Physics Requirement and Simulation Status Report

Gang Li (IHEP)
Manqi Ruan (IHEP)
Dayong Wang (PKU)

On behalf of the group

2014.9.12 Shanghai

Team and training activities

- Training interested people to form the team

- Another dedicated school on GEANT4/Mokka @Nankai Aug11-15, 2014
- Part of iSTEP2014

two-day training in Oct 2013

GEANT4/Mokka School@ Nankai, Aug11-15 2014

Closing ceremony

iSTEP 2014, Aug20-29 2014

Outline

- Simuation and reconstruction chain
  - key areas of technologies
  - status, major challenges and plans
  - addressed by Plenary talks
    - Interaction region and MDI
    - Computing
- Demonstration of Physics potential
  - Higgs measureeants with ongoing fastsim/Fullsim studies
  - EW physics potential @Z and physics@ WW
- Pre-CDR Status and timeline
- Summary

Overall Strategy of Detector Design

- ILC detectors, especially ILD as a reference
- Special issues
  - –Power pulsing not possible:
    - more cooling and/or less channels?
  - –Due to lower c.m.s. energy:
    - smaller detector
    - very fine granularity not necessary?
  - –L* = 1.5m or 2.5m (cf. 3.5m at ILC)
    - less solid angle coverage
    - special considerations at the interaction region
- "The detector" in pre-CDR
  - –Similar performance as ILD for the physics to be addressed
  - –(Hopefully) less technology challenges than ILD

Simulation: baseline starting from ILC

- Fastsim based on Baseline requirements
  - VTX：space resolution: ~5 um
  - TPC + Inner Tracking: delta(1/P)~ 5e-5 (1/GeV)
  - Calo: accurate shower sepration, good particle ID，jet energy resolution 3 - 4%
  - Others: Power consumption, data-taking rate etc
- FullSim consider many new designs for CEPC:
  - Changed granularity
  - Changed L*
  - Changed VTX inner radius
  - **Changed TPC outer Radius**
  - Changed Detector Half Z
  - Changed Yoke/Muon thickness
  - Changed Sub detector design
  - …

→ Cepc_v0 in production

- All these items be optimized based on simulation, iterate with physics analysis (Fast – Full Simulation) and cost estimation
- Next benchmark: cepc_v1: L*=1.5m, no scaling

Processing to Full Simulation

- Geometry: modifying as we want
- Full Reconstruction: adjusting to new geometries
- Sample:
  - Signal (o(100 k)): Full Simulated, reconstructed and Validated
    - ILD, and ILD with Smaller L*: Validated
    - Smaller L* & Smaller TPC: In Validating, minor unexpected pattern emerge
    - ...
  - Background:
    - ILC Reconstructed DST file
    - Fast simulated
- Tactic:
  - Accomplish the analysis at ILD & Smaller L* ILD, then process to further modified version
  - Process background Full Simulation once we got enough computing resource

Simulation: Key technologies

		Cooperation	Comments
BeamBk & MDI	GunieaPig,	?	Need iterate with Acc group
Generator	Madgraph		Very limited manpower
	Whizard	contact author	Validation phase
	Geant 4 - Mokka		Relatively strongly supported
Simulation	Delphes		Very limited manpower
	Dedicated cepc	author	Using Ideal PFA approach
	Tracking		Optimization phase, man
Reconstruction	PFA		power consumer
	FlavorTagging		Validation phase
Analysis	Generic tool	-	Waiting for full - reco sample
	Combination	Author, adjusting	
Computing	Distributed		Tested, adjusting to cepc
Software Framework			Initialized, to understand, follow recent development

Contact person needed for each sub group

	Technology	People	Core+St	~FTE	Level
BeamBk & MDI	GunieaPig, etc	朱宏博，修青磊	2 + 0 (?)	1.2	User
Generator	Madgraph	晏启树，李强	2 + 2	0.2	
	Whizard	李刚，莫欣	2 + 0	0.6	
	Geant 4 - Mokka	徐音，谌勋	2 + 3	1	
Simulation	Delphes	晏启树，李强	2 + 2	0.1	
	Dedicated cepc	李刚，曼奇，振兴	2 + 1	0.3	Deve
	Tracking	李波，灵慧，北江	3 + 1	1.5	
Reconstruction	PFA	曼奇，曈光	2 + 0	0.9	
	Flavor Tagging	李刚	1 + 0	0.3	
Analysis	Generic tool	李刚	1 + 0	0.2	Deve
	Combination	方亚泉，陈明水	2 + 4	0.8	
Computing	Distributed	张晓梅，颜田		1	
Software Framework		邹佳恒，谌勋 陈江川，张瑶	4	?	Learning/ following

Generator & Fast Simulation

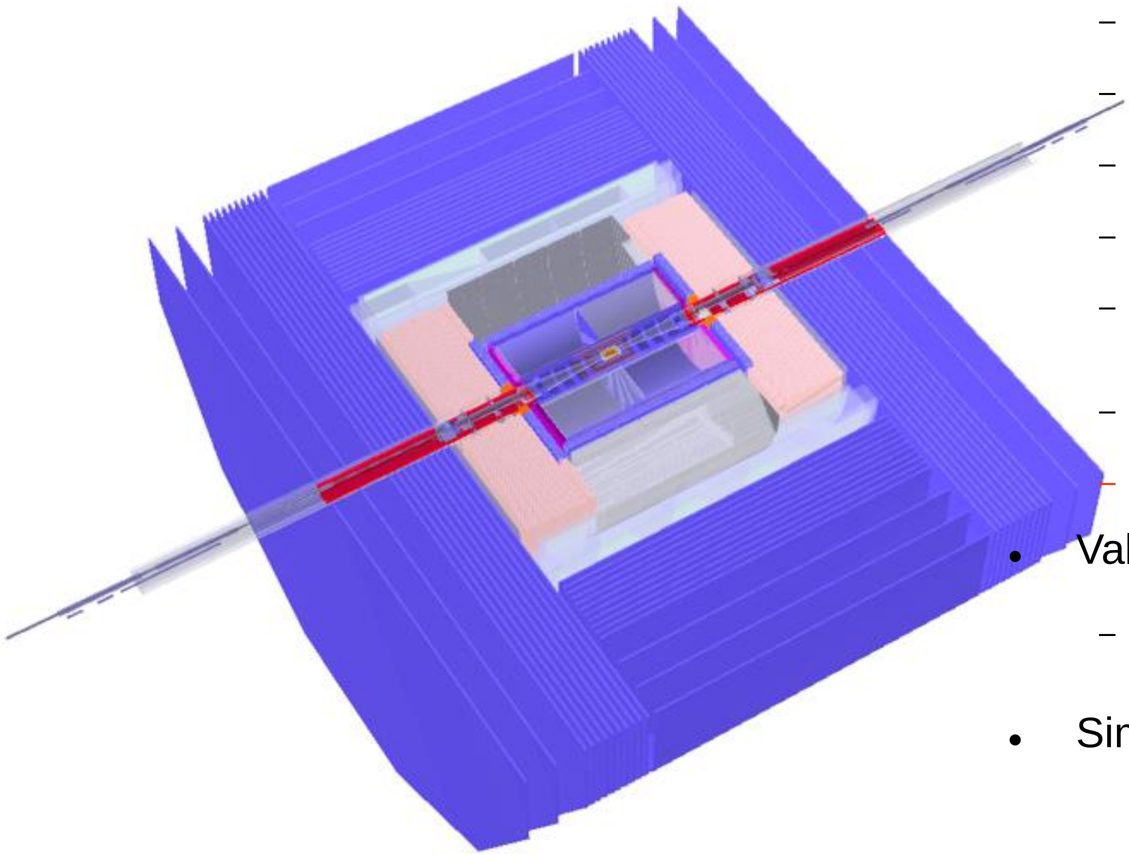
- Existing tool: Whizard, Madgraph; Delphes & CEPC_FS
- Team & cooperations
  - Yan qishu & Li qiang's team, Mo xin (PostDoc at IHEP), Xiu Qinglei
  - 1 extra experienced FTE + 1-2 Ph.D is needed
  - Contact with the author (Wolfgang)
- Goal
  - Short term: professional users that can provide right sample
    - A reference sample (wi/wo Beamstrahlung) will be provided by the end of October with the latest version of Whizard
  - Middle term: contribute to the src code
    - Synergies with theoretic studies
    - Communication with SPPC detector R & D
- CEPC_FS (*indispensable for CEPC Z pole & SPPC studies, of great help to detector optimization*): Generic Fast Simulation/Analysis Framework. Li gang, Chen Zhenxing, WEI yuqian

Geant 4 Simulation

- Existing tool: Mokka: mysql-based Geant 4 simulation toolkit
- Goal
  - ✓ Modify code at src code level (**achieved**)
  - ✓ Develop, upgrade and integrate src code according to Sub-D studies
  - ✓ Maintenance: source code & mysql DB
- Team
  - ✓ Yu chunxu, Xu yin (Nankai U's team), Chen xun (SJTU)
  - ✓ Trained people at each sub detector group
  - ✓ Students
- Cooperations: in contact with Mokka team (Emilia Bevache)
- Toward the future: follow the development of generic geometry tool, 0.5 extra FTE needed

...Successful combination of ILD expertise and Local Geant 4 expertise...

Detector design: ILD → cepc_v0

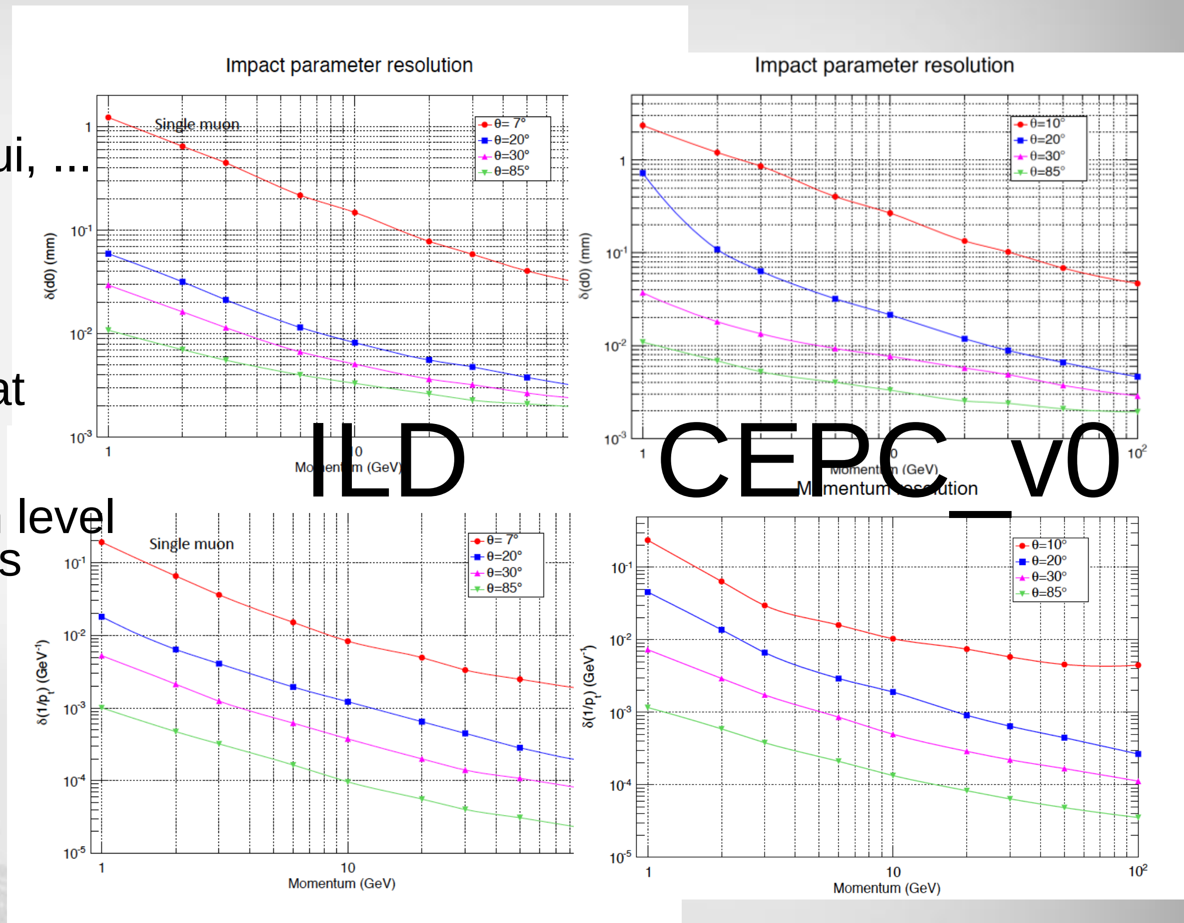


- Geometry changes
  - TPC Radius 1808 → 1365 mm (?)
  - TPC Half Z 2350 → 1900 mm (?)
  - HCAL Layer Num: 48 → 40 (?)
  - ECAL Layer Num: 30 → 16 (?)
  - ECAL/HCAL Cell Size: 5/10 mm → 20 mm (?)
  - B Field: 3.5 T → 3 T (?)
  - **L*: 3.5 m → 1.5 m**
- Validation:
  - How much luminosity we can achieve with L* = 1.5 m ???
- Simulation: Geometry implemented

See Xuyin & Chenxun's talk
Appreciation to Emilia, LLR

Reconstruction: Tracking

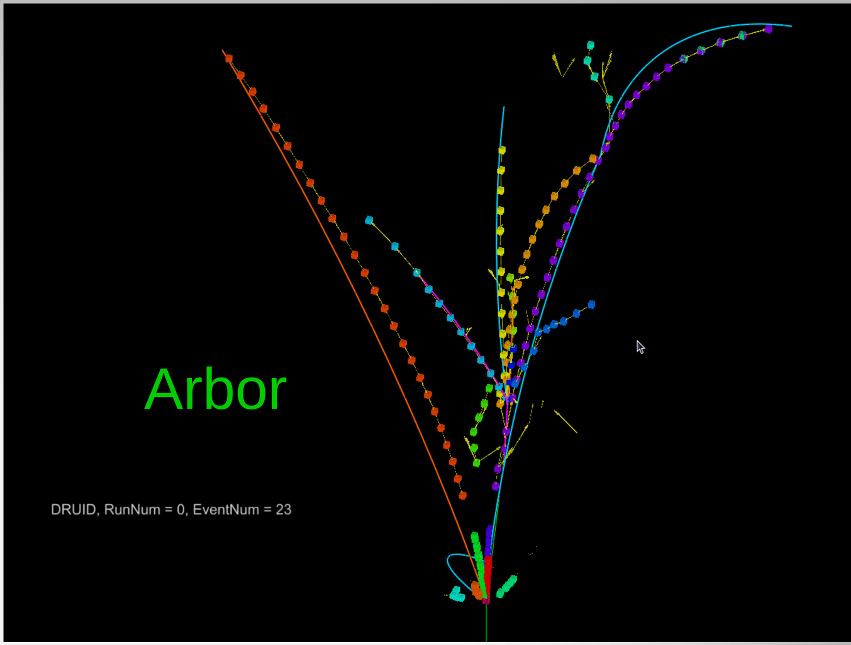
- We have expertise
  - ILC: Li Bo
  - BES: Liangliang, Linghui, ...
- Focus
  - performance analysis at cepc_v0
    - Tracker level
    - Full Reconstruction level
  - FTD Designs, fragments merging algorithm
- Goal
  - Validate the design in 2 month,
  - iterate the detector design with detector simulation, tracker performance analysis and recon chain optimization

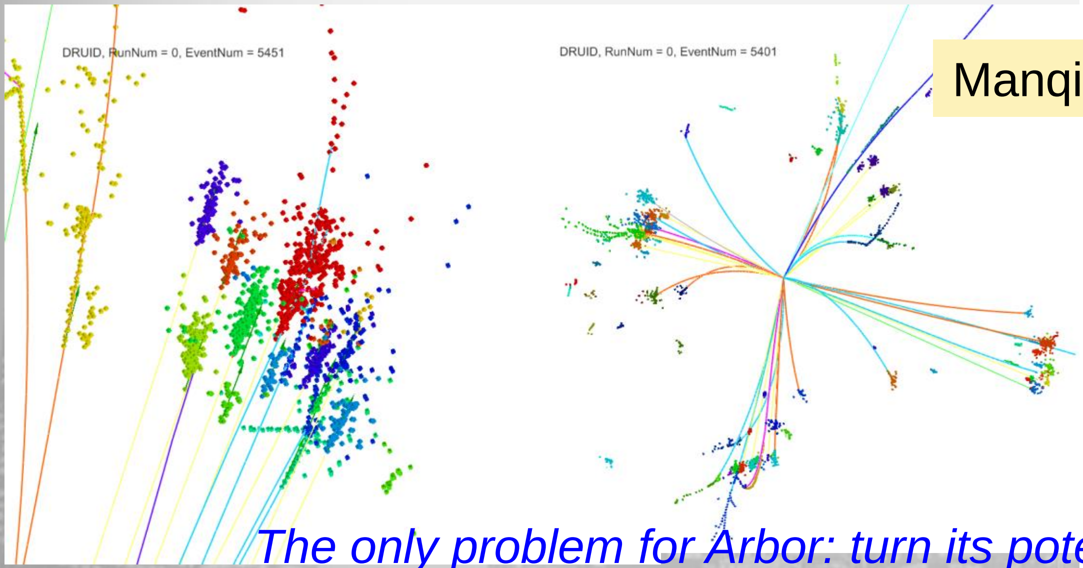


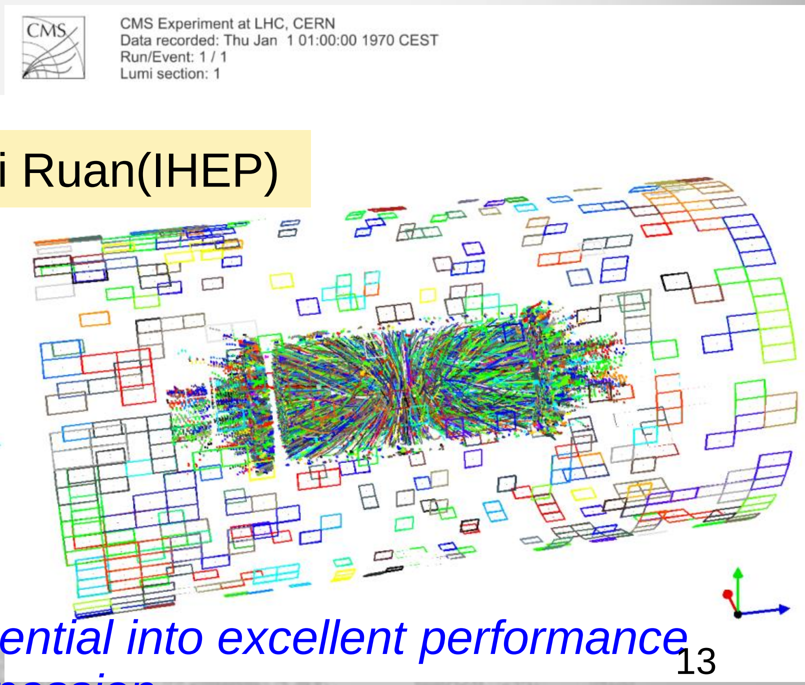
Libo, yuqian, et al: working hard to understand the difference

Reconstruction step
Arbor PFA

- generic PFA to future
  - Excellent separation & sub-shower structure recognition
  - Clear physics interpretation
- breakthrough at speed: < 1min to process an event with ~100k hits (eg, CMS detector with 140 Pile up)
- applying to Full Simulation at CEPC



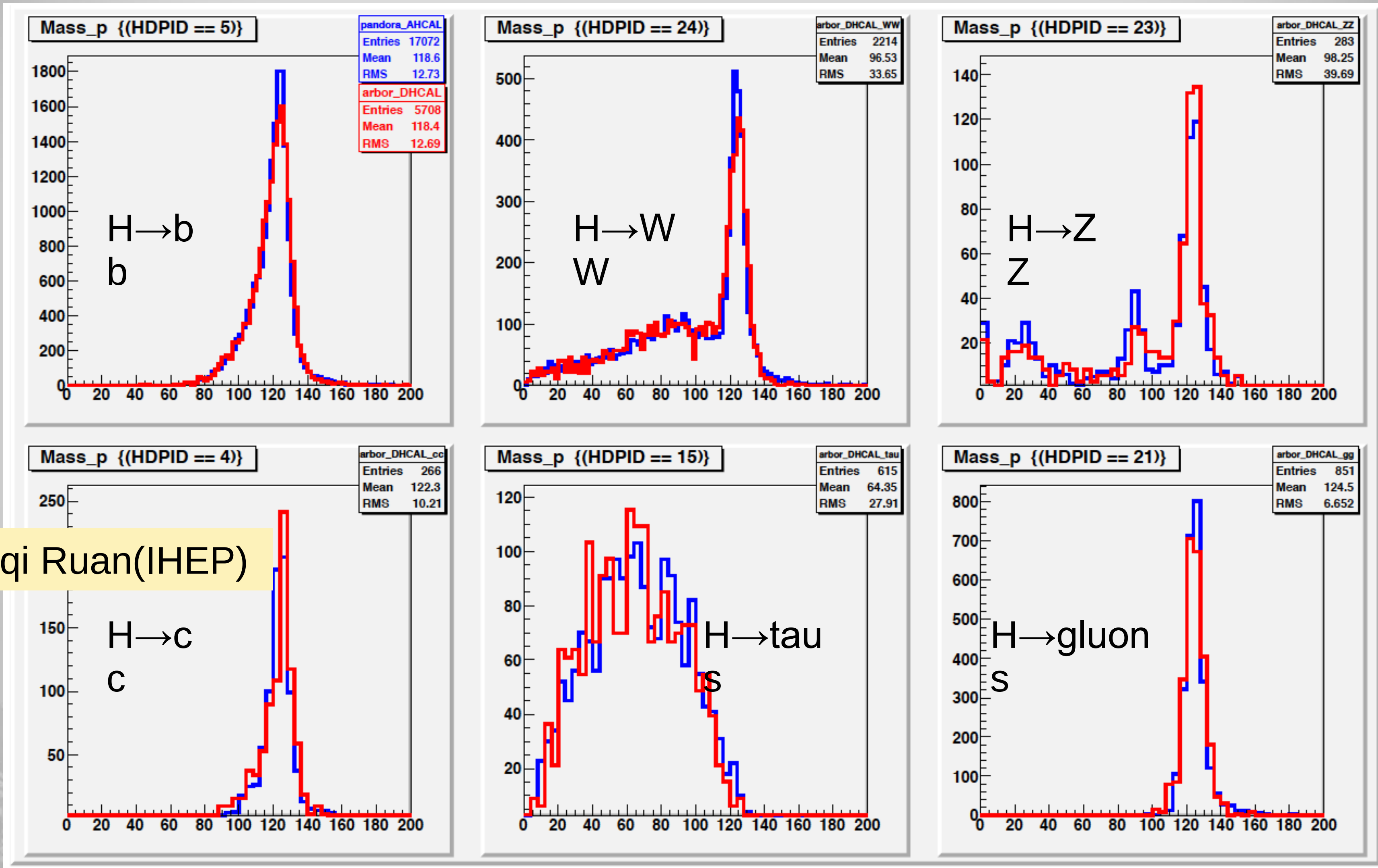




Manqi Ruan(IHEP)

The only problem for Arbor: turn its potential into excellent performance
time, patient & passion...

Arbor vs Pandora



Manqi Ruan(IHEP)

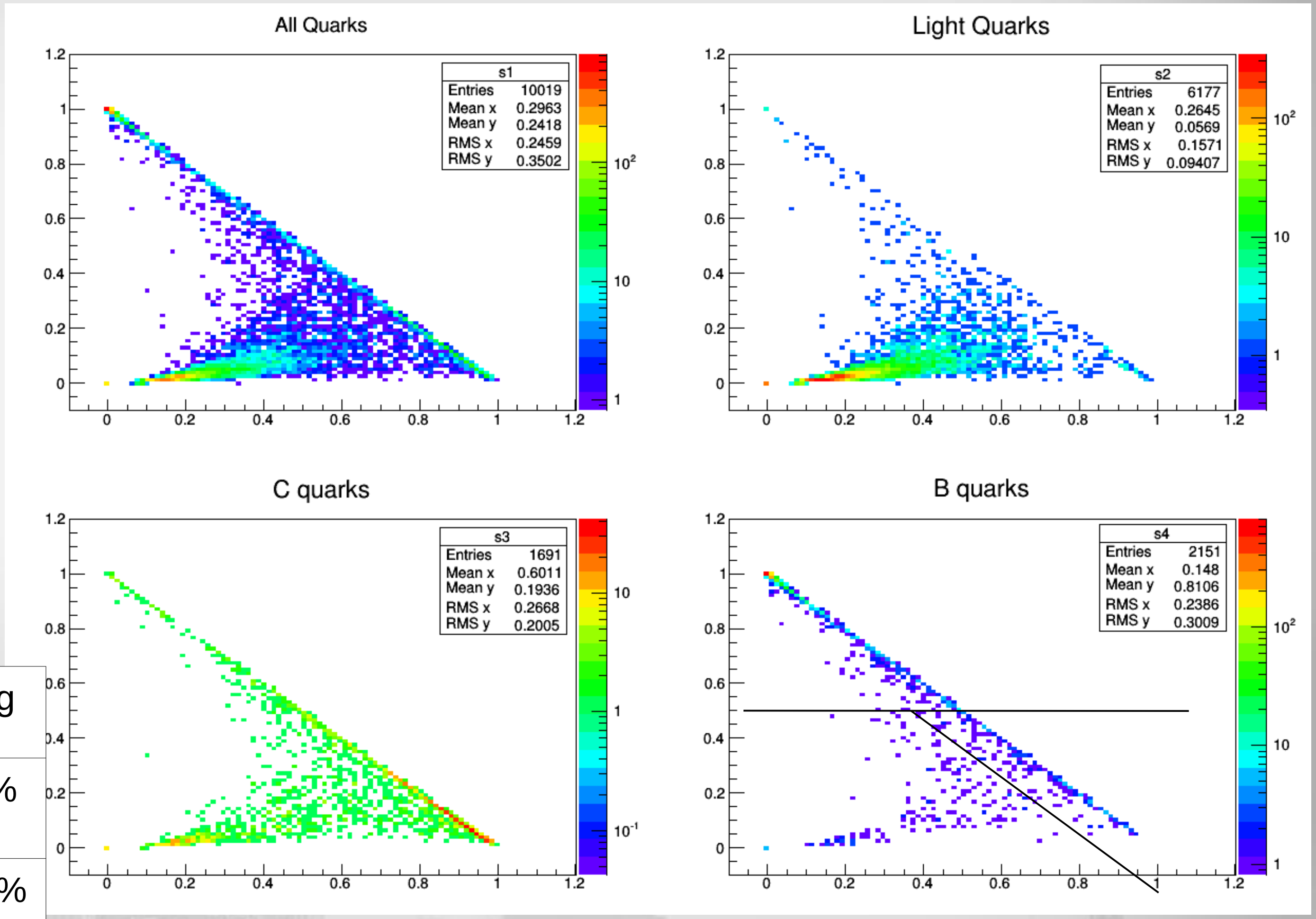
Arbor Uses GRPC Hadron Calorimeter, whose intrinsic resolution – based on current energy estimator is worse than that Pandora Used (Scintillator Tile Analogy HCAL).

Flavor tagging

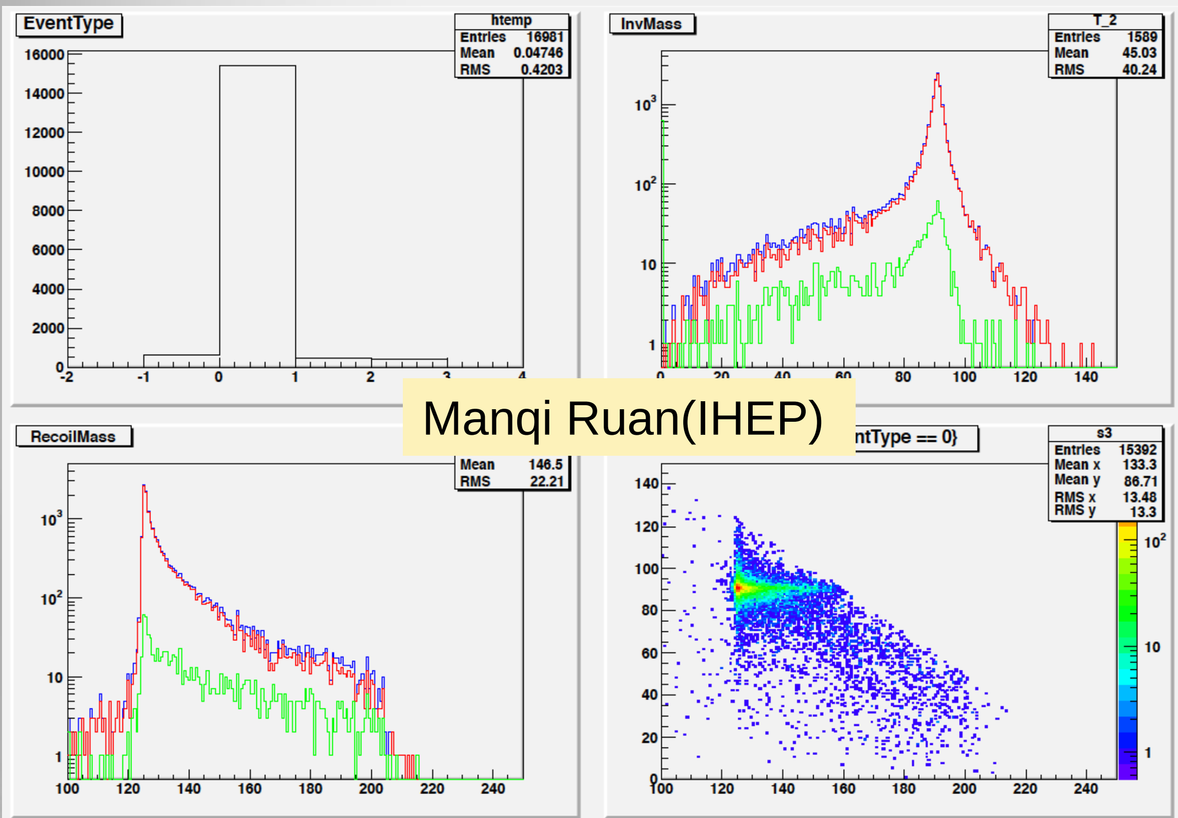
- Gang: LCFI is working now – need to see if it works as expected
- Jet Clustering is also an issue...

An example non-loss Migration Matrix

	b	c	udsg
b	81.8%	9.3%	8.9%
c	9.0%	50.2%	40.7%
udsg	0.96%	1.9%	97.2%



Full Simulation: Muon Tagging



Manqi Ruan(IHEP)

Arbor & Pandora give similar muon ID performance with M_Z cut (Wenzhao. Liang,SJTU)

- Efficiency (single muon)
  - Arbor: ~ Pandora:
  - Need to investigate further and try to recover lost muons
    - Optimization within Arbor?
- Purity (single muon)
  - Arbor: ~100%, Pandora: ~100%

Arbor result from Manqi:
Single Muon Tagging efficiency (including acceptance) ~ 97%

Software framework

- ILCSoft is workable, but at longterm, we need new software framework
  - Efficient: parallel-able, distributable, data size control
  - Flexible: python control
  - Transparent: clear & neat architectures
  - General: i.e, generic geometry description
  - Extendable.
- Goal:
  - Create SVN/Git service, Maintain & test software releases
  - To understand the key requirement for software chains
  - Follow the development of future softwares
- Team: Chen Jiangchuan, Zou jiaheng, Zhang yao & Chen Xun (SJTU)

Beam background & MDI design

- Beam energy/spatial spread, beam photon energy spectrum, Radiation background & Flux spatial distribution
  - Beamstrahlung photons & Photon to electron/positron (Guineapig)

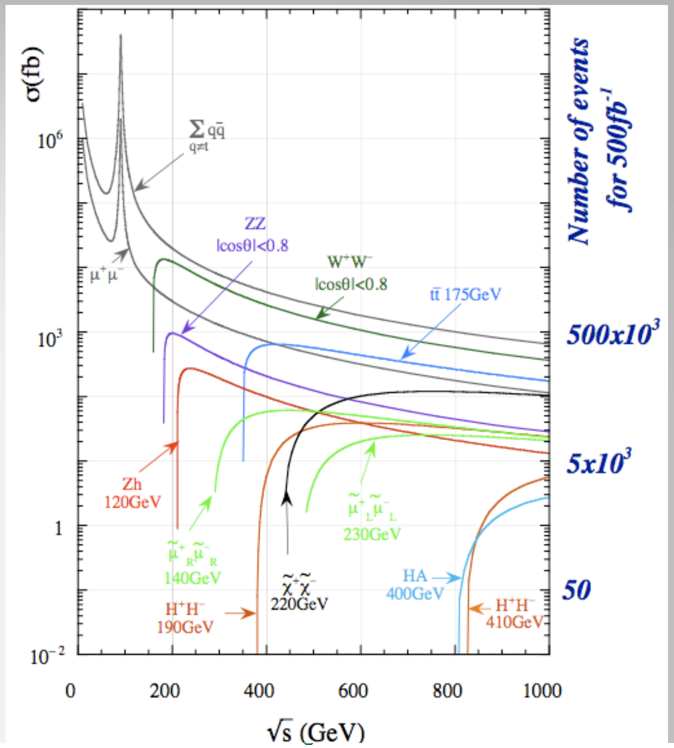
Number of primary background particles from Beamstrahlung of CEPC is about 5% of ILC (Qinglei)

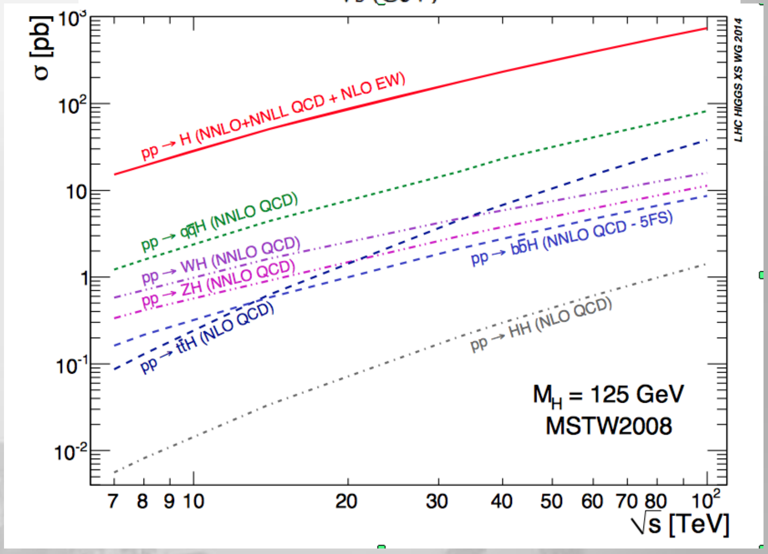
More details see Hongbo&Yiwei's talk tomorrow

  - Photon to hadrons (Mini Jets)
  - Neutron Flux (Fluka, a must for SPPC detector design)
  - Crucial for interaction region design
- Team
  - Need to efficiency communicate with accelerator team
  - Discussion with MDI experts is needed
  - Activity should be enhanced: at least 1 extra FTE is needed, to have an reliable MDI design
- Goal:
  - **A reasonable IP region design with head-on beam in 2-3 month?**

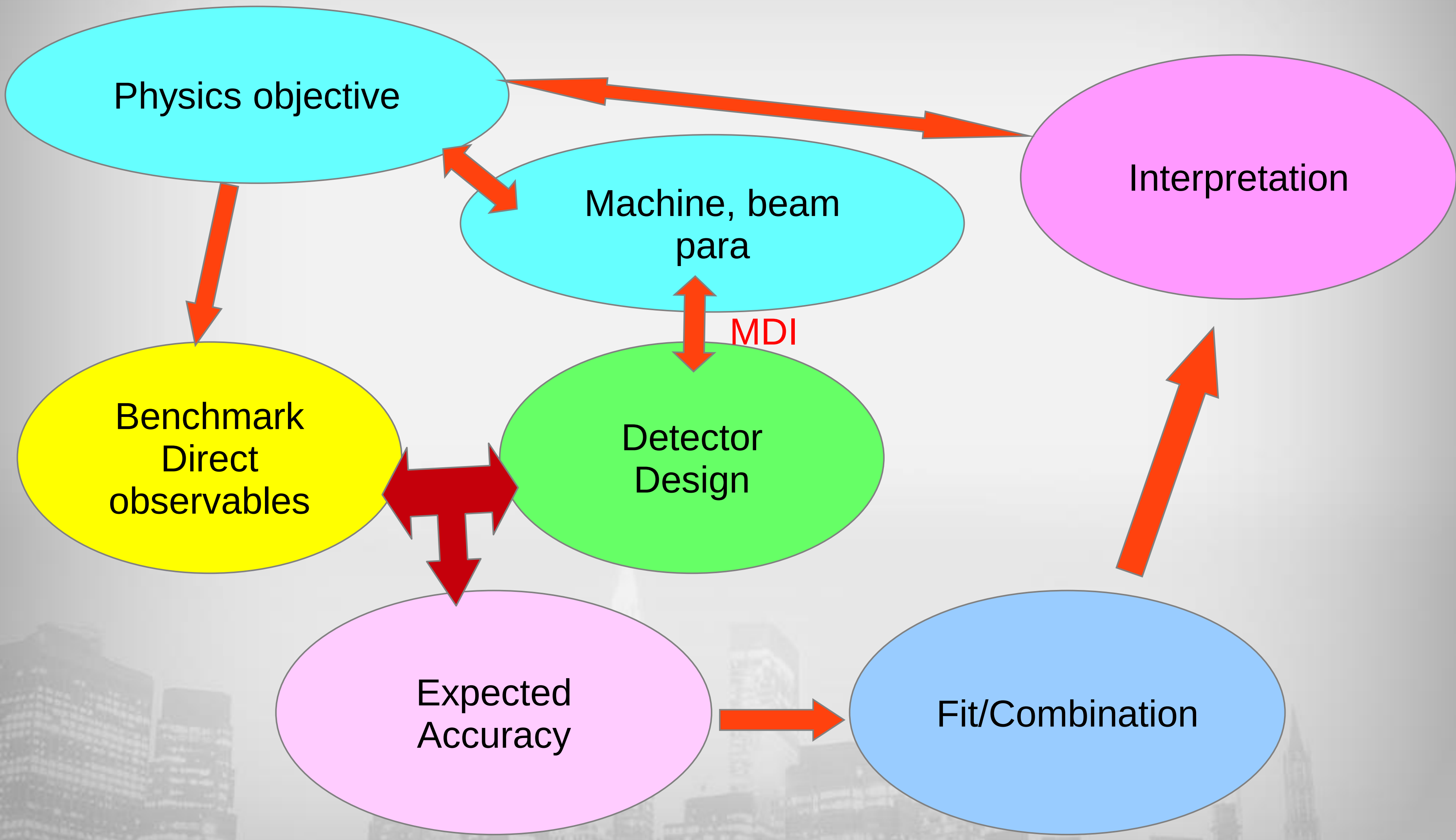
Resource & Distributed Computing

- Some Number:
  - CEPC: 10^6 Higgs, 10^8 Physics event, 10^{12} Z
  - SPPC: 10^{10} Higgs, 10^{12} top
  - o(1k) CPUs, o(PB) storage is needed (and dedicated Fast Simulation tool)
- Status: 10% of our demands
  - o(100) CPUs & 100 T storage at IHEP
  - Applying similar amount now
  - participants are expected to contribute
- Distributed computing could be one way to easily coordinates distanced resources
  - Successfully tested locally (at WhU, Many Thanks!) See Xiaomei Zhang, Tian Yan (IHEP) talk this morning





Demonstration of Physics potential

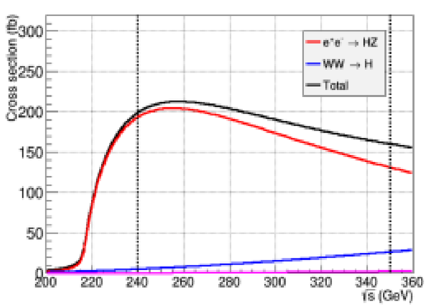


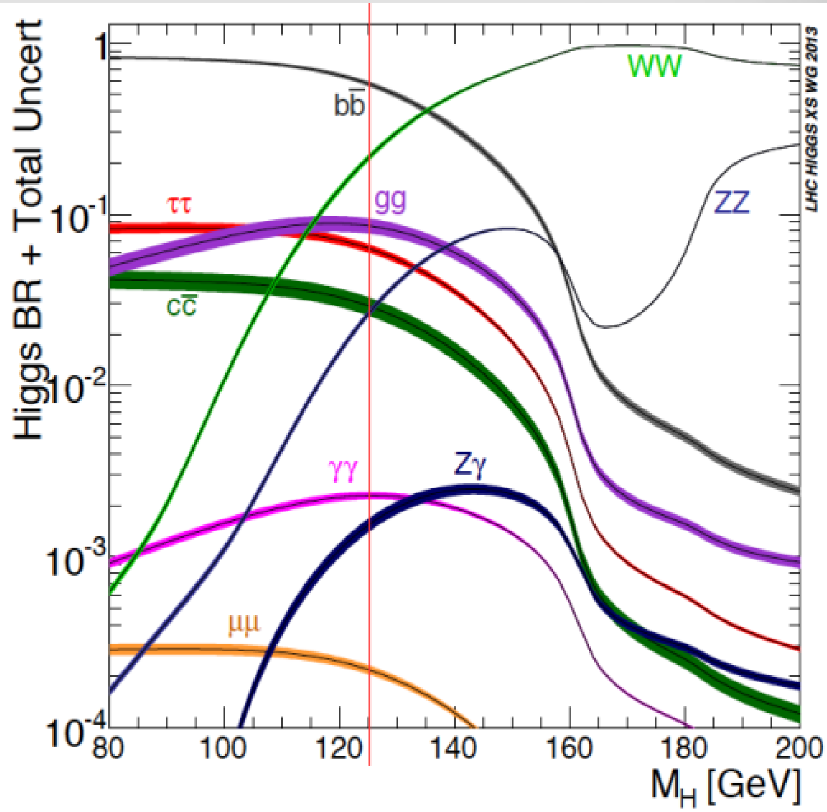
SM Higgs Observables at CEPC

Mass, spin, σ(ZH):
model independent measurement of g(HZZ)

σ(ZH)/σ(vvH)*Br(H→X)

Access to the absolute value of Higgs width, Br(H→inv) and all the couplings

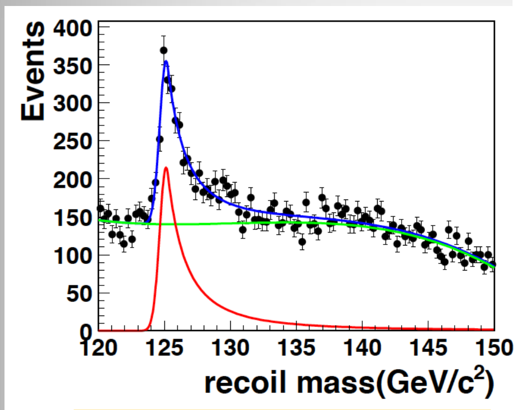




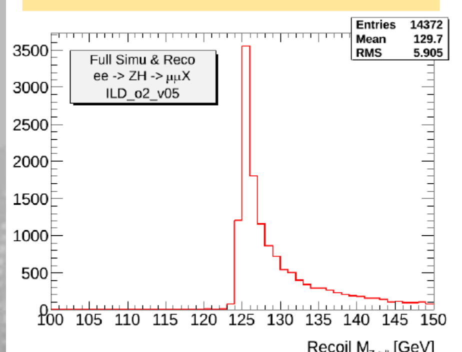
Mode	$b\bar{b}$	$c\bar{c}$	gg	WW^*	$\mu^+\mu^-$	$\tau^+\tau^-$	ZZ^*	$\gamma\gamma$	$Z\gamma$
BR (%)	57.8	2.7	8.6	21.6	0.02	6.4	2.7	0.23	0.16
	g(Hbb),	g(Hcc),	g(Htt),	g(HWW)/Γ_H,	g(Hμμ),	g(Hττ),	g(HZZ)/Γ_H,	g(HWW)/g(Htt)	

Major analyses on Higgs covered

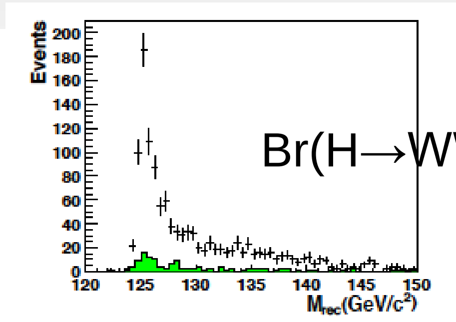
Higgs
recoil mass & Xsec

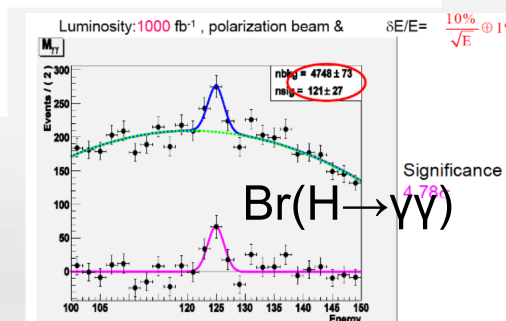


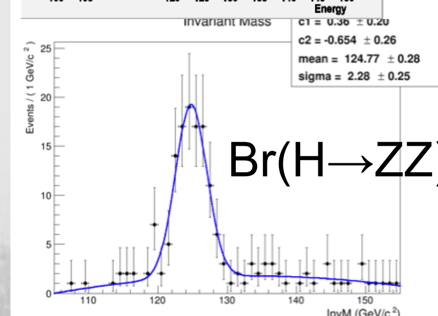
→Recoil Mass of Z → μμ
Mean = 129.7 GeV
RMS = 5.9 GeV



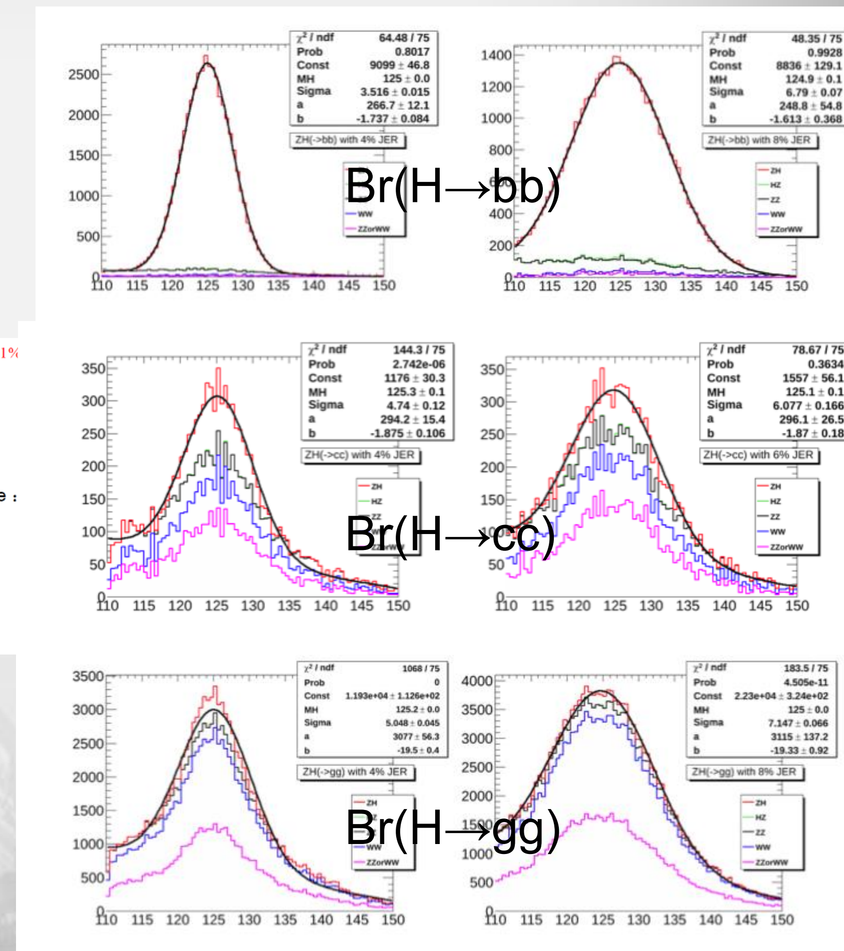
Br(H→bosons)







Br(H→2 jets)



Higgs analysis at CEPC

Optimistic Perspective
By the end of 2014

To be validated by Full Simulation

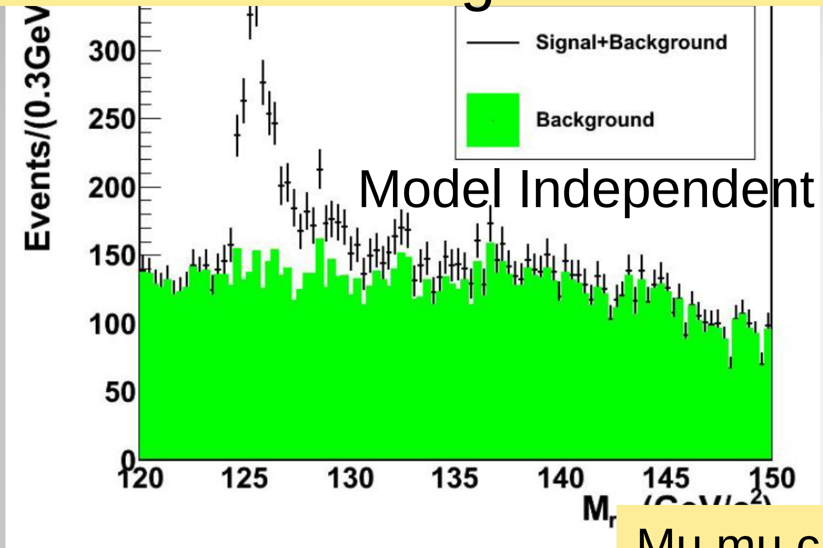
Fast Simulation Level

	CEPC @ 5 ab^{-1}	Current Status	Responsable & perspective
mH (Model Independent)	8 MeV	12 MeV (μμH)	IHEP, CCNU
σ(ZH)	0.7 %	1.2 %	IHEP, CCNU
Higgs CP		Theoretically Investigated	THU, HKU
Δ(σ*Br)/(σ*Br)			
ZH, H→bb	0.4%	0.22% (qqH channel)	SJTU, IHEP
H→cc	2.1%	2.2 – 2.8%	SJTU, IHEP
H→gg	1.8%	1.8 – 2.4%	SJTU, IHEP
H→WW*	**1.3%**		IHEP, PKU
H→ττ	1.2%	Efforts initialized	IHEP, USTC
H→ZZ*	5.1%		SDU
H→γγ	8%	~ 12% (ννH)	WhU, IHEP
H→μμ	?		UCAS, IHEP
H→Inv.	0.3%		IHEP, HKU, HKUST
ννH, H→bb	**3.8%**	Efforts initialized	PKU, IHEP

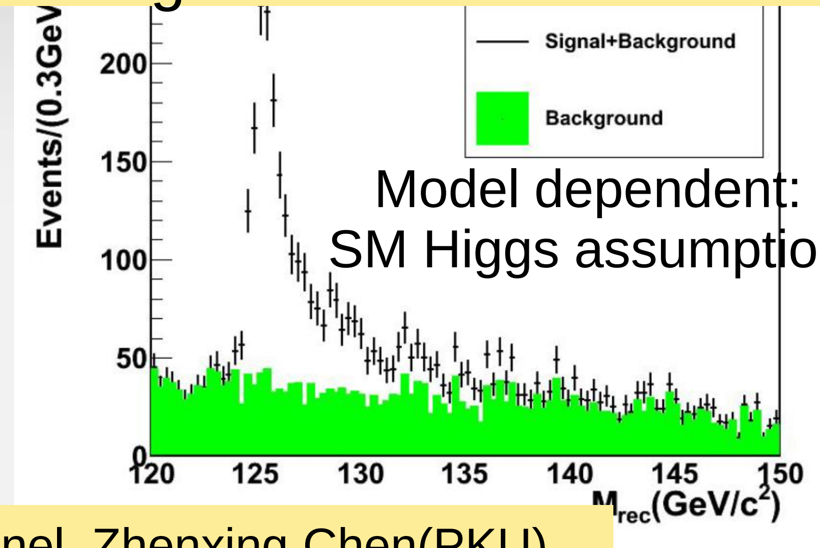
23

Higgs mass & Cross section

FullSim Signal + FastSim Background at 500 fb^{-1}



Model Independent



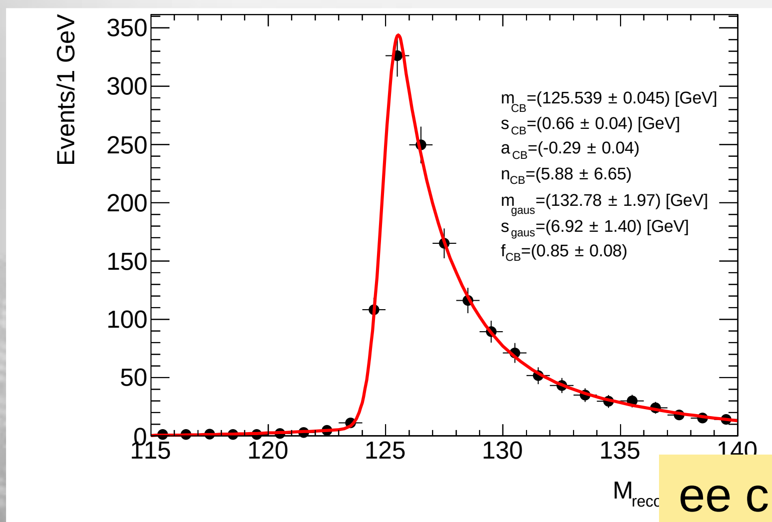
Model dependent:
SM Higgs assumption

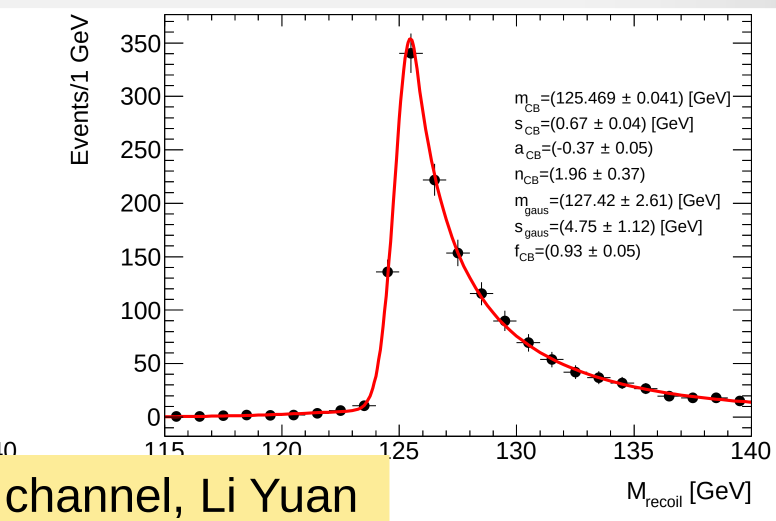
Mu mu channel, Zhenxing Chen(PKU)

R_{TPC}: 1365 mm

R_{TPC}: 1808 mm

24



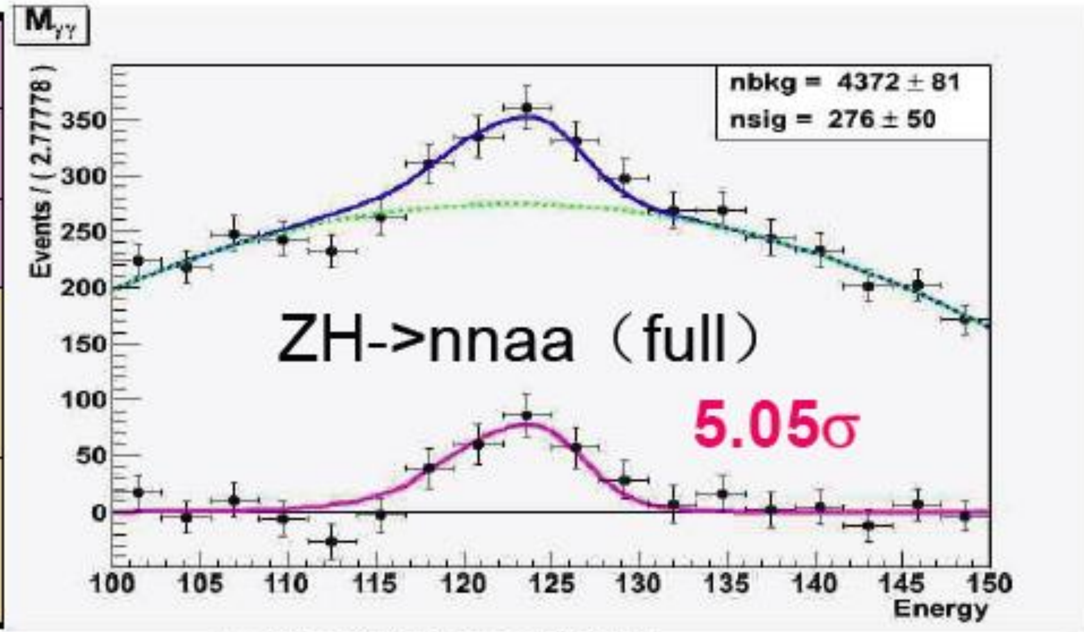


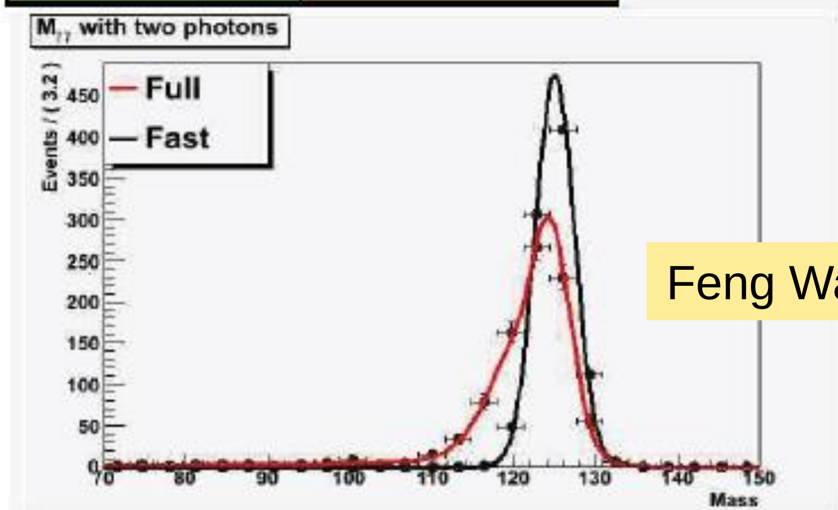
ee channel, Li Yuan

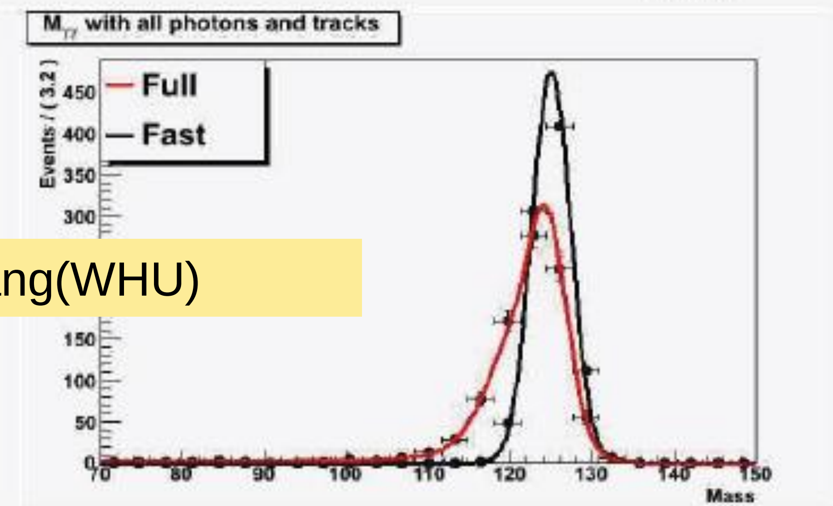
H→di photon

Better ECAL is needed!

ZH->qqaa&nnaa(fast)	
Luminosity: $5ab^{-1}$	
δE/E	Significnce
$\frac{10\%}{\sqrt{E}} \oplus 1\%$	9.96σ
$\frac{16\%}{\sqrt{E}} \oplus 1\%$	6.82σ



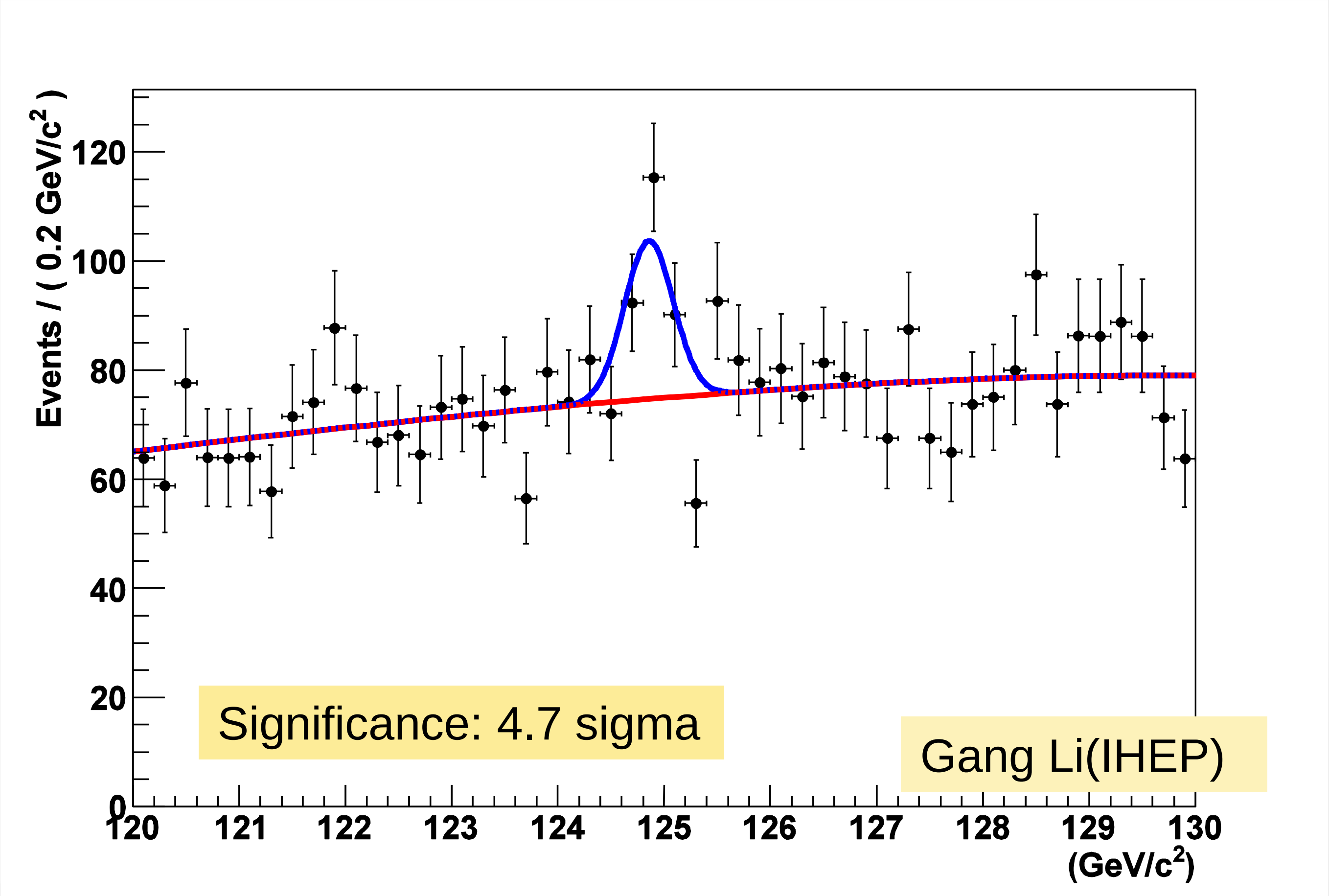




Feng Wang(WHU)

Optimization are certainly needed in every aspects!...
Actually poses very strict constrain to ECAL design

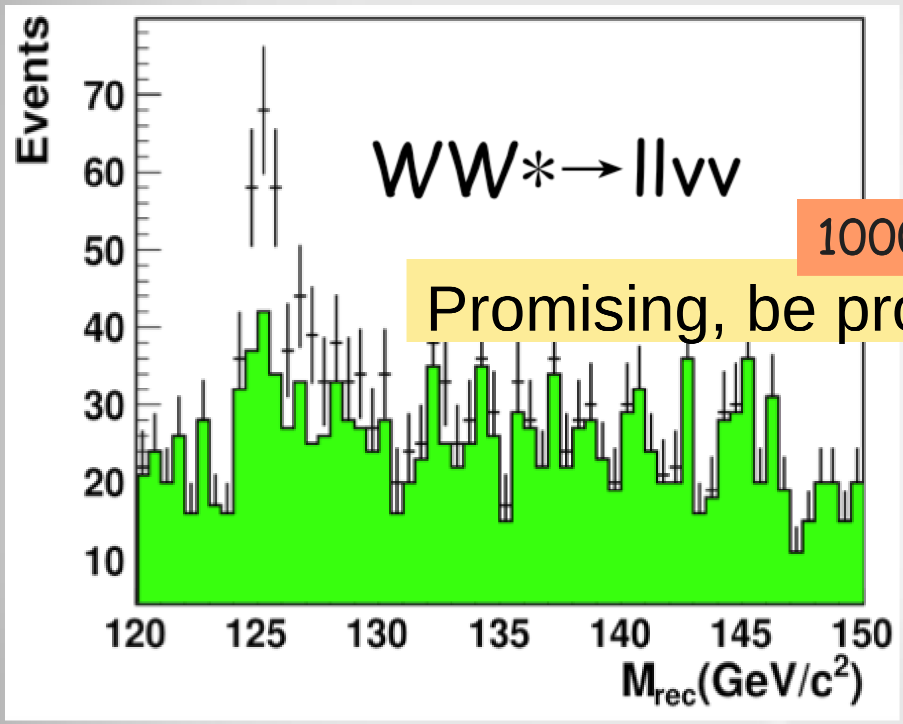
H->mu mu

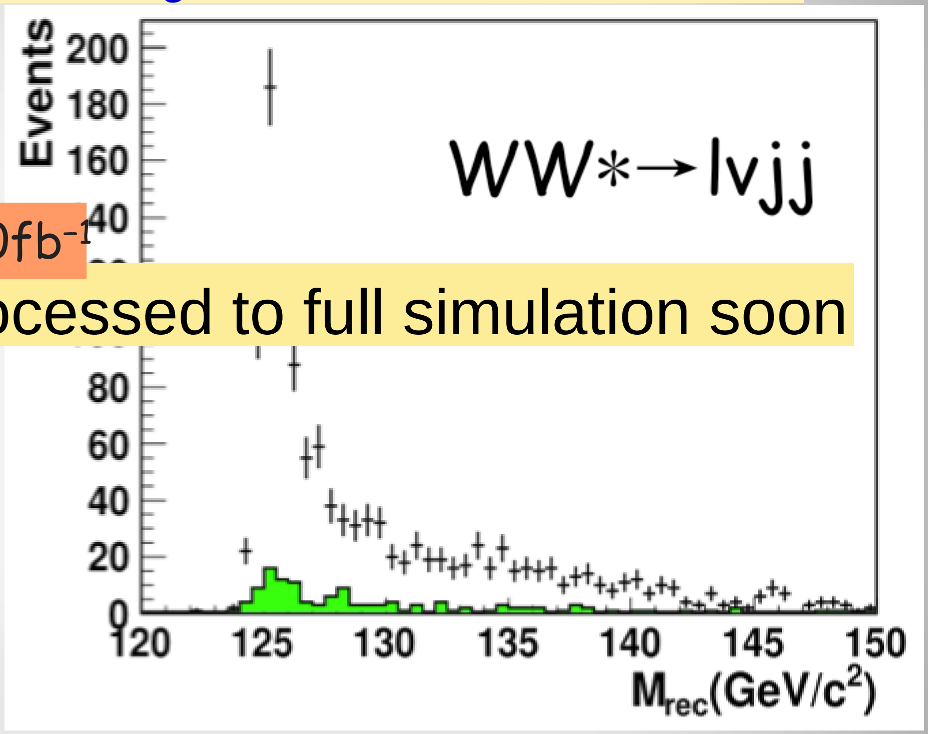


Better tracking is needed!

H→WW

Zhenxing Chen, PKU





$1000fb^{-1}$

Promising, be processed to full simulation soon

Branching ratio of H → WW* has been studied with the luminosity of $1000fb^{-1}$. Combined result shows that the branching ratio is 21.3% and the relative precision can reach 2.8%.

This methods could also be applied to other channels, investigation ongoing

- ZH->ZZZ->ll+vv+jj (Xuan et al)
- ZH->ll+bb (Jianping et al)

Combination efforts: From observation to measurements

- Goal (short term):
  - **Have the statistical tools ready and implement for the combination of Higgs for different channels:**
    - Channels: bb,cc,gg,tautau, WW,gamgam,etc.
    - Combined measurement of cross-section, branching-ratio, coupling between H to b,c,tau,w, etc.
    - Tools: ATLAS Roostats (**Jin, Yaquan**) + introduced one from Jianming (**Jianming, Nikos, Zhaoxu**) and CMS Higgs analysis tool (**Mingshui and Tongguang**).
- Process:
  - use ILC inputs to develop the tools (**done**)
    - Develop and valid the tools by comparing ILC result.
    - Some systematic such as theory, JES, etc can be taken into account (**Nikos**).
  - As long as the CEPC inputs (e.g. Ns, Nb, shape after selection) are ready, work on CEPC results (2 more weeks) (**done, but some inputs may be optimistic due to the fast simulation and a coupling of channels still missing**)
    - collect input (channel by channel) from individual teams.
  - Pack and document results (2 weeks) (**Jianming, Yaquan,Nikos**) (in progress).
  - Develop the statistical tool introducing shape information (**frame is there, need to fill full simulated results to extract the shape**).
  - We are documenting the results….
  - We have regular meeting very Friday night at 10pm….
- Longer term:
  - Combine LHC results (high lum) with higher luminosity (**Mingshui and Tongguang**).
  - Try different Beyond SM models to test the sensitivity (**Nikos,etc..**).
  - Develop new methods beyond LHC.
  - Eventually form a statistic form to solve the issues different CEPC analysis meet.

Preliminary results for the expected precision of the measurement

	ILC 250fb-1		CEPC 500 fb-1		CEPC 2000 fb-1		CEPC 5000 fb-1	
	w/o sys (%)	w/ sys (%)	w/o sys (%)	w/ sys (%)	w/o sys (%)	w/ sys (%)	w/o sys (%)	w/ sys (%)
Br : bb	0.82	1.38	0.65	1.29	0.33	1.16	0.21	1.14
cc	10.64	13.84	6.82	6.91	3.41	3.59	2.16	2.43
gg	8.83	10.70	5.62	5.73	2.81	3.03	1.78	2.10
tautau	3.53	3.60	3.76	3.93	1.87	2.18	1.19	1.64
ww	8.05	8.13	4.48	4.61	2.24	2.50	1.42	1.80
gamgam	N/A	N/A	51.97	51.98	26.45	26.48	16.79	16.83
Cross-section	0.79	1.18	0.63	1.07	0.32	0.82	0.20	0.68

✓ The tools are ready for the measurement; those results donot consider shape information.

✓The systematics incorporating in the fit are 1% for each branching ratio, 0.5% for xsection (theory)

✓ At the level of ~1 ab-1, The improvement of ΔBr/Br is limited by the constraint of the systematic uncertainty.

One caveat: assume ratio of eff. of bb,cc, gg for leptonical Z Decays and hadronic Z decay (will be replaced with new inputs)

Interpretation: Need enhancement!

	Absolute σ(ZH)	Absolute decay branching Ratios	Absolute Width	Direct Measurement of g(Htt) & g(HHH)
ILC	+	+	++	+
CEPC	++	++	+	-
ILC + CEPC	++	++	++	++
e+e- + LHC	++	+++	++	++++
e+e- + LHC + SPPC	++	+++	++	+++++

- Explain to the community, and public: what do you observed indeed??
- Some benchmark models that appreciate Branching Ratio measurements??
  - Branching ratios: CEPC > ILC (~ 3 times), Width: ILC ~ CEPC
- Capability of definitively answer some question?
  - 1^{st} or 2^{nd} Phase transition?
  - Existence of WIMP?
  - More ideas are needed to make motivation for CEPC more pressing

EW physics potential

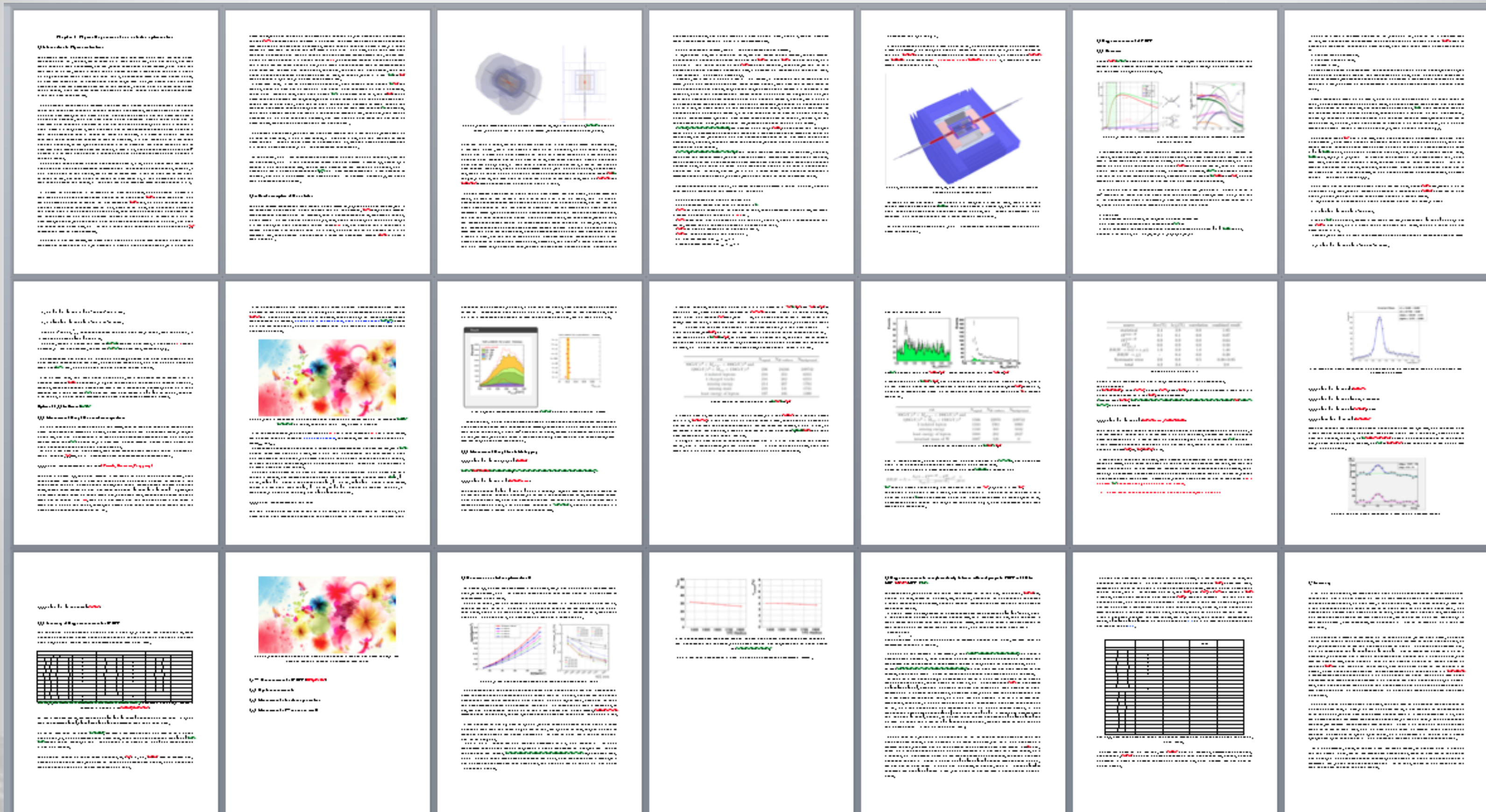
Observable	LEP precision	CEPC precision
$A_{FB\ (b)}$	1.7%	0.15%
$Sin^2\theta_W$	0.1%	0.01%
R^b	~0.3%	0.08%
N_ν (direct measurement)	1.7%	0.18%
R^{mu}	0.2%	0.05%
R^{tau}	0.2%	0.05%

See Zhijun Liang's talk for updated summary

Measurements at WW threshold

- Understand the potential to measure all observables related to multi-gauge-boson production
- Define a strategy for optimal W mass measurement (scan of the WW threshold, direct measurement),
- other W properties, such as width and branching fractions.
- Various SM tests
- More colleagues are welcome to join for these topics

Pre CDR: Skelton



To be filled up soon and put into SVN

Pre-CDR: layout

- X.1: Introduction to Physics Motivation and accelerator parameters
- X.2: A brief description of the detector
  - ILD & cepc_v0
- X.3: Higgs Measurements →
  - Overview
  - Measurement through the recoil mass spectrum
  - Measurement through final state tagging
  - Summary (Interpretation)
- X.4: W & Z
  - Z pole
  - Neutrino Generation
  - W mass, width & Triplet Gauge Coupling
- X.5: Discussion on Detector Optimization
- X.6: Complementary with other projects
- X.7: Summary

Mass, Xsec: 杨迎, 振兴, 袁莉，李文钊

Br(H->mumu): 滨龙, 袁莉，李刚

Br(H->inv): 振兴, 艳珺

Br(H->bb, cc, gg): SJTU(建平，etc)

Br(H->WW): 振兴

Br(H->tautau): USTC(建北,蒋鹏等)，曈光

Br(H->gammagamma): 王峰

Br(H->ZZ): SDU，杨轩

Br(H->Zgamma) ?

sigma(vvH)*Br(H->bb): PKU, 刘帅

Higgs CP (陈宁，艳珺)

Time Line & Goal

- Pre CDR (~ 2014. 12)
  - **Professional User of ILC Soft**
  - Sample: Signal Simulated at ILD, ILD_v2 – cepc_v0 (Smaller L*, TPC, ...)
  - Fast Sim/MC-Truth analysis for all Higgs measurement, estimation on Z & W
  - Half analysis processed with Full-Sim (*signal; bkgrd use ILC sample...*) at ILD and cepc_v0
- Mid-term (~ 2016. 12)
  - **Novice developer of CEPC Soft/Simulation/Reco Algorithms**
  - Fix MDI design with acc. Integrate some of our own sub-detector design
  - Detector model converge to 1 – 2 benchmarks, all Higgs analysis processed to Full Sim
  - Mature reconstruction chain, new software framework released
- Longer term (~ 2018. 12)
  - Iteration with sub-D group on detector design
  - Software framework optimization
  - **Master all the key tech. Dominate, or become a key player for any essential package**

Summary

- Tech. Focus: Full Simulation Train works!
  - Current: Reconstruction (Flavor tagging & PFA), MDI design, General analysis framework design (*dedicated training on reco might be a priority in coming 6 month*)
  - Middle term: Generator/Fast Simu Studies, Software frameworks
- The skeleton of Physics Requirement chapter for Pre-CDR is ready
  - Update the physics result every month
  - Enhance the physics interpretation
- Moving forward to post-preCDR stage
  - Mastering key technologies: 14 sub-groups with clear short term goal
  - Preparing the computing resource
    - 1/3 might be ready at IHEP
    - Need supports from participating institutes: tools ready

Happy birthday, CEPC

Please – join us!