 2l'2ν_l,
zz_sl	6575-76		1422.1	713.5		533.9	
zzorww_h	6553-54		12383.3	224.8		3152.0	
zzorww_l	6721-22		1636.0	54.0		422.5	2l2ν_l (l:μ,τ)

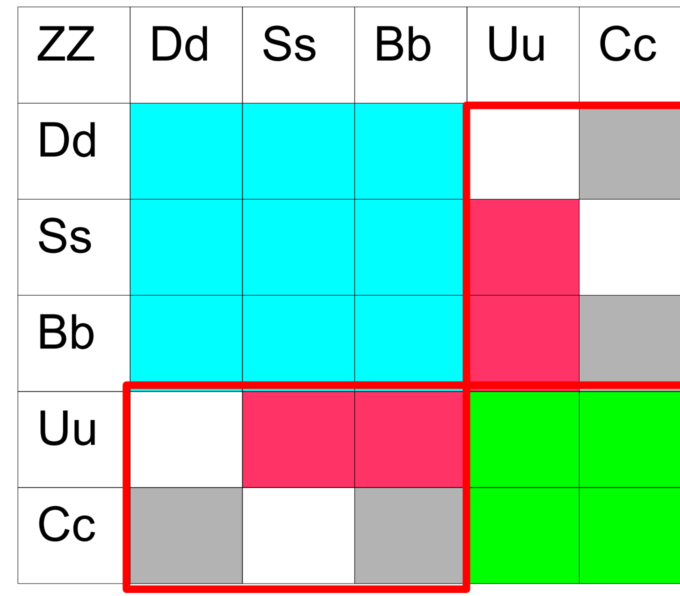
Background: WW & ZZ, hadronic



Single W:

	V	Br
Ud	~ 0.974 ~	0.475
Us	~ 0.225 ~	0.025
Ub	~ 0.004 ~	0
Cd	~ 0.23 ~	0.025
Cs	~ 1.006 ~	0.475
Cb	~ 0.04 ~	7e-4





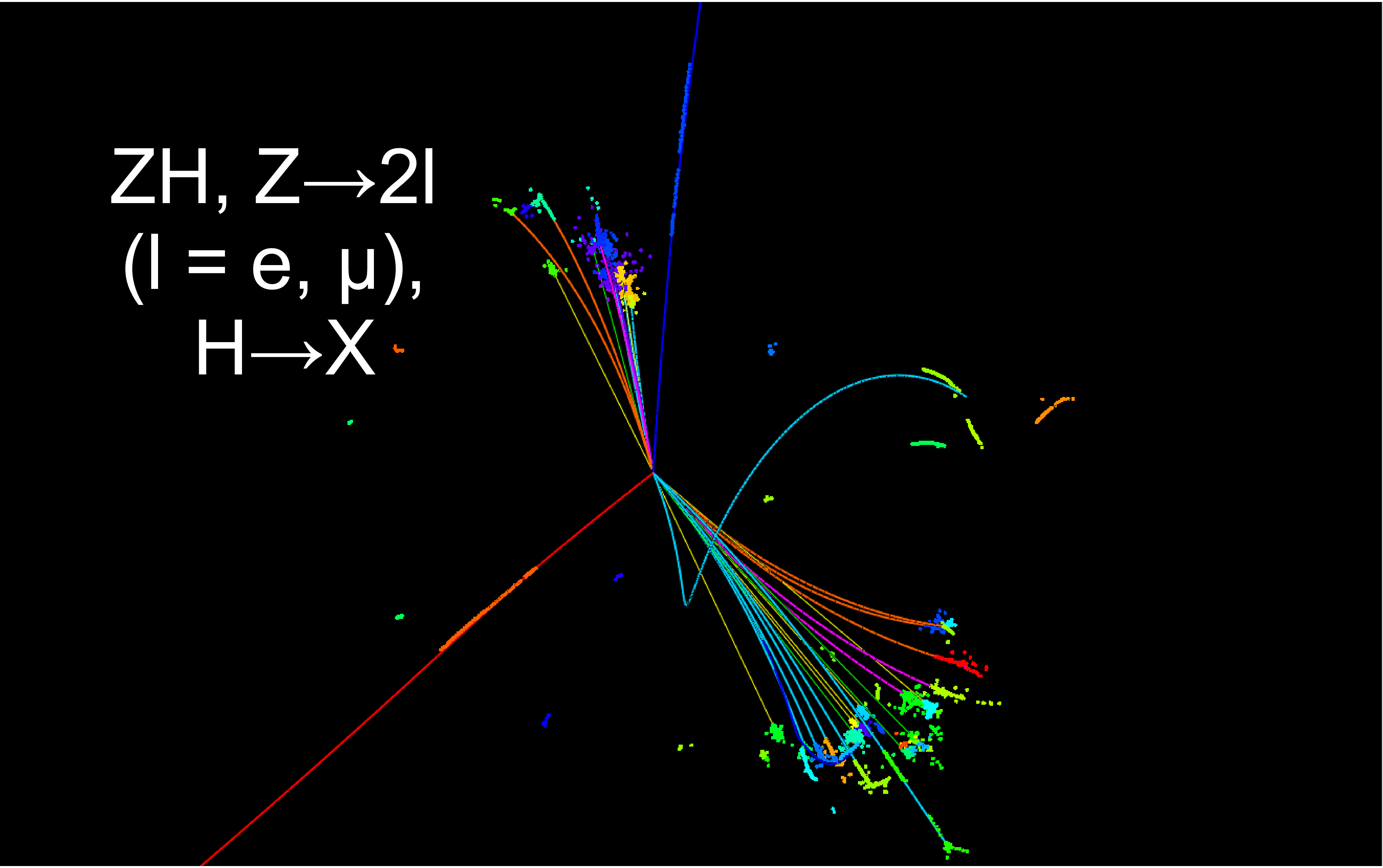
Single Z:
Uu ~ 15%
Dd ~ 12%

Xsec/fb	LL	LR	RL	RR	Non-pola/evts at 500 fb^{-1}
ww_h		14874	136.4		3752 fb ~ 1.87 M
zz_h		1402	604		502 fb ~ 250 k
zzorww_h		12383	225		3152 fb ~ 1.58 M

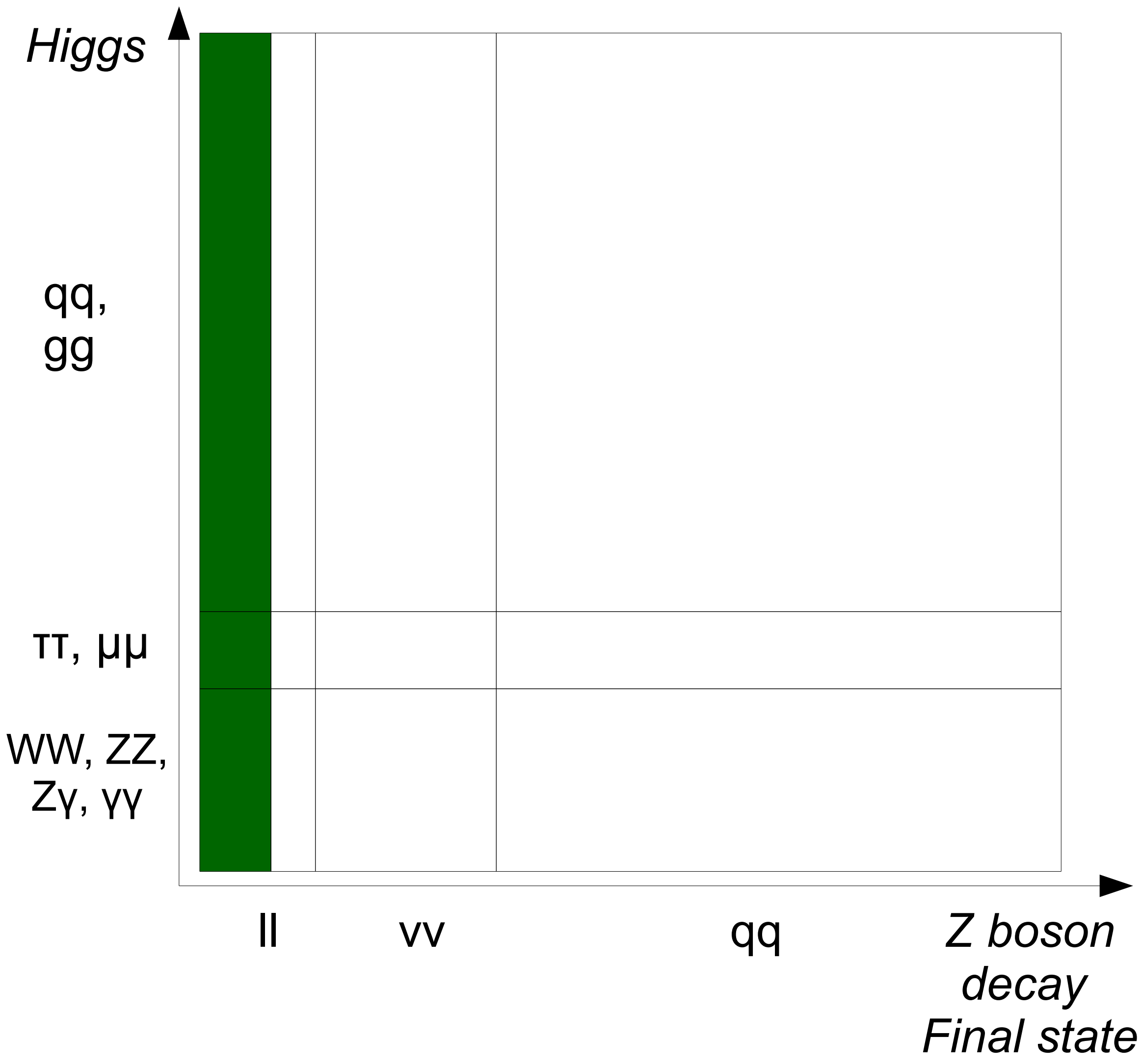
Signal, ZH with Z to qq and Higgs to qq or gg ~ 48.6 k

Background & Analysis: general remark

- Without any selection, the statistic total background is roughly 2 orders higher than Signal
  - Dominated by WW
  - ZZ, irreducible background ~ 5 times larger than ZH
- Event Selection should reduce the background to the same order of magnitude as the Signal
  - Tagging different final state: lepton ID & Flavor tagging
  - Kinematic selection: rely on PFA
- Good statistic:
  - Detector should be efficiency oriented


ZH, Z→2l
(l = e, μ),
H→X

ZH, Z→2l (l = ee, μμ), H→X



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

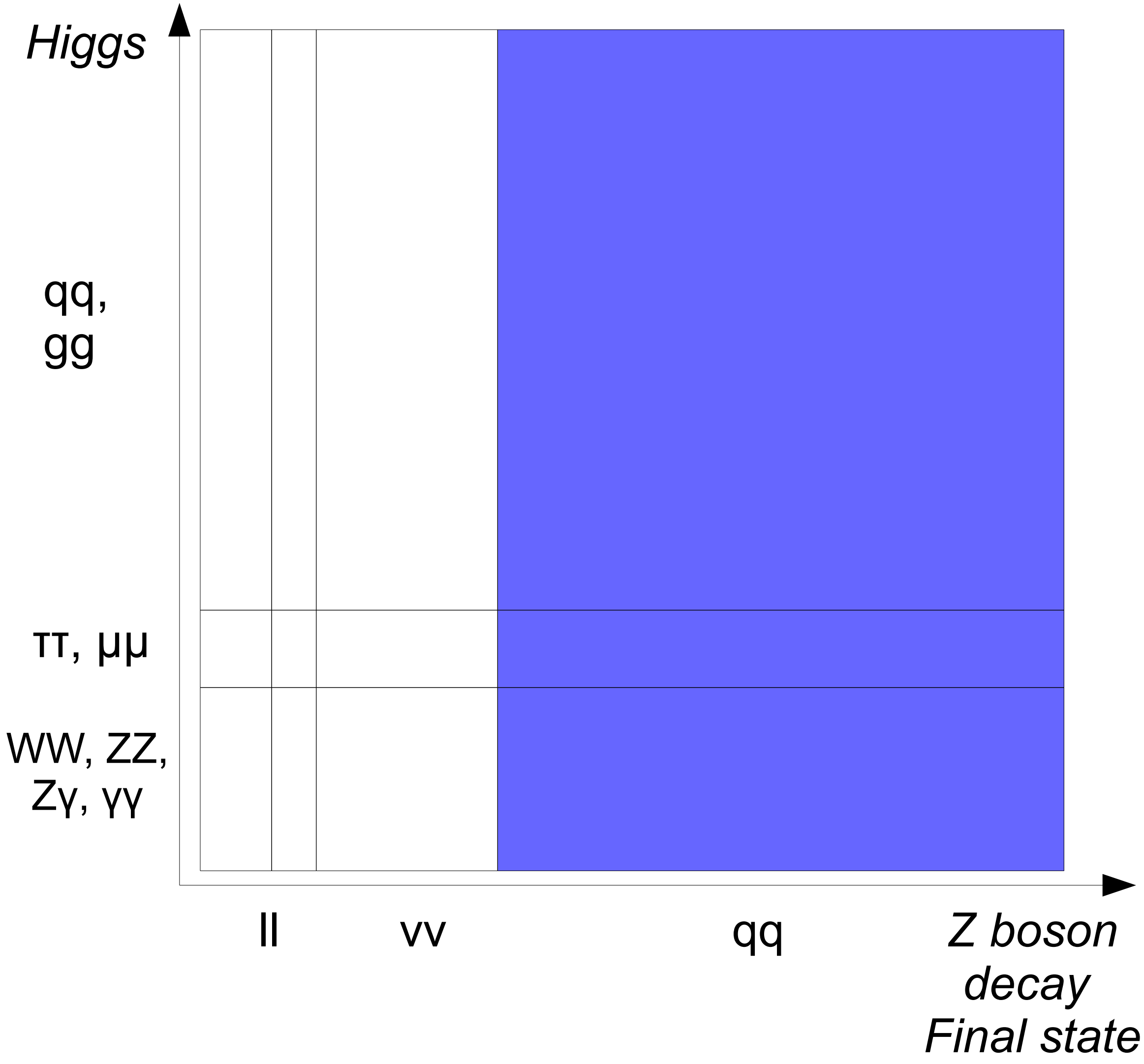
Objective Observables:

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→2q, H→X



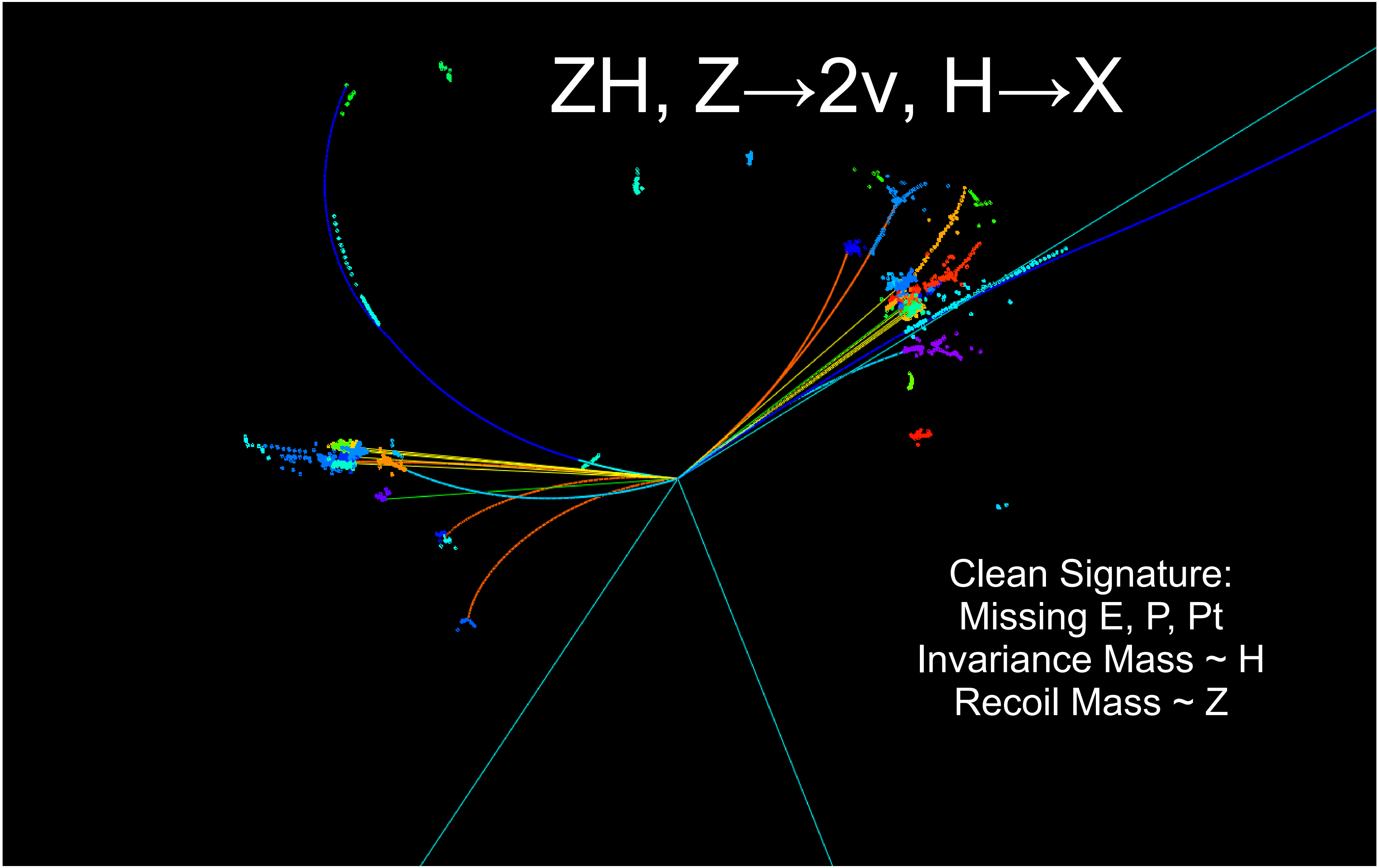
Model independent tagging of ZH events from recoil mass spectrum to di-jet system. Statistic ~ 70k evts

Objective Observables:

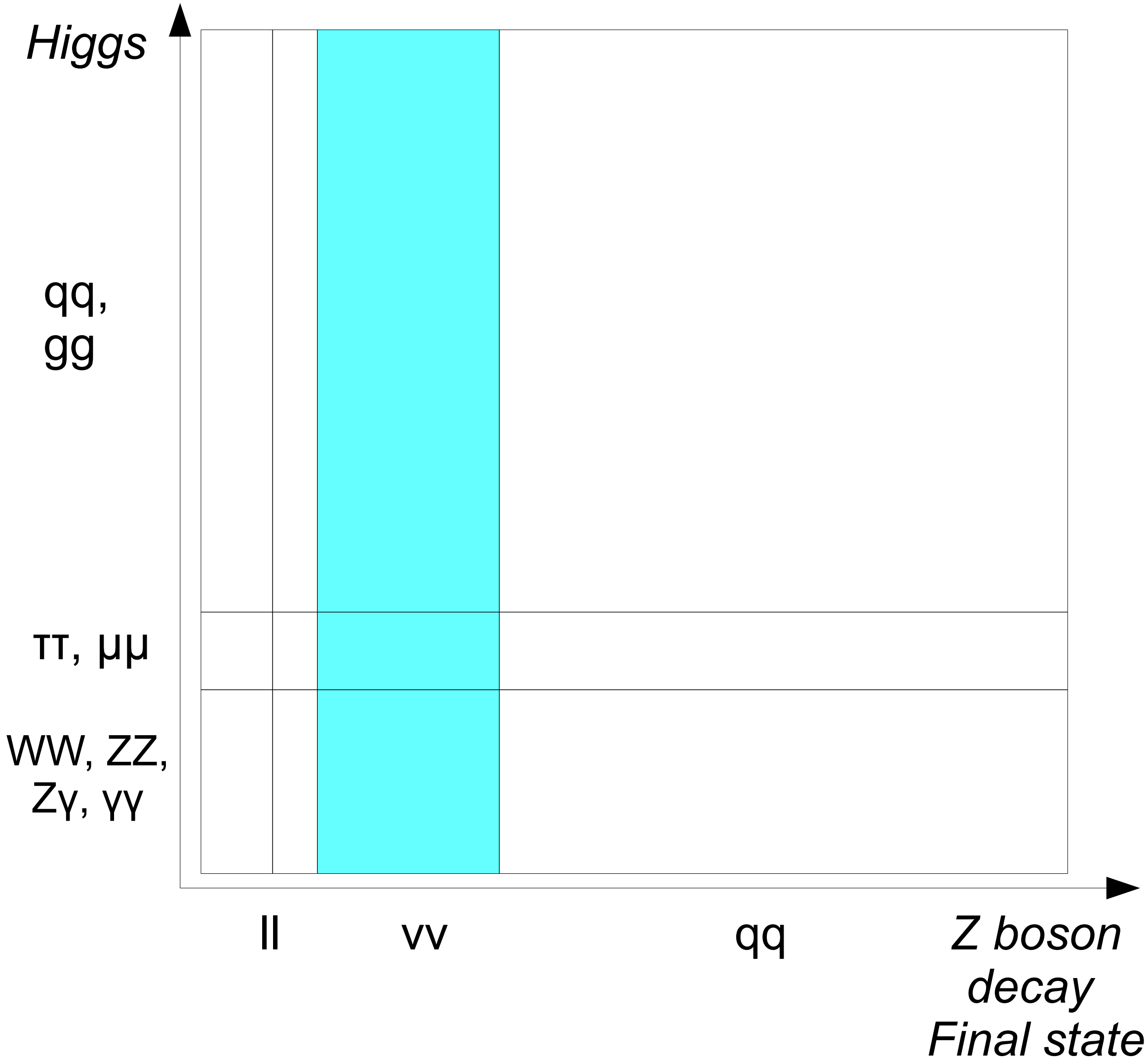
Recoil mass spectrum:
Higgs mass, σ(HZ)

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

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


ZH, Z→2ν, H→X
Clean Signature:
Missing E, P, Pt
Invariance Mass ~ H
Recoil Mass ~ Z

ZH, Z→2ν, H→X



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

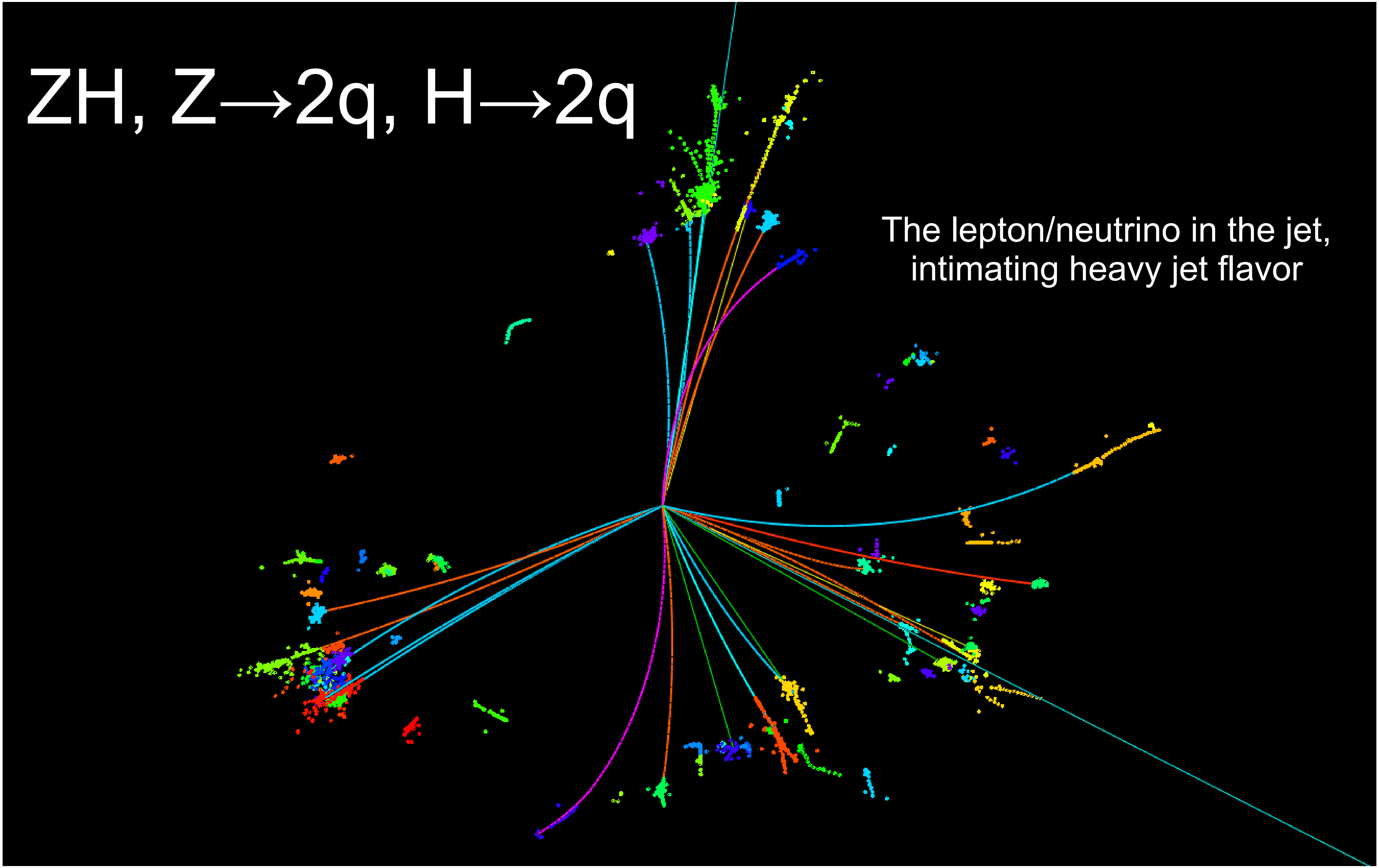
Objective Observables:

Higgs mass, σ(HZ)*Br(H→X)

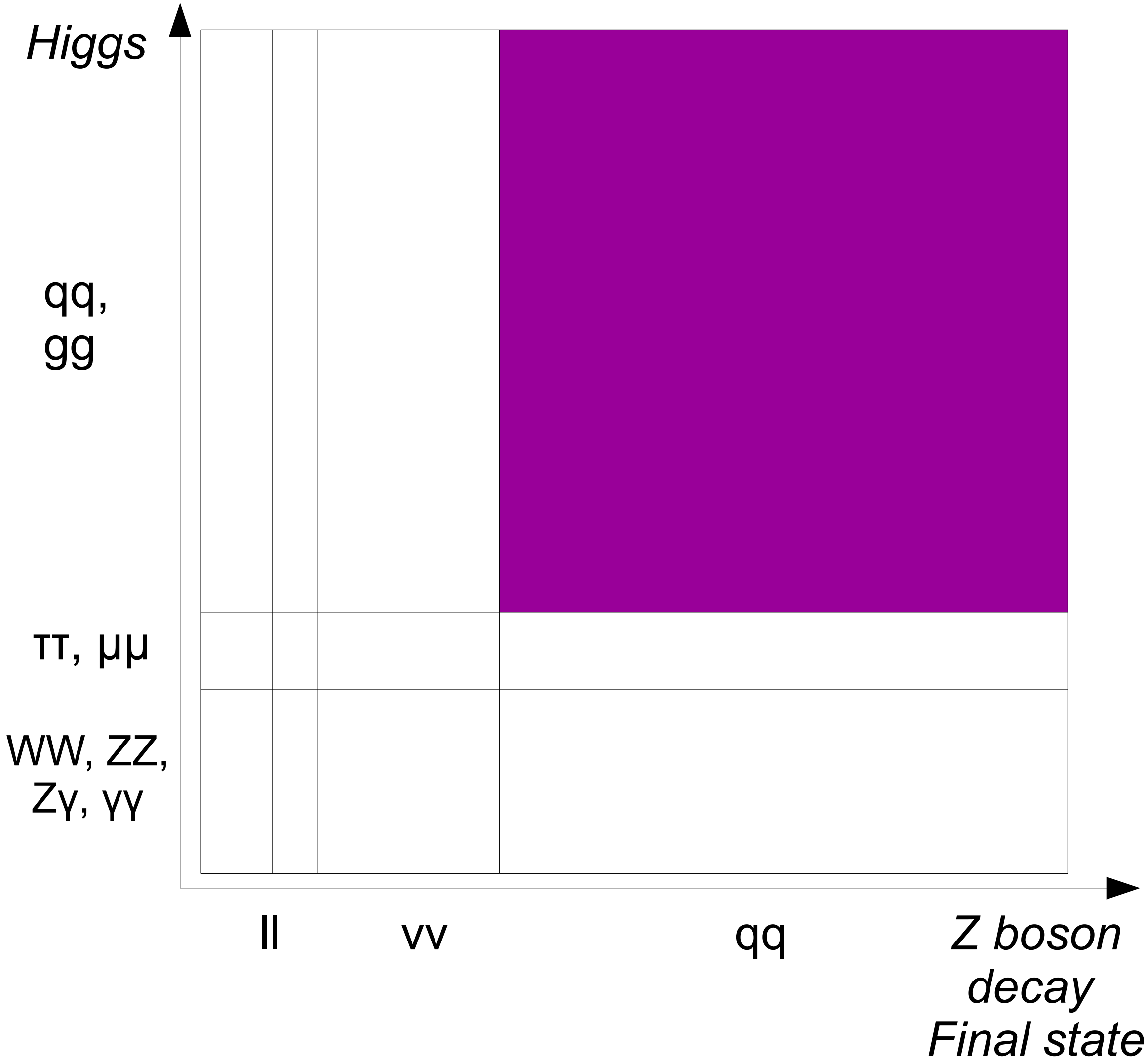
Critical performances/algorithms:

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

ZH, Z→2q, H→2q



ZH, Z→2q, H→2q



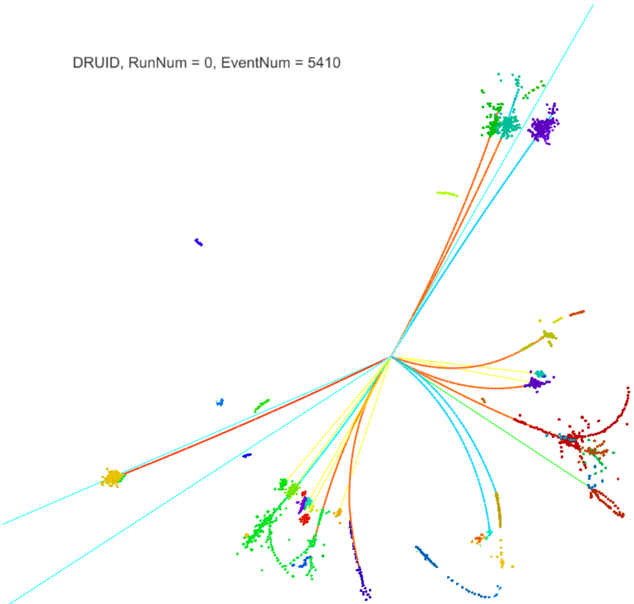
Tag the ZH events from invariant
Mass of all 2-jets combinations.
Statistics ~ 50k evts

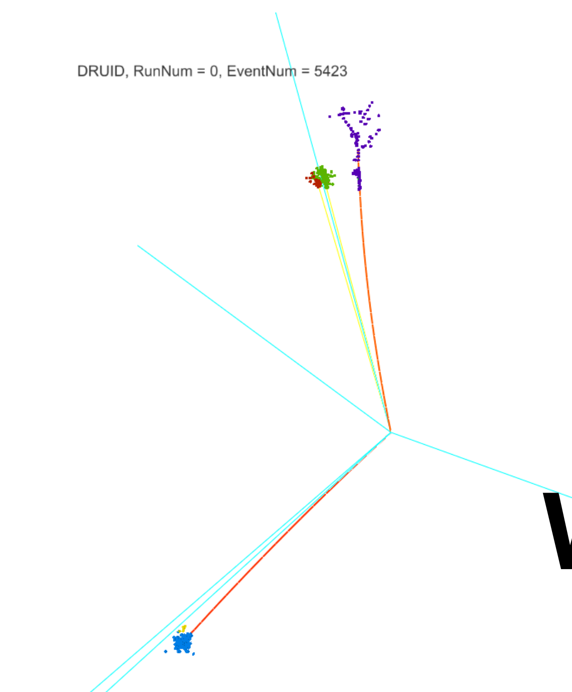
Objective Observables:

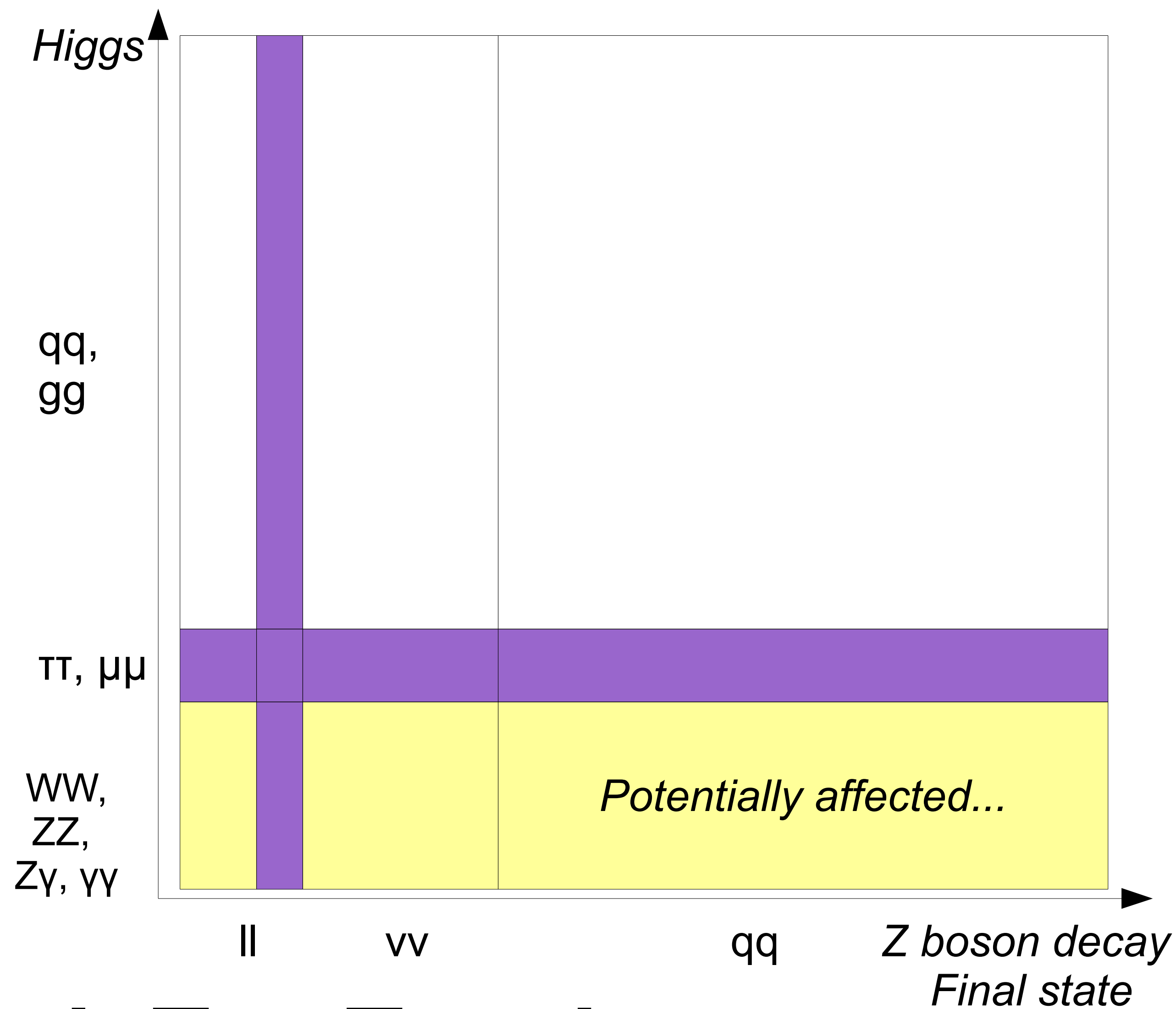
Higgs mass, σ(HZ)*Br(H→2j),
σ(HZ)*Br(H→2b, 2c, 2g),

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

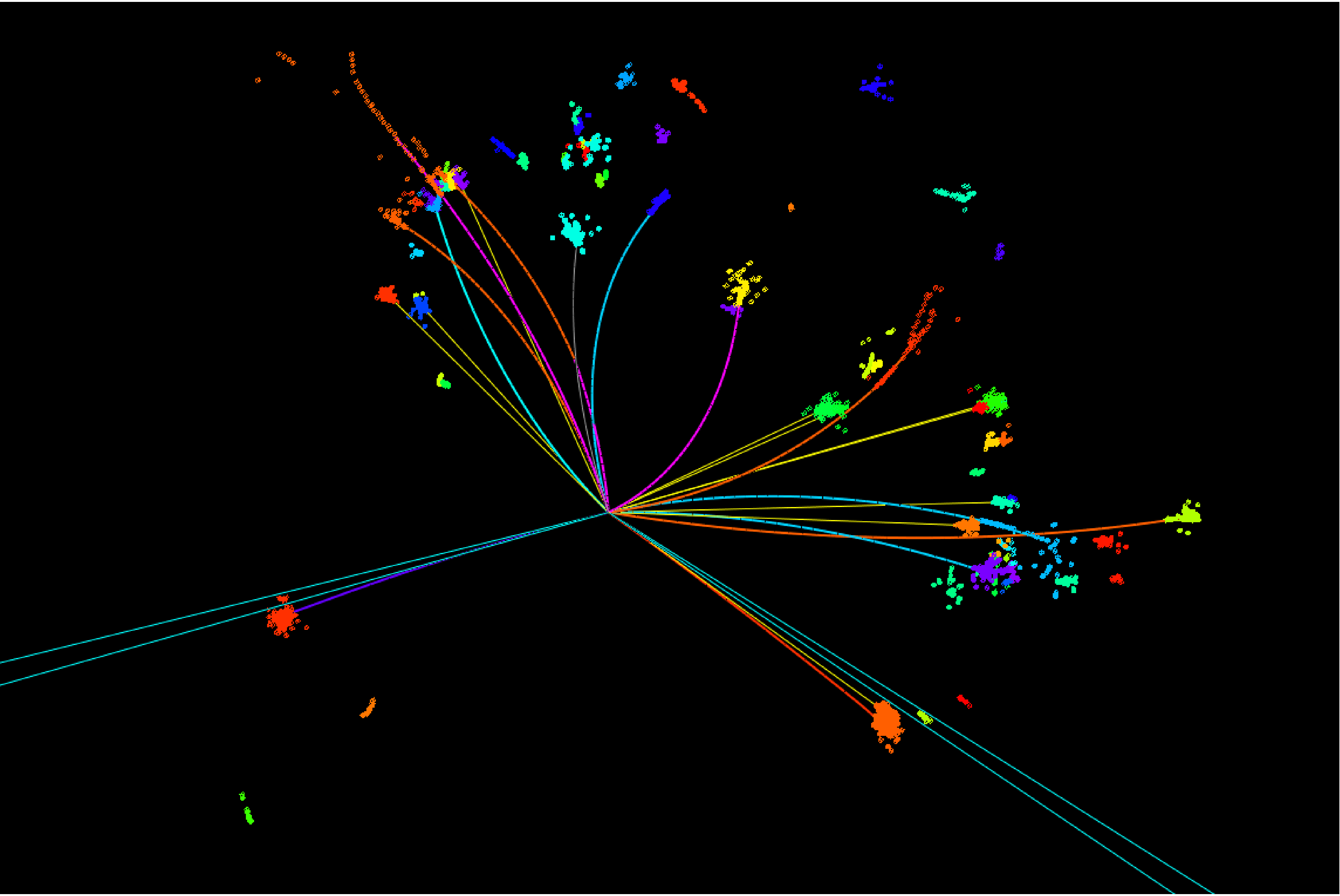
Another P.o.V: algorithm



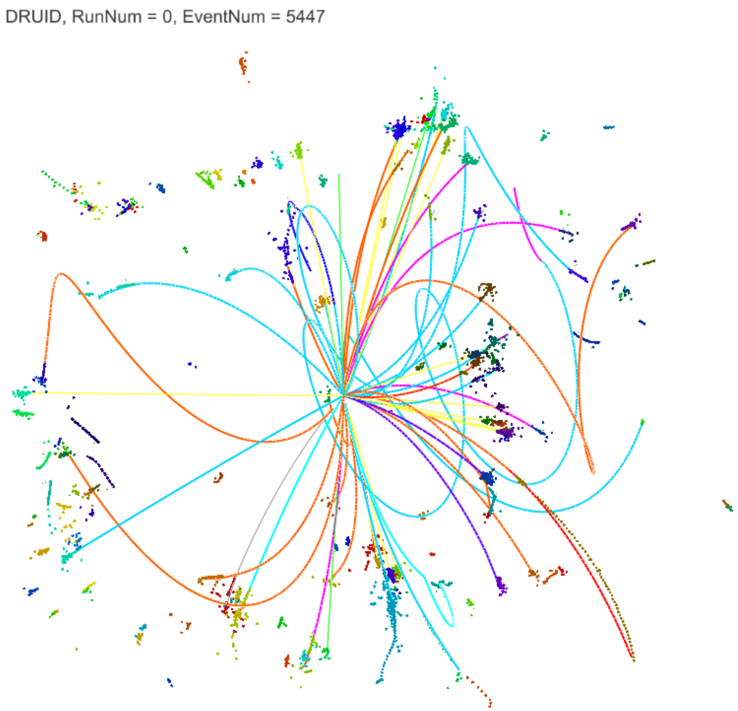




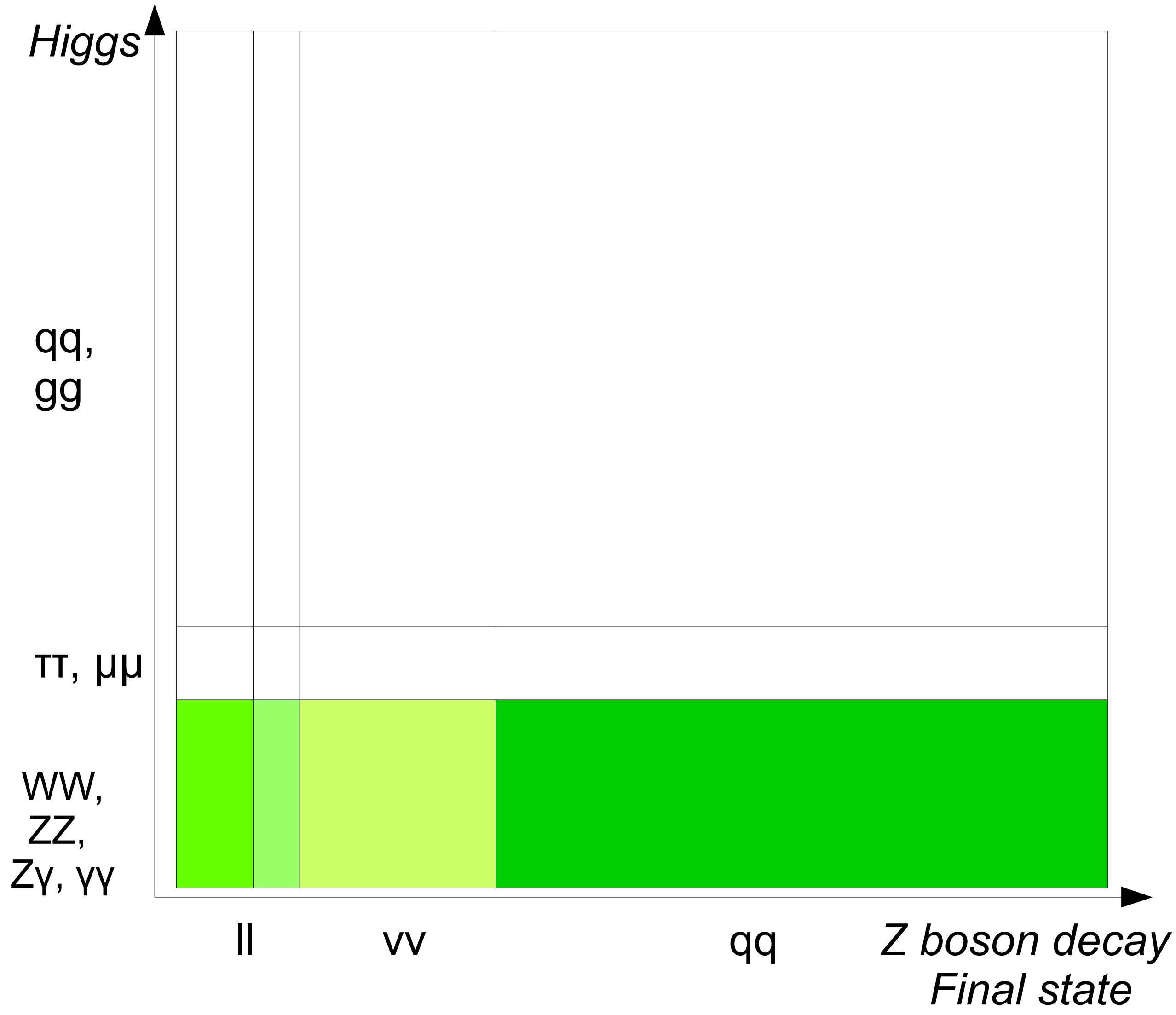
Wanted: Tau Tagging



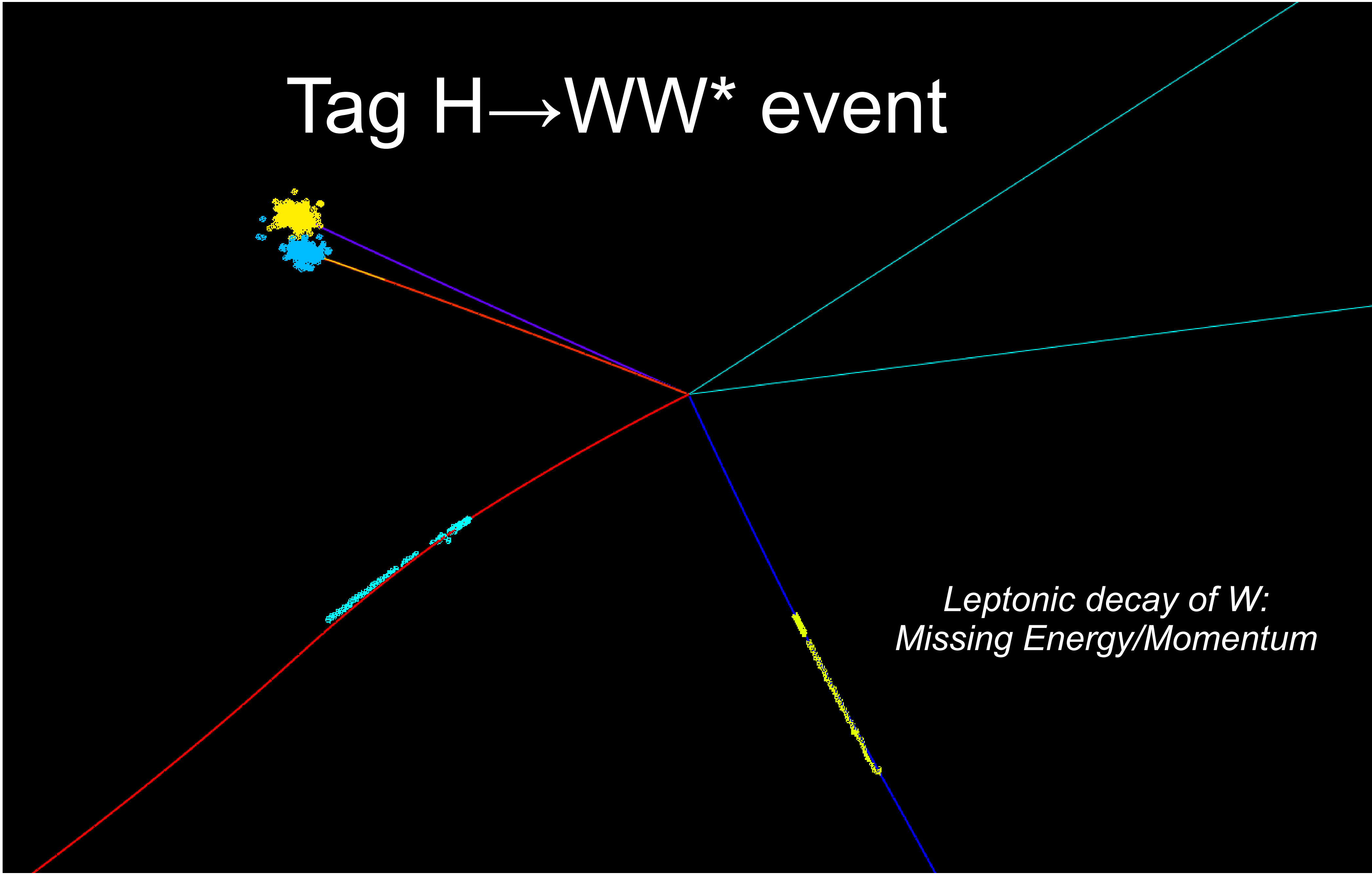
Br(H→WW, ZZ) ~ Width Measurement



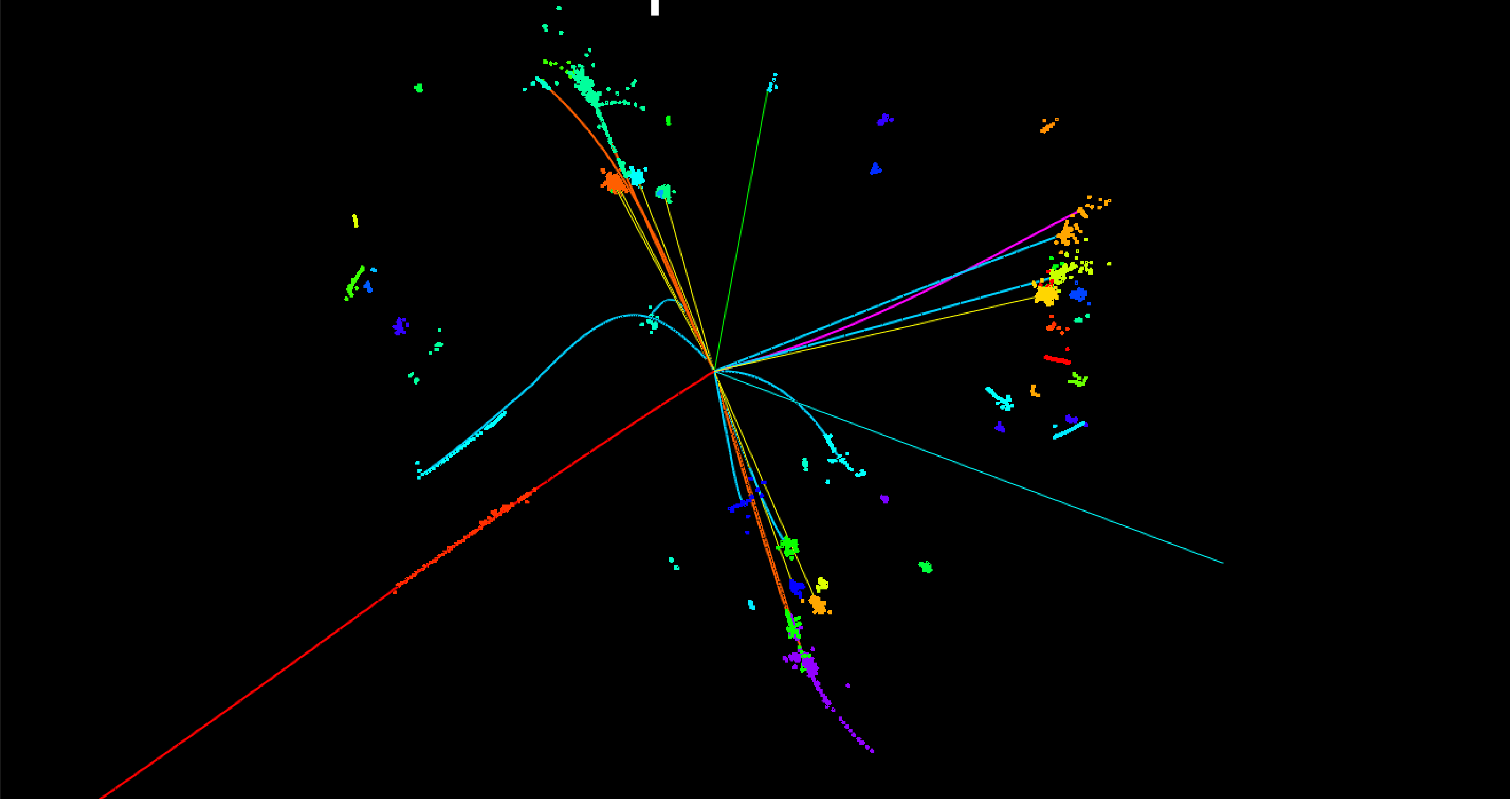
Important,
challenging,
Exciting.



Tag H→WW* event



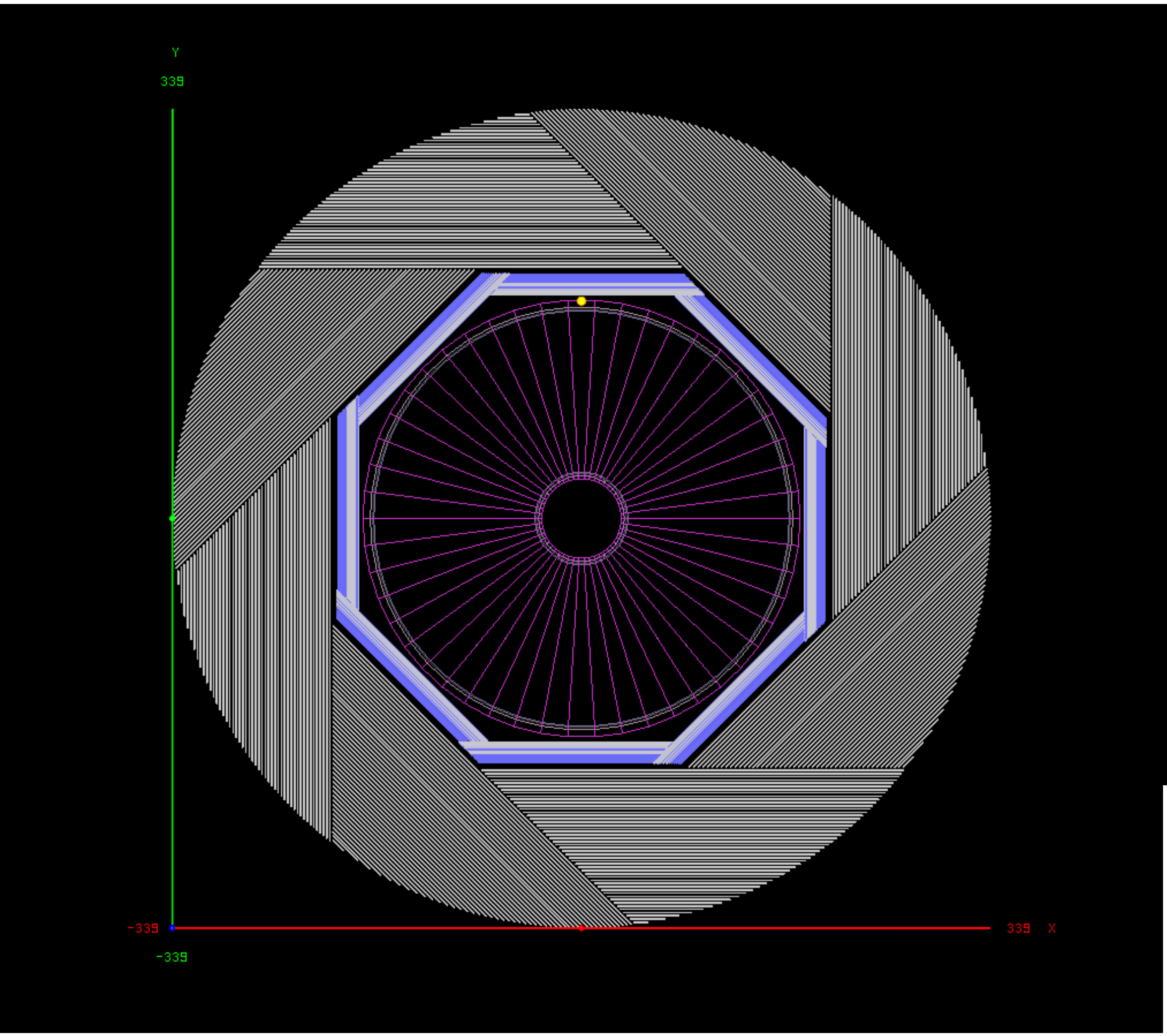
H→WW*→2qlν

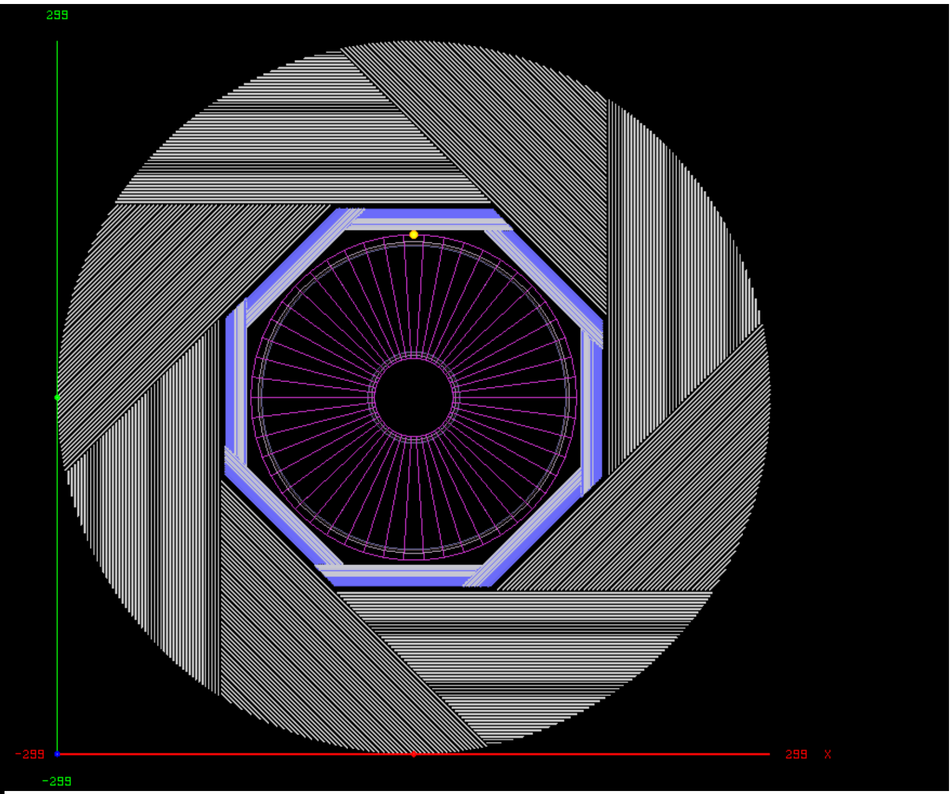


From ILD to CEPC detector

- 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

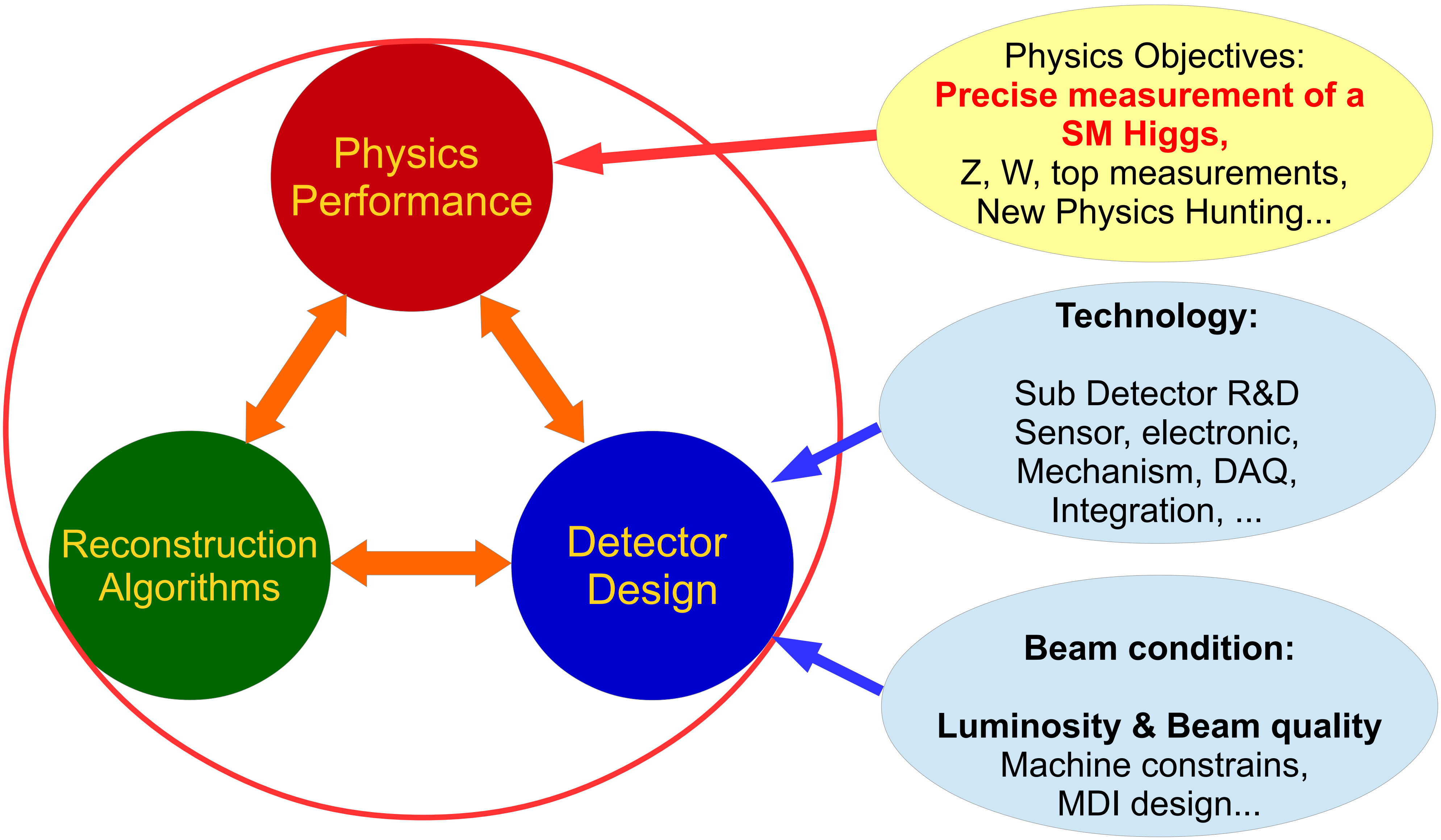
Design new geometry





More details in YY's talk

Detector optimization: Basic ingredients




Higgs, the focus,
the gate
CEPC, the KEY

Spared

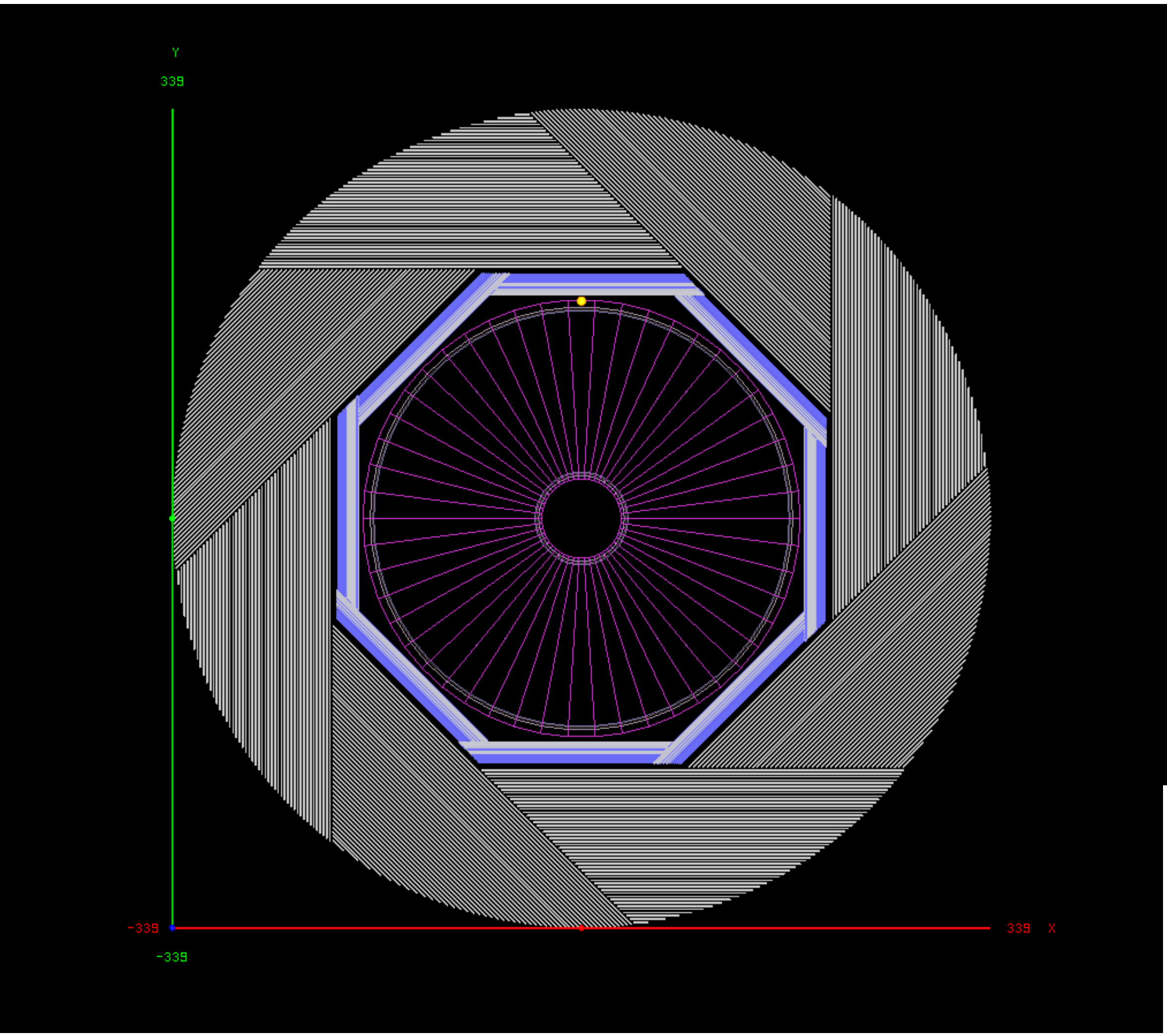
Observables and expected accuracy

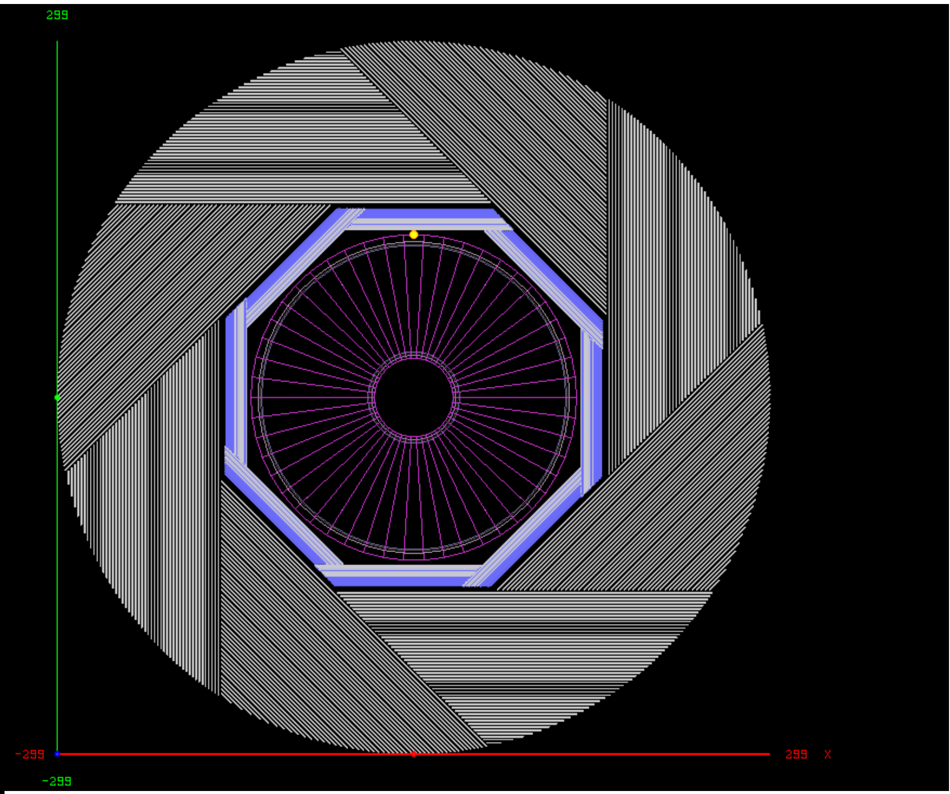
Accelerator → Physical Quantity ↓	LHC 300 fb^{-1} /expt	HL-LHC 3000 fb^{-1} /expt	ILC 250 GeV 250 fb^{-1} 5 yrs	Full ILC 250+350+ 1000 GeV 5yrs each	CLIC 350 GeV (500 fb^{-1}) 1.4 TeV (1.5 ab^{-1}) 5 yrs each	LEP3, 4 IP 240 GeV 2 ab^{-1} (*) 5 yrs	TLEP, 4 IP 240 GeV 10 ab^{-1} 5 yrs (*) 350 GeV 1.4 ab^{-1} 5 yrs (*)
N_H	1.7×10^7	1.7×10^8	6×10^4 ZH	10^5 ZH 1.4×10^5 Hνν	7.5×10^4 ZH 4.7×10^5 Hνν	4×10^5 ZH	2×10^6 ZH 3.5×10^4 Hνν
m_H (MeV)	100	50	35	35	100	26	7
$\Delta\Gamma_H / \Gamma_H$	--	--	10%	3%	ongoing	4%	1.3%
$\Delta\Gamma_{inv} / \Gamma_H$	Indirect (30%?)	Indirect (10% ?)	1.5%	1.0%	ongoing	0.35%	0.15%
$\Delta g_{H\gamma\gamma} / g_{H\gamma\gamma}$	6.5 – 5.1%	5.4 – 1.5%	--	5%	ongoing	3.4%	1.4%
$\Delta g_{Hgg} / g_{Hgg}$	11 – 5.7%	7.5 – 2.7%	4.5%	2.5%	< 3%	2.2%	0.7%
$\Delta g_{Hww} / g_{Hww}$	5.7 – 2.7%	4.5 – 1.0%	4.3%	1%	~1%	1.5%	0.25%
$\Delta g_{HZZ} / g_{HZZ}$	5.7 – 2.7%	4.5 – 1.0%	1.3%	1.5%	~1%	0.65%	0.2%
$\Delta g_{HHH} / g_{HHH}$	--	< 30% (2 expts)	--	~30%	~22% (~11% at 3 TeV)	--	--
$\Delta g_{H\mu\mu} / g_{H\mu\mu}$	< 30%	< 10%	--	--	10%	14%	7%
$\Delta g_{H\tau\tau} / g_{H\tau\tau}$	8.5 – 5.1%	5.4 – 2.0%	3.5%	2.5%	≤ 3%	1.5%	0.4%
$\Delta g_{Hcc} / g_{Hcc}$	--	--	3.7%	2%	2%	2.0%	0.65%
$\Delta g_{Hbb} / g_{Hbb}$	15 – 6.9%	11 —2.7%	1.4%	1%	1%	0.7%	0.22%
$\Delta g_{Htt} / g_{Htt}$	14 – 8.7%	8.0 – 3.9%	--	5%	3%	--	30%

ArXiV: 1302.3318 (在测算耦合常数时未考虑总宽度误差)

	e^+e^- collider	photon collider
c.m.s	240 GeV	160 GeV
N_{Higgs}	100k	50k
δM_H/MeV	26	60
Spin/Parity	Yes	Yes
$\sigma(HZ)$	2.3%	
$\sigma(HZ)\mathrm{Br}(\mathrm{H} \to \mathrm{b\bar{b}})$	1%	
$\sigma(HZ)\mathrm{Br}(\mathrm{H} \to \mathrm{WW}^*)$	5.5%	
$\sigma(HZ)\mathrm{Br}(\mathrm{H} \to \mathrm{gg})$	6.1%	
$\sigma(HZ)\mathrm{Br}(\mathrm{H} \to \tau^+\tau^-)$	3.6%	
$\sigma(HZ)\mathrm{Br}(\mathrm{H} \to \mathrm{c\bar{c}})$	7.2%	
$\sigma(HZ)\mathrm{Br}(\mathrm{H} \to \mathrm{ZZ}^*)$	16%	
$\sigma(HZ)\mathrm{Br}(\mathrm{H} \to \gamma\gamma)$	26%	
$\sigma(HZ)\mathrm{Br}(\mathrm{H} \to \mu^+\mu^-)$	29%	
$\sigma(HZ)\mathrm{Br}(\mathrm{H} \to \mathrm{invisible})$	0.5%	
$\Gamma(H \to \gamma\gamma)\mathrm{Br}(\mathrm{H} \to \mathrm{b\bar{b}})$		1%
$\Gamma(H \to \gamma\gamma)\mathrm{Br}(\mathrm{H} \to \mathrm{WW}^*)$		3%
$\Gamma(H \to \gamma\gamma)\mathrm{Br}(\mathrm{H} \to \gamma\gamma)$		12%
$\Gamma(H \to \gamma\gamma)\mathrm{Br}(\mathrm{H} \to \mathrm{ZZ}^*)$		6%
$\Gamma(H \to \gamma\gamma)\mathrm{Br}(\mathrm{H} \to \mathrm{Z}\gamma)$		20%
$\Gamma(H \to \gamma\gamma)\mathrm{Br}(\mathrm{H} \to \mu^+\mu^-)$		38%

Design new geometry

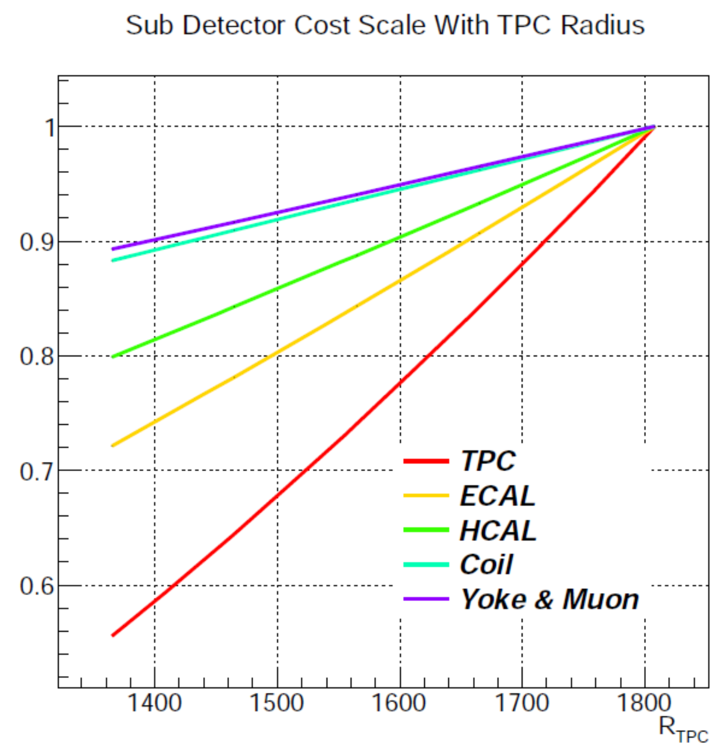


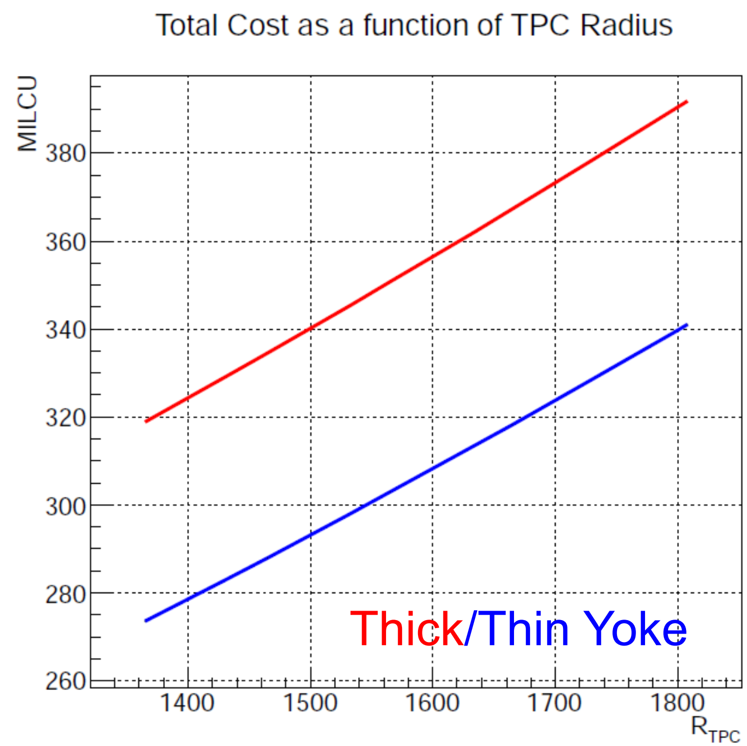


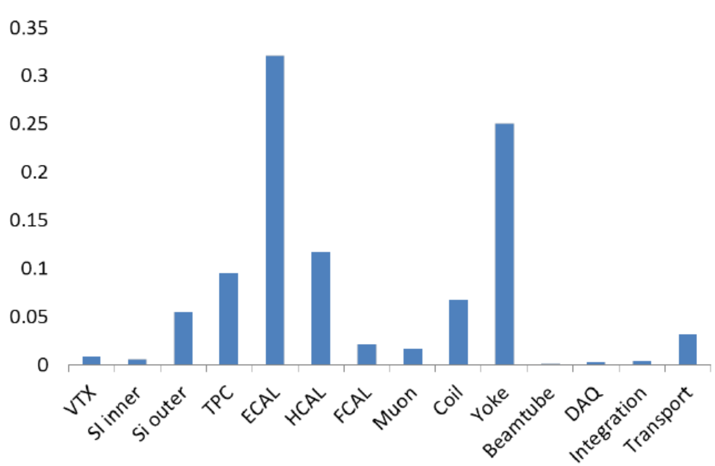
Validated at Hits map & Event display

Spin off – geometry validation analysis chains

Cost estimation: extrapolate from ILD

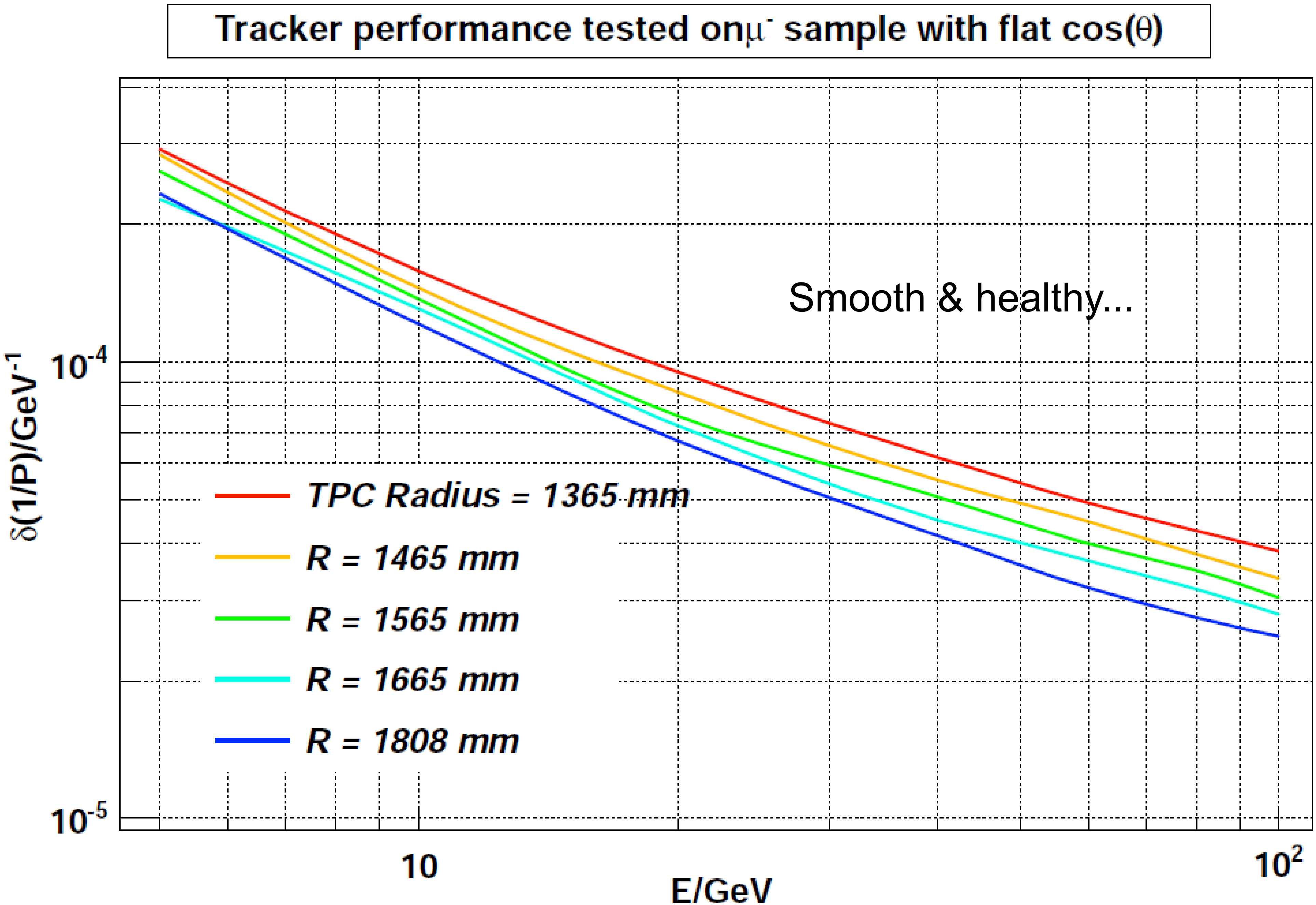




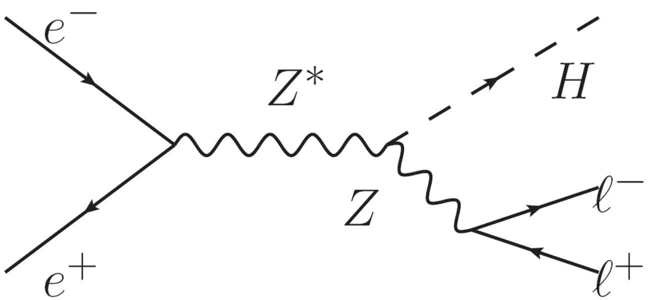


ILD Cost ~ 400 MILCU
CEPC detector ~ 270 MILCU
~ 1.6 Billion CNY
~ 3 B CNY for 2 detectors;

Without manpower

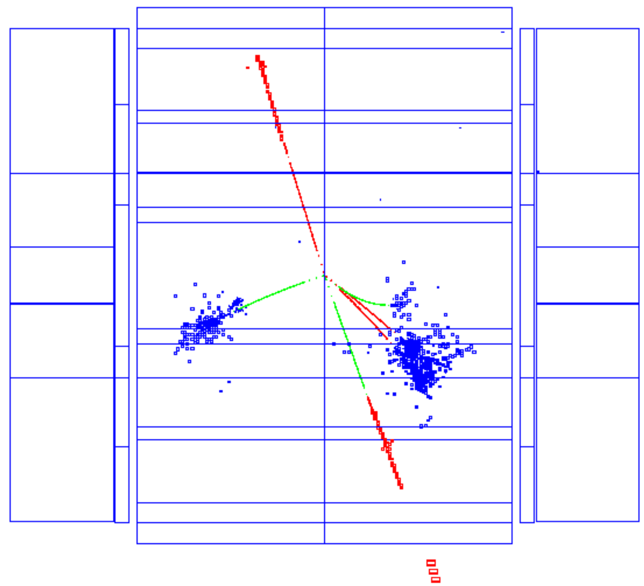

Tracker performance tested on μ⁻ sample with flat cos(θ)
Smooth & healthy...
TPC Radius = 1365 mm
R = 1465 mm
R = 1565 mm
R = 1665 mm
R = 1808 mm
δ(1/P)/GeV⁻¹
10⁻⁴
10⁻⁵
10
10²
E/GeV

Higgs recoil mass spectrum: mH and σ(ZH) measurement

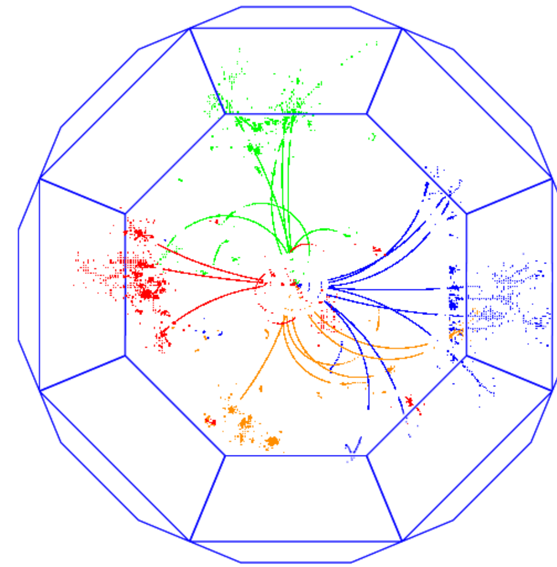


$$m_h^2 = s + m_{dileptons}^2 - 2(E_1 + E_2)\sqrt{s}$$

ZH→μμ(Z)ττ(H)



ZH→qq(Z)bb(H)

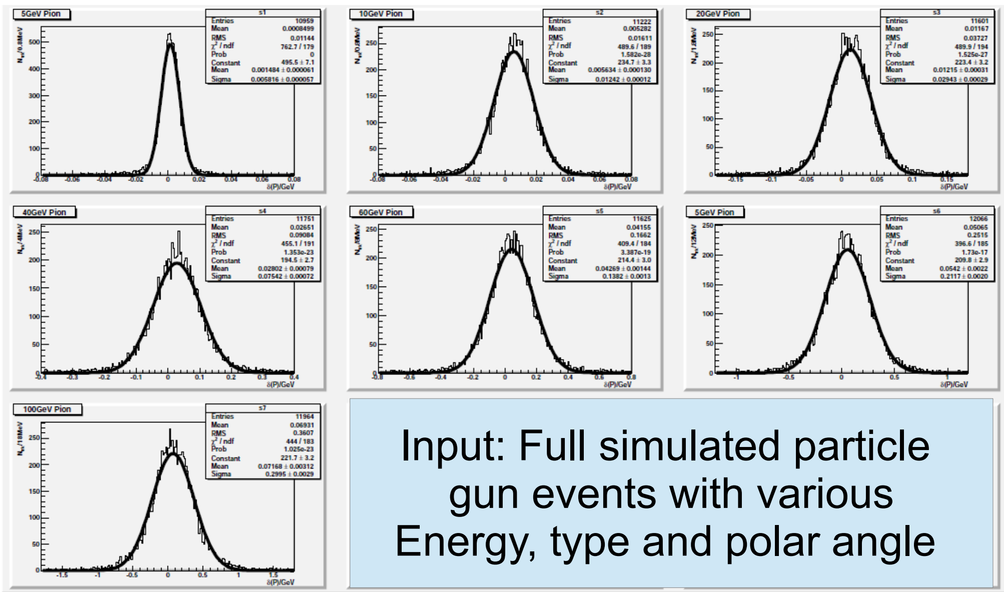


反冲质量方法：
通过质心能量及 Z 的四动量推算 Higgs 粒子四动量，进而计算其不变质量。
对 Higgs 衰变末态的信息不做任何要求：模型无关的测量。

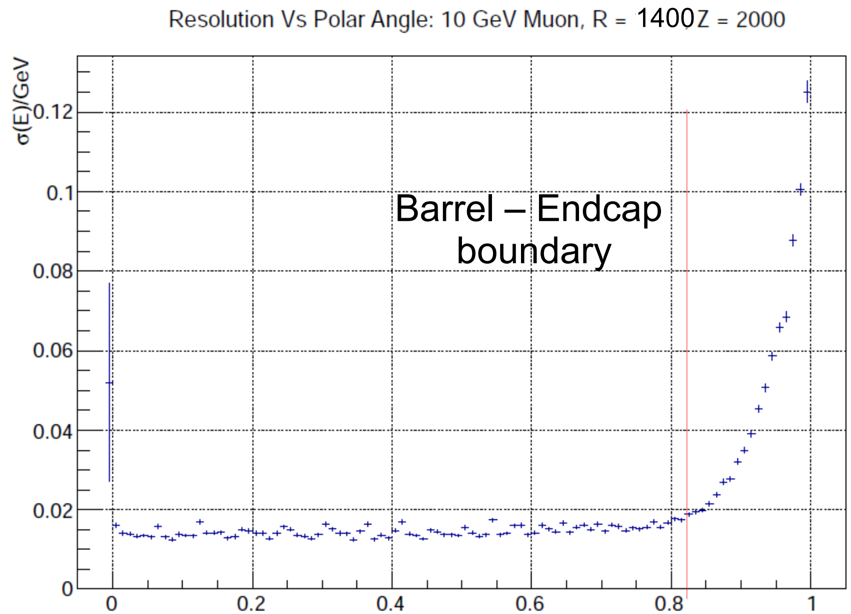
利用 LC 探测器精良的径迹系统，通过 Z 衰变轻子道 (Z→μμ) 测量 Higgs 反冲质量。

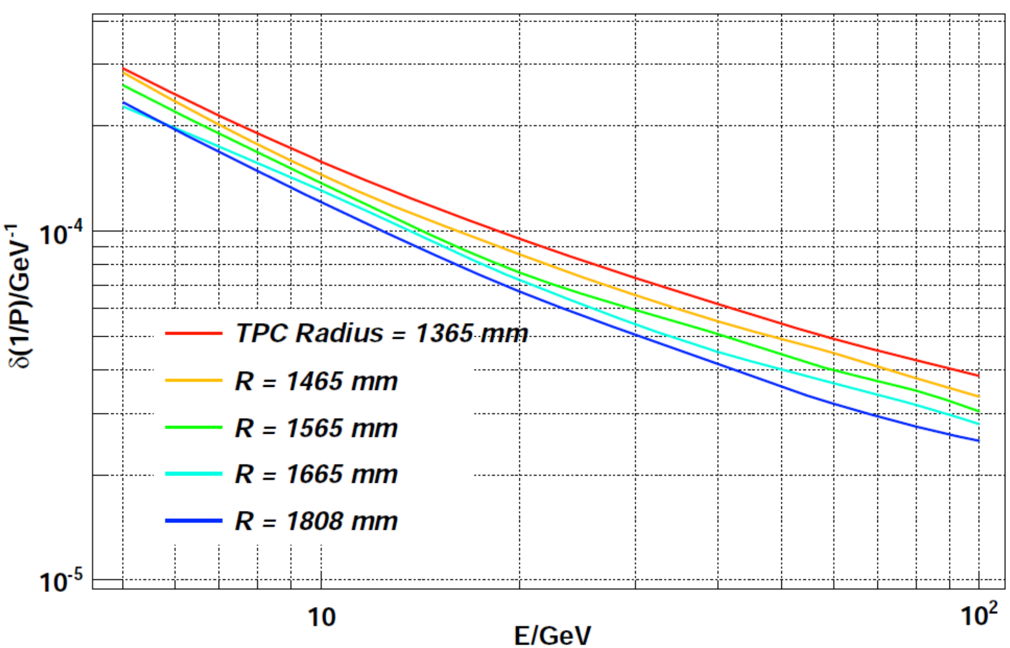
该方法可同样用于 Z→qq 末态：**需要好的喷注能量分辨，依赖粒子流算法**

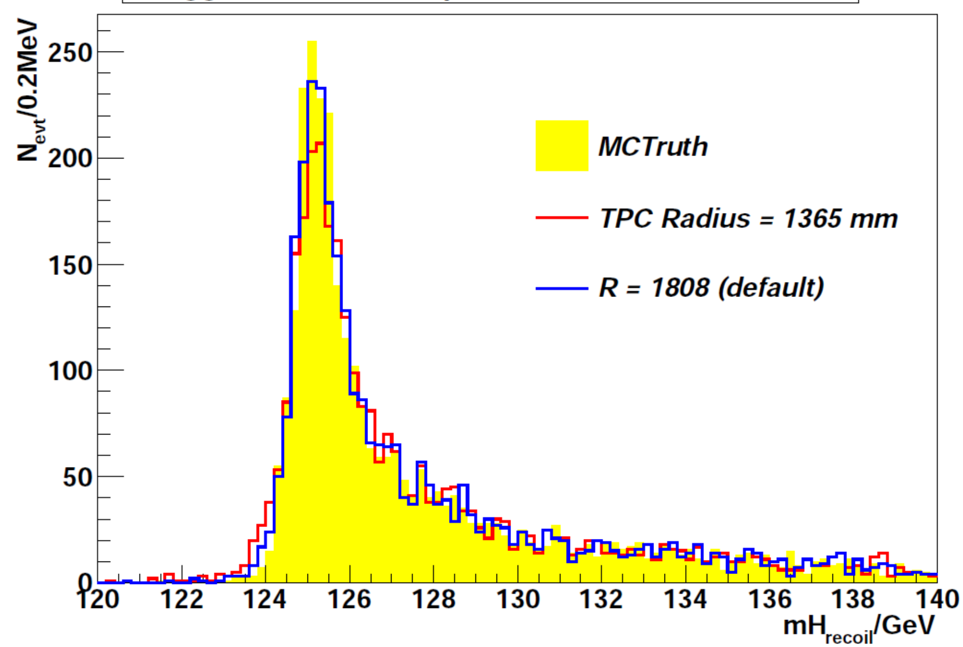
Fast simulation of recoil mass spectrum



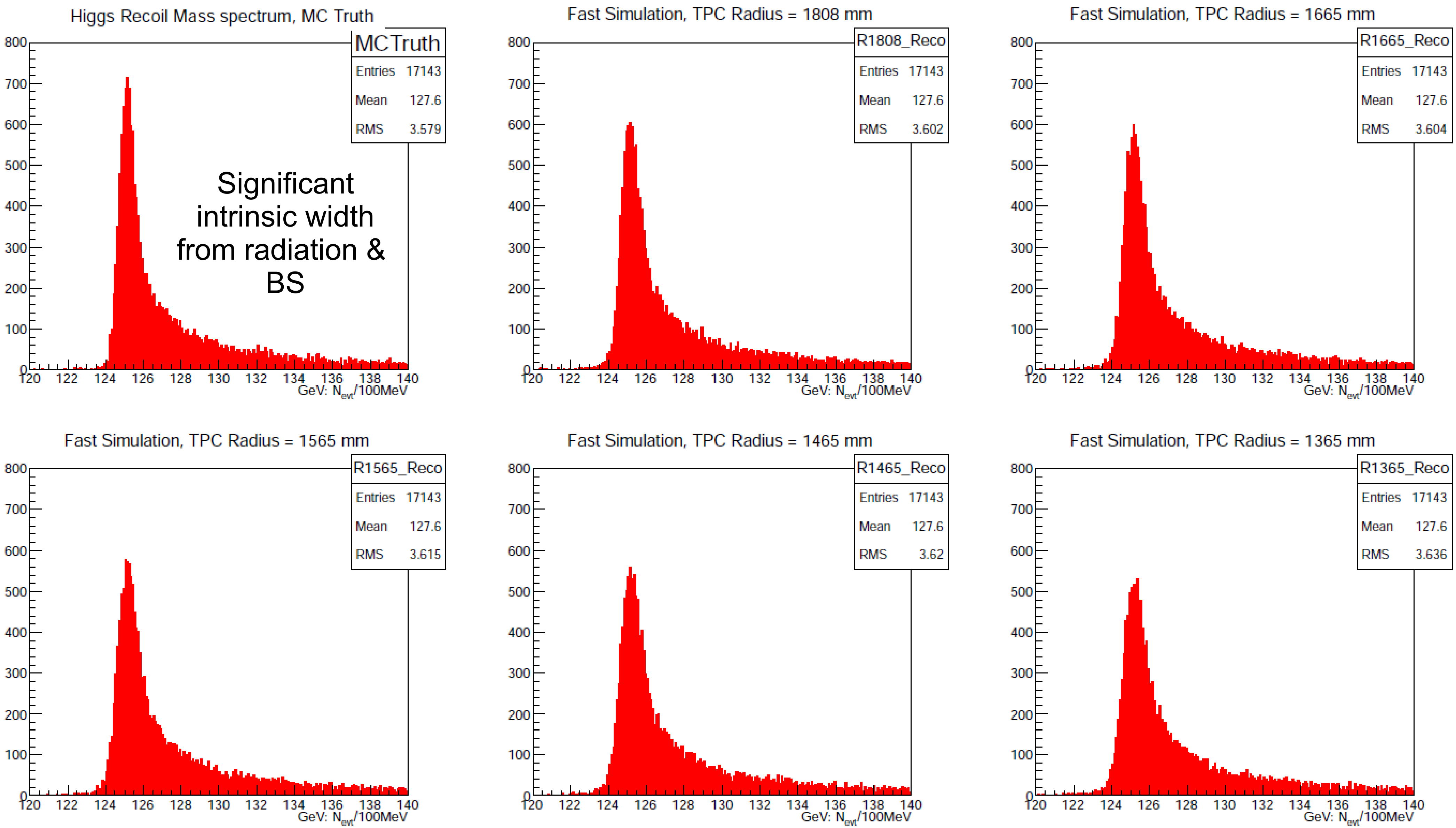
Input: Full simulated particle gun events with various Energy, type and polar angle





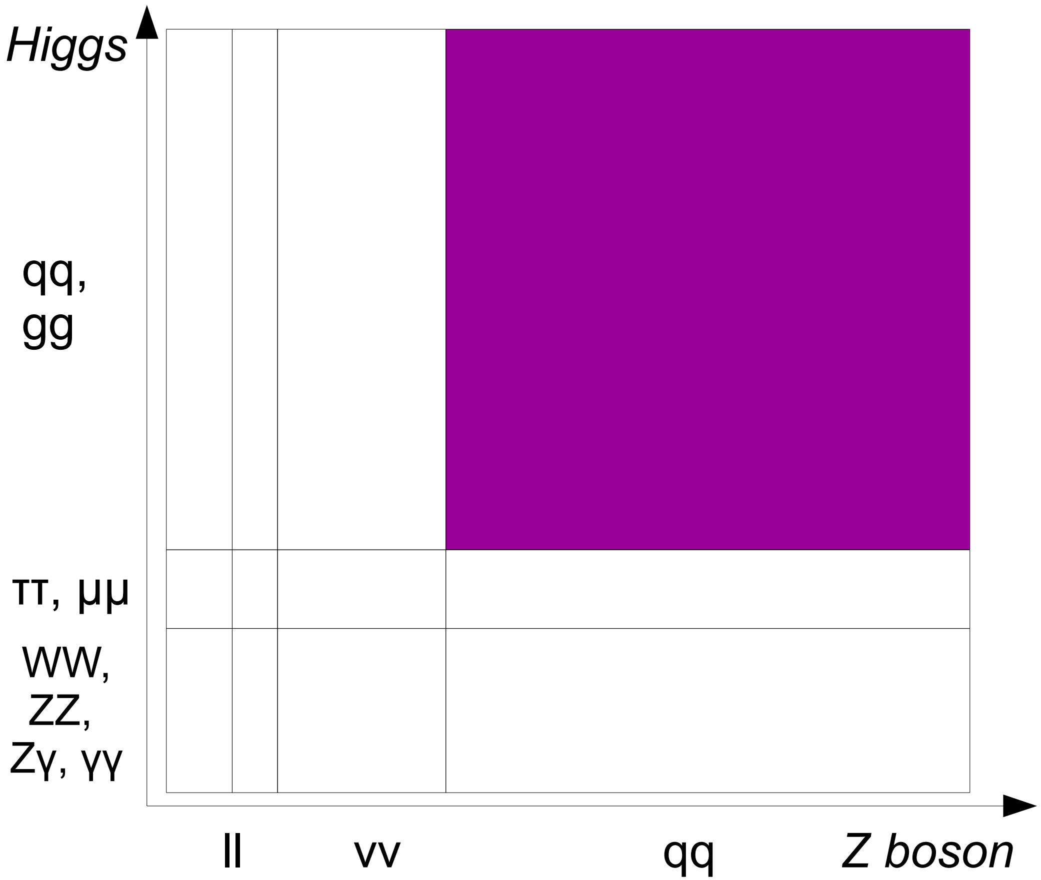


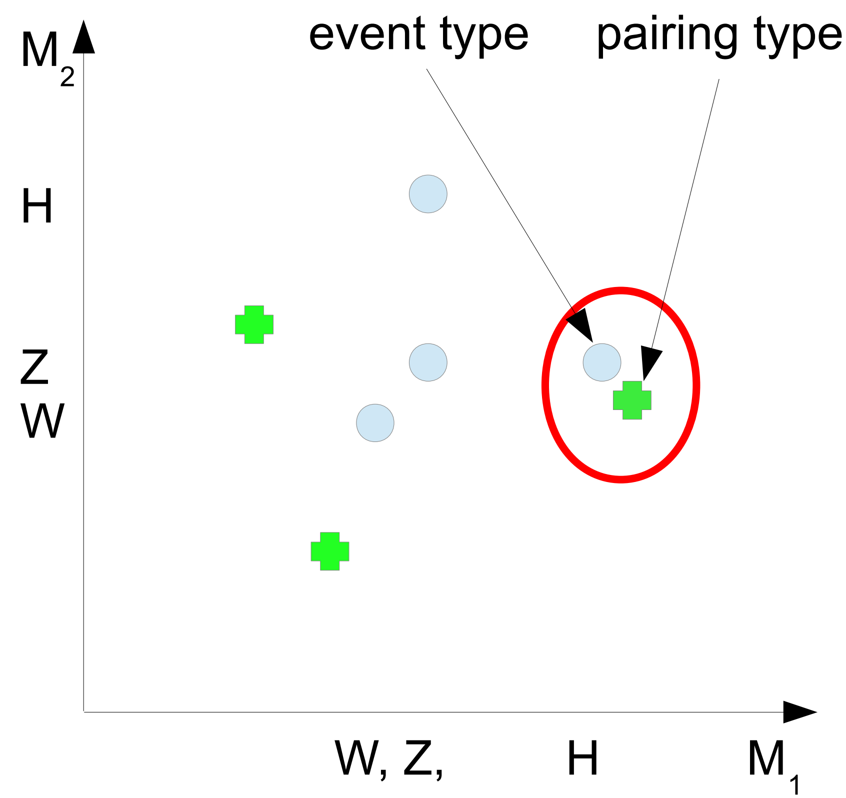
Recoil mass at different TPC Radius



Nevts scaled by a factor of ~ 5

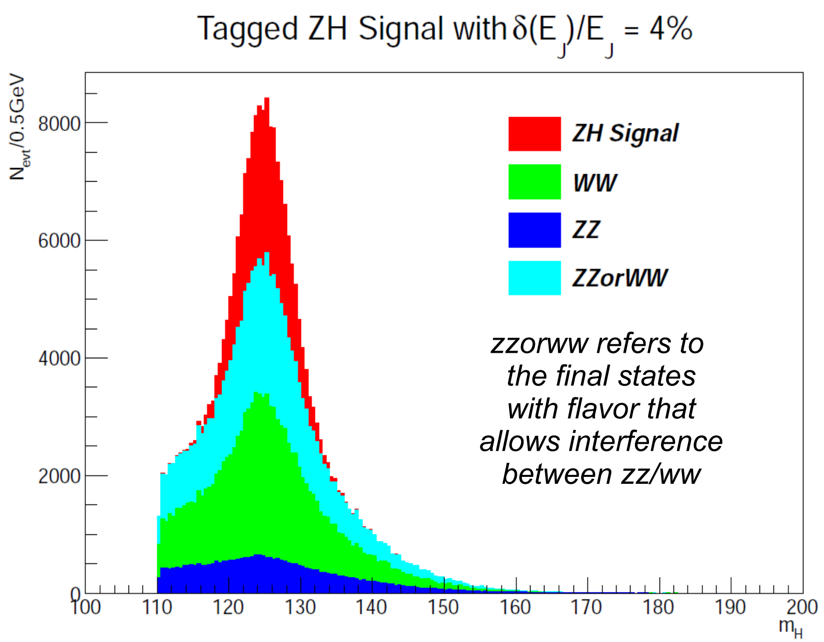
Measurement of σ(HZ)*Br(H→2j)

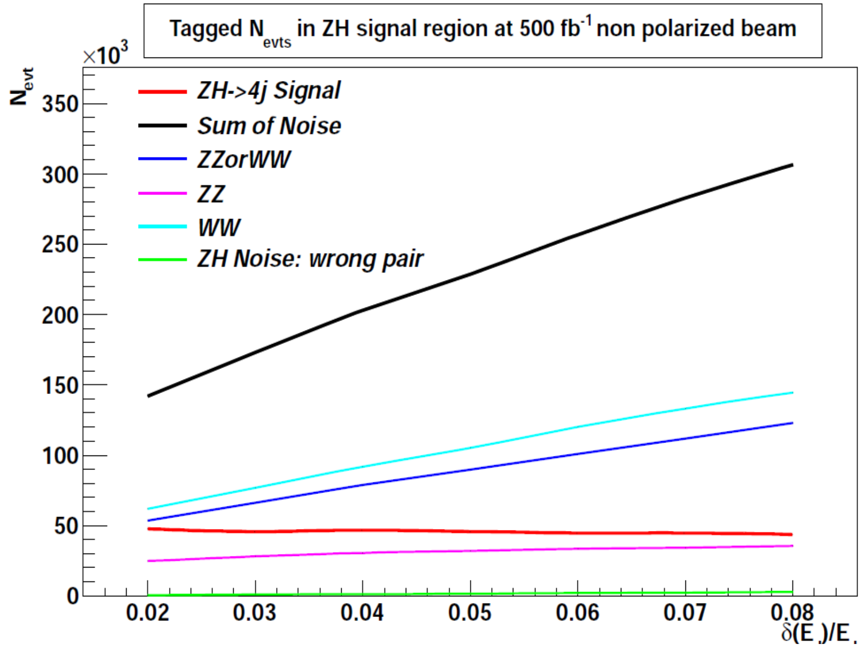


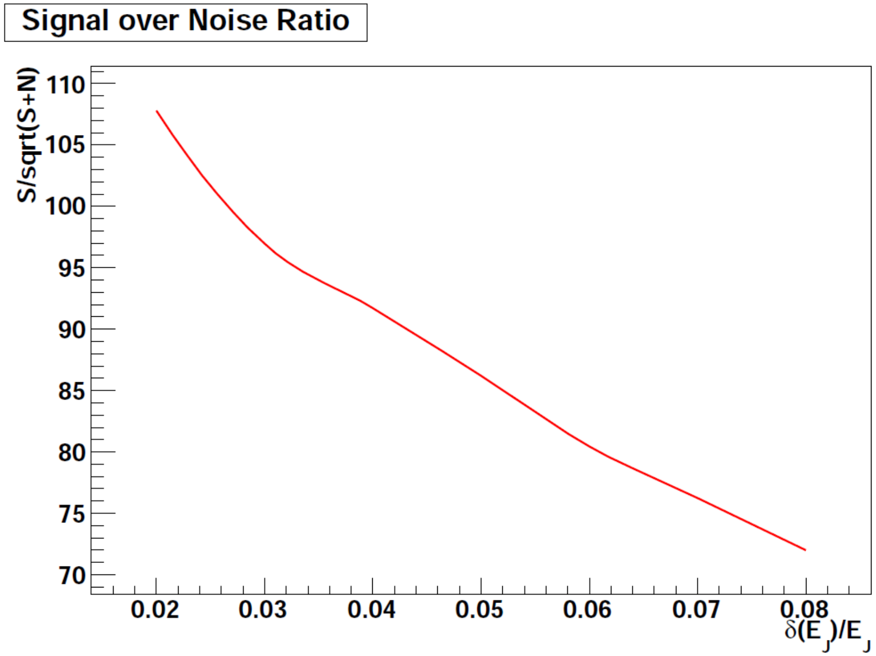


- Represent reconstructed jets by MC Truth quark * percentage energy smearing
- Main backgrounds ZZ, WW events into 4 jets
- Define Chi2 = $((M_{i,j} – MB_1)/\sigma_1)^2 + ((M_{k,l} – MB_2)/\sigma_2)^2$, Ijkl runs over all 3 combinations
- The minimal chi2 indicates both event type and jet pairing

Performance at different Jet E resolution





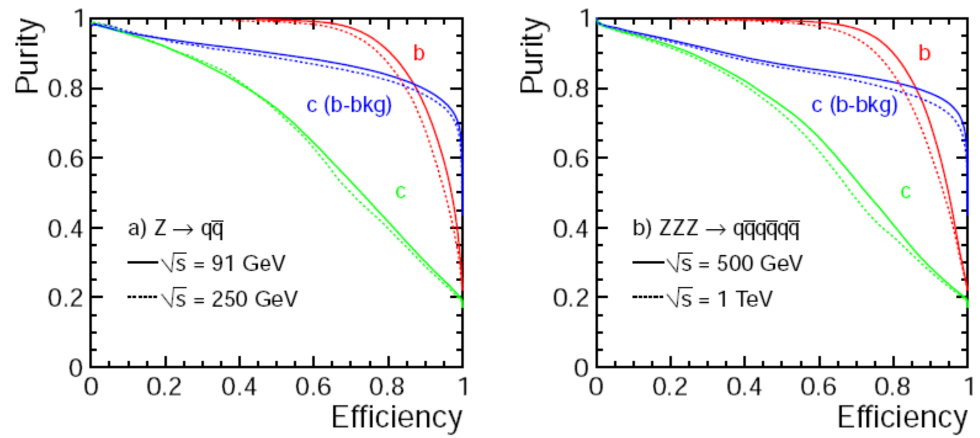


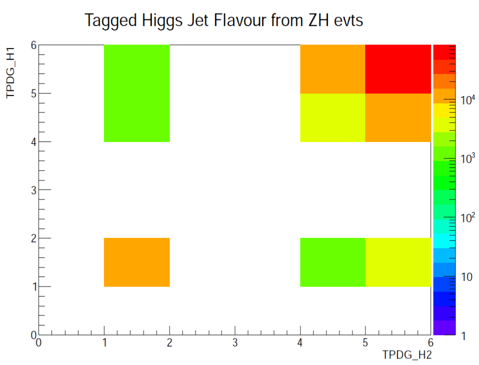
σ(H→2j) measurement easily reaches percentage level accuracy;

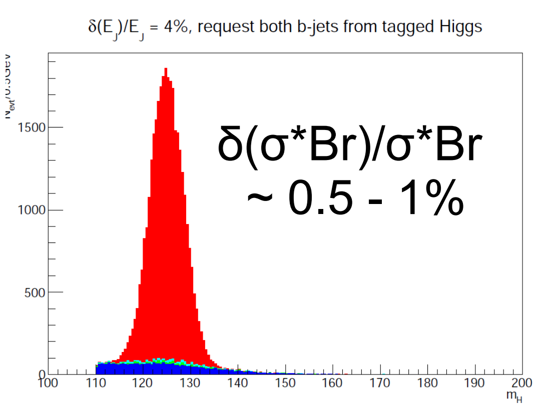
Performance weakly depends on the jet Energy resolution: δσ/σ ~ 1-1.5 %

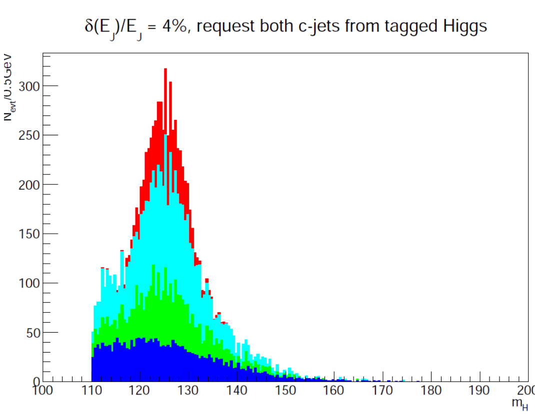
Modeling of Flavor tagging

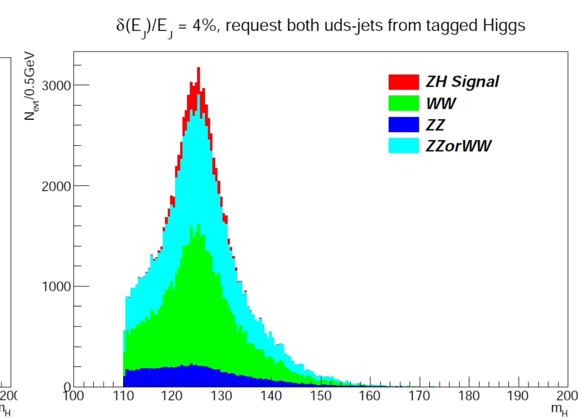
	b	c	uds	undef
b	0.90	0.08	0.02	
c	0.25	0.70	0.05	
uds	0.03	0.06	0.91	





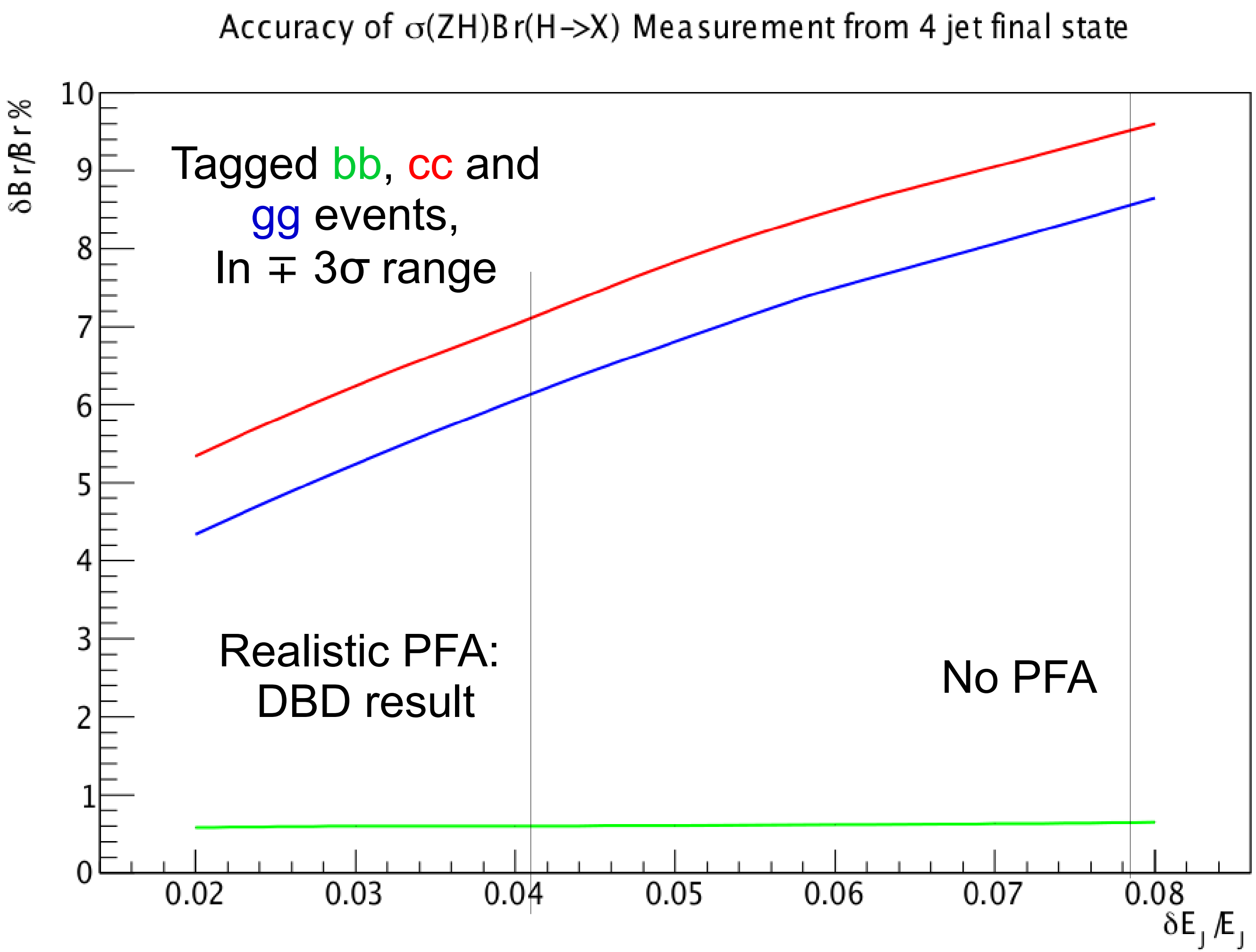






*O = M*T; M, Migration Matrix*
O, T: vector of number of events in each final state, Observed & Truth
T = T(Branching ratios)

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...

Status of on going analysis

Physics performance	Detector performance	Detector design	Experiment Life circle/plan

σ(HZ)/Mass

σ(HZ)*Br(H→2j)
J = b, c, q...
Z→2j

σ(HZ)*Br(H→2X)
Z→2j, 2l

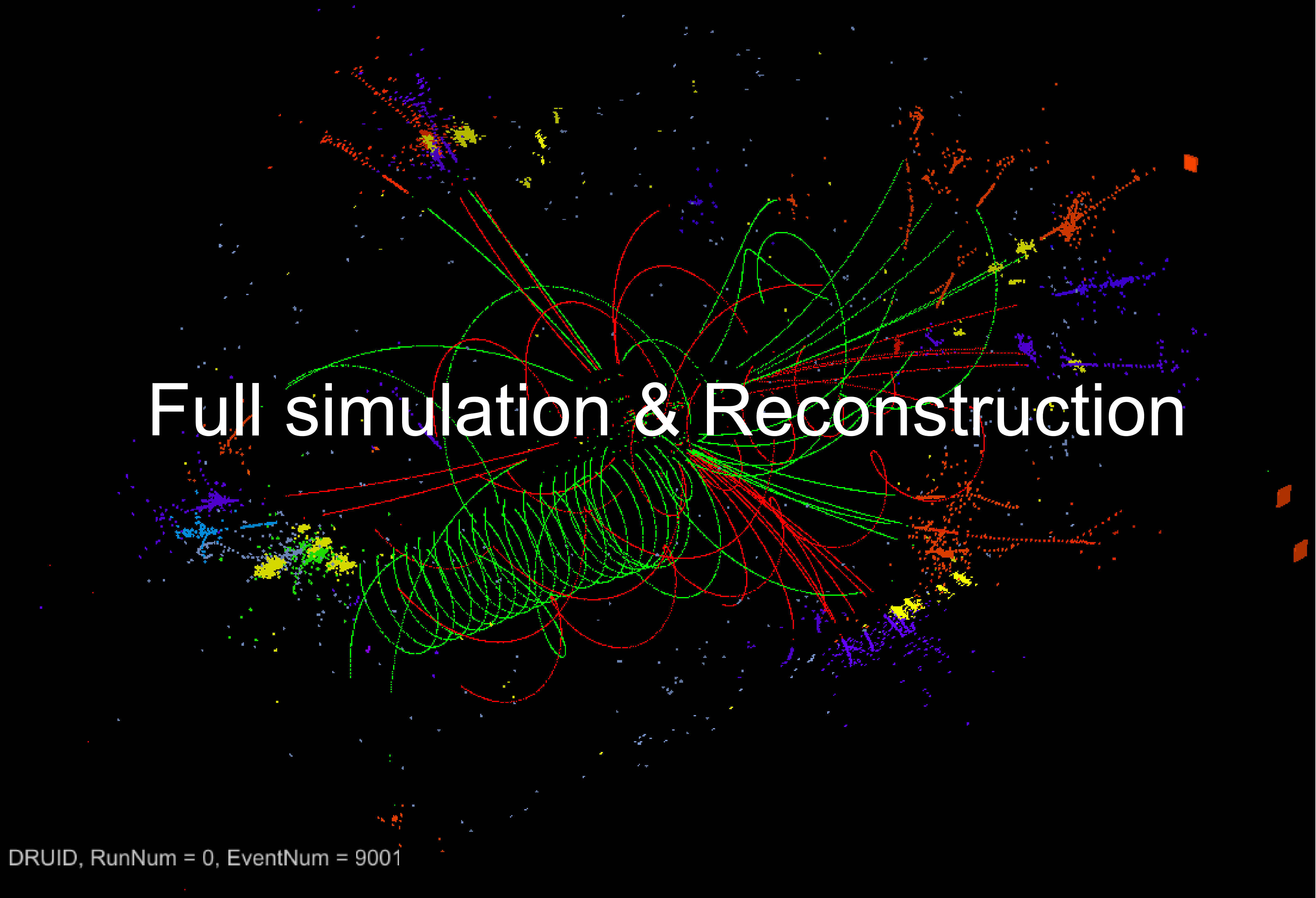
Full Simulation
/reconstruction

5/8 observables touched.
Remaining: Br(H->WW, tautau), spin

Priority:
Development & optimization on **PFA** and other reconstruction, recognition Algorithms on full simulation basis (preferably, after we summarize the knowledge from fast simulation...)

Need manpower & time!

Full simulation & Reconstruction



Full simulation

Started: 50 busy CPUs

Target geometry

- *Default one*
- *1-2 benchmark models (to be fixed)*

Tactics

- *Signal (~300k) at each model: 1 week (done)*
- *Background (~10M) at 1 model: 7 month...*
- *Fast simulation tools validation: Fast – Full Simulation comparison: enable extrapolation*
- *Reconstruction algorithm development, validation & optimization: hardcore*
  - ***PFA optimization***
  - ***Lepton id & Tau id***
  - ***Jet tagging & clustering...***

[manqi@lxslc508 ~]$ qstat -u yangy

pbssrv.ihep.ac.cn:

Job ID	Username	Queue	Jobname	SessID	NDS	TSK	Req'd Memory	Req'd Time	S	Elap Time
9671113.pbssrv.i	yangy	higgsq	sub_job16.sh	23831	--	--	--	--	R	20:25
9671114.pbssrv.i	yangy	higgsq	sub_job17.sh	10669	--	--	--	--	R	20:24
9671118.pbssrv.i	yangy	higgsq	sub_job21.sh	1319	--	--	--	--	R	20:25
9671120.pbssrv.i	yangy	higgsq	sub_job23.sh	10897	--	--	--	--	R	20:25
9671123.pbssrv.i	yangy	higgsq	sub_job26.sh	20671	--	--	--	--	R	20:25
9671126.pbssrv.i	yangy	higgsq	sub_job29.sh	11111	--	--	--	--	R	20:25
9671127.pbssrv.i	yangy	higgsq	sub_job30.sh	878	--	--	--	--	R	20:25
9671129.pbssrv.i	yangy	higgsq	sub_job32.sh	20941	--	--	--	--	R	20:21
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9681583.pbssrv.i	yangy	higgsq	sub_job1.sh	31591	--	--	--	--	R	09:48
9682037.pbssrv.i	yangy	higgsq	sub_job10.sh	24084	--	--	--	--	R	09:31
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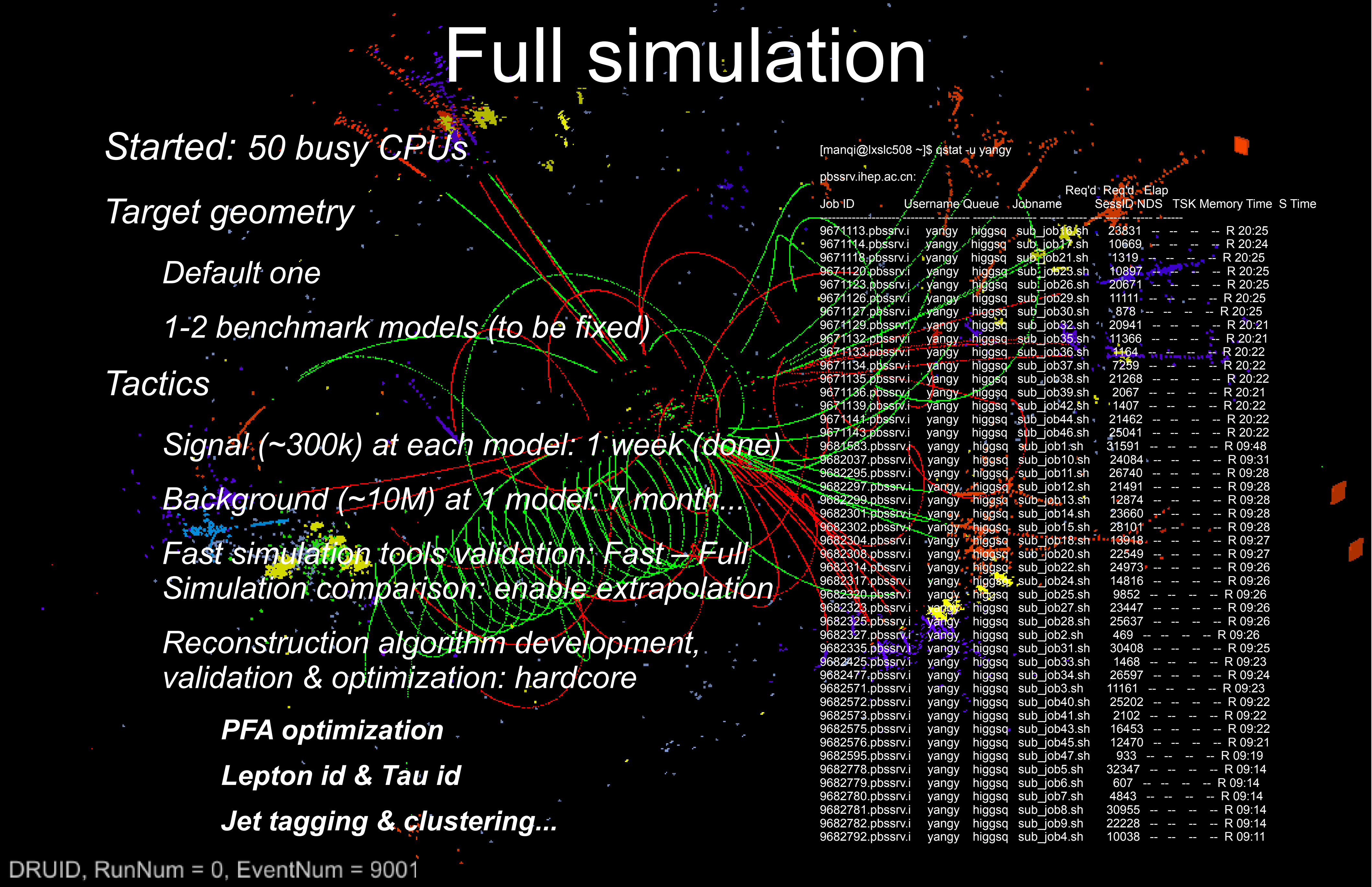
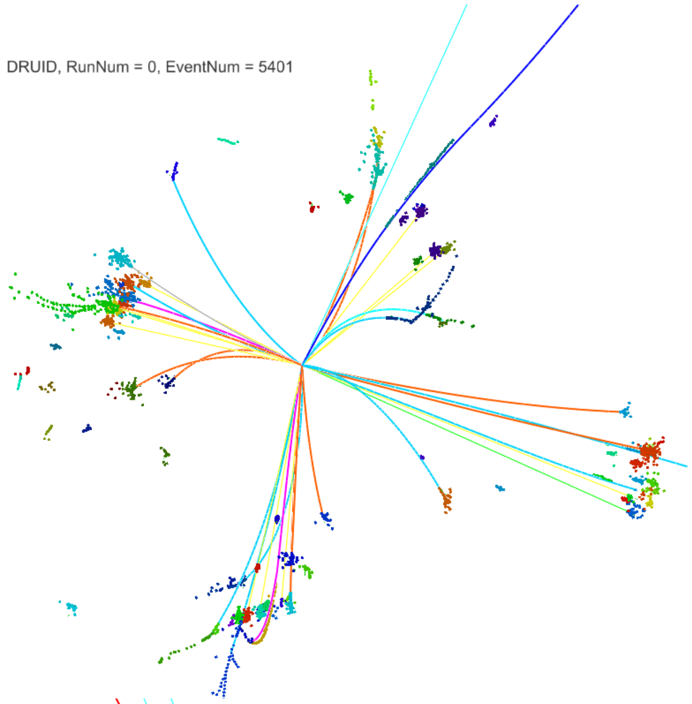
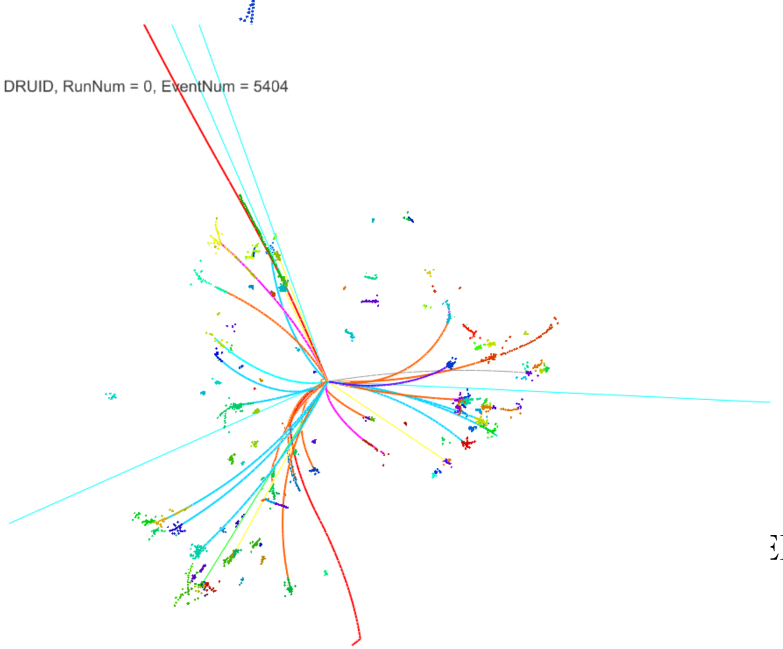
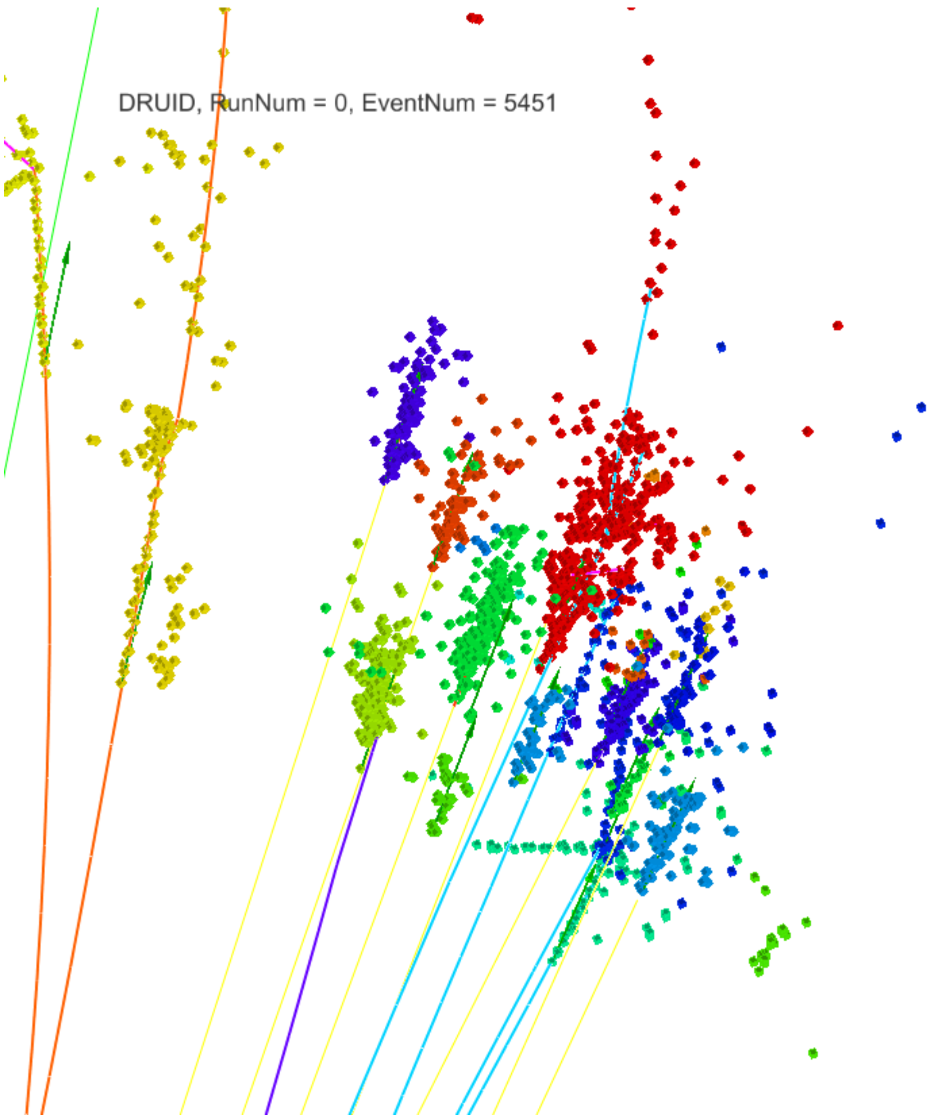
9682297.pbssrv.i	yangy	higgsq	sub_job12.sh	21491	--	--	--	--	R	09:28
9682299.pbssrv.i	yangy	higgsq	sub_job13.sh	12874	--	--	--	--	R	09:28
9682301.pbssrv.i	yangy	higgsq	sub_job14.sh	23660	--	--	--	--	R	09:28
9682302.pbssrv.i	yangy	higgsq	sub_job15.sh	28101	--	--	--	--	R	09:28
9682304.pbssrv.i	yangy	higgsq	sub_job18.sh	13918	--	--	--	--	R	09:27
9682308.pbssrv.i	yangy	higgsq	sub_job20.sh	22549	--	--	--	--	R	09:27
9682314.pbssrv.i	yangy	higgsq	sub_job22.sh	24973	--	--	--	--	R	09:26
9682317.pbssrv.i	yangy	higgsq	sub_job24.sh	14816	--	--	--	--	R	09:26
9682320.pbssrv.i	yangy	higgsq	sub_job25.sh	9852	--	--	--	--	R	09:26
9682323.pbssrv.i	yangy	higgsq	sub_job27.sh	23447	--	--	--	--	R	09:26
9682325.pbssrv.i	yangy	higgsq	sub_job28.sh	25637	--	--	--	--	R	09:26
9682327.pbssrv.i	yangy	higgsq	sub_job2.sh	469	--	--	--	--	R	09:26
9682335.pbssrv.i	yangy	higgsq	sub_job31.sh	30408	--	--	--	--	R	09:25
9682425.pbssrv.i	yangy	higgsq	sub_job33.sh	1468	--	--	--	--	R	09:23
9682477.pbssrv.i	yangy	higgsq	sub_job34.sh	26597	--	--	--	--	R	09:24
9682571.pbssrv.i	yangy	higgsq	sub_job3.sh	11161	--	--	--	--	R	09:23
9682572.pbssrv.i	yangy	higgsq	sub_job40.sh	25202	--	--	--	--	R	09:22
9682573.pbssrv.i	yangy	higgsq	sub_job41.sh	2102	--	--	--	--	R	09:22
9682575.pbssrv.i	yangy	higgsq	sub_job43.sh	16453	--	--	--	--	R	09:22
9682576.pbssrv.i	yangy	higgsq	sub_job45.sh	12470	--	--	--	--	R	09:21
9682595.pbssrv.i	yangy	higgsq	sub_job47.sh	933	--	--	--	--	R	09:19
9682778.pbssrv.i	yangy	higgsq	sub_job5.sh	32347	--	--	--	--	R	09:14
9682779.pbssrv.i	yangy	higgsq	sub_job6.sh	607	--	--	--	--	R	09:14
9682780.pbssrv.i	yangy	higgsq	sub_job7.sh	4843	--	--	--	--	R	09:14
9682781.pbssrv.i	yangy	higgsq	sub_job8.sh	30955	--	--	--	--	R	09:14
9682782.pbssrv.i	yangy	higgsq	sub_job9.sh	22228	--	--	--	--	R	09:14
9682792.pbssrv.i	yangy	higgsq	sub_job4.sh	10038	--	--	--	--	R	09:11



Reconstruction with Arbor



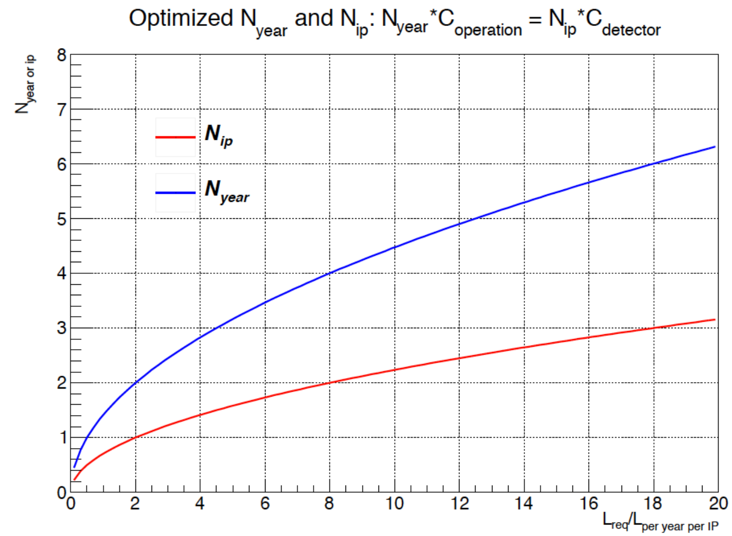




Principle: reconstruct every energetic final state particle

Open discussing

- *Operation program: 100 k Higgs, or more?*
  - *Electricity cost ~ 10^9 CNY/y (half a detector)*
    - *Site power 200 MW, $2*10^7$ s/y, 0.5 CNY/kwh*
  - *Objective: 100k Higgs, or more?*
    - *200 - 400 fb^{-1} per IP per year?*
    - *ILC: 250 fb^{-1}/5 year;*
    - *LEP3: 100 fb^{-1}/(year*IP), 2 ab^{-1} with 4 IP.*
    - *TLEP: 10 ab^{-1}*
- *Detector: as precise as possible*
  - *hardware + reconstruction*
- ***Detector geometry**: tell me your concern!*
- ***Logo & Name?***



	ILC-250	TLEP-240
σ_{HZ}	2.5%	0.4%
$\sigma_{HZ}\times BR(H\to bb)$	1.0%	0.1%
$\sigma_{HZ}\times BR(H\to cc)$	6.9%	1.3%
$\sigma_{HZ}\times BR(H\to gg)$	8.5%	1.4%
$\sigma_{HZ}\times BR(H\to WW^*)$	8.0%	0.9%
$\sigma_{HZ}\times BR(H\to \tau\tau)$	5.0%	0.9%
$\sigma_{HZ}\times BR(H\to ZZ^*)$	28%	3.1%
$\sigma_{HZ}\times BR(H\to \gamma\gamma)$	27%	3.0%
$\sigma_{HZ}\times BR(H\to \mu\mu)$	–	13%
Γ_{INV} / Γ_H	< 1.5%	< 0.3%
m_H	40 MeV	8 MeV
	ILC-350	TLEP-350
$\sigma_{WW\to H}$	3%	0.5%
Γ_H	5.5%	1.1%