Experiment Summary &
The CEPC-SppC Study Group – Status

XinChou Lou
Institute of High Energy Physics
Beijing, China

April 25, 2014

The CEPC-SppC Study Group

Status Report

On Behalf of the CEPC-SppC Study Group

April 25, 2014

Outline

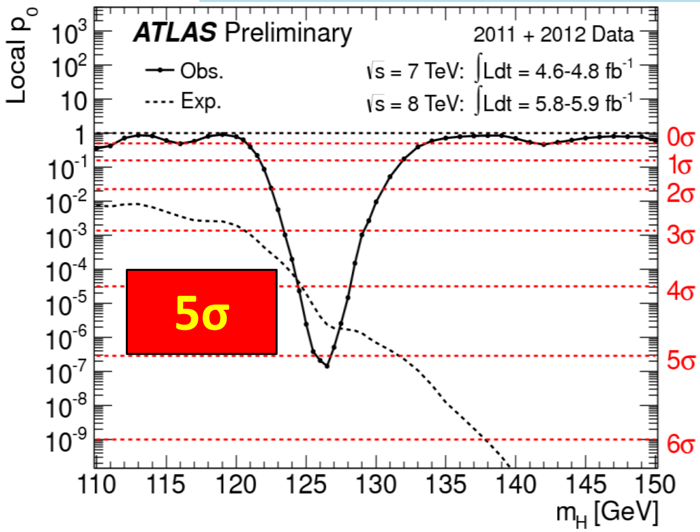
- CEPC-SppC a Higgs factory and a high energy pp collider
- Organization
- PRE-CDR physics, feasibility, technology, design, schedule, cost estimate
- Current status
  theory, accelerator, detector,
  site consideration, civil engineering,
  manpower, etc.
- Plan and prospects

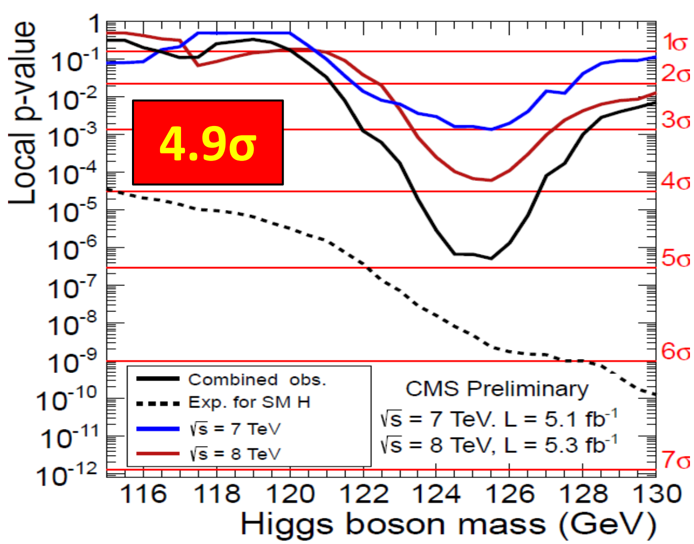
The CEPC-SppC Study Group

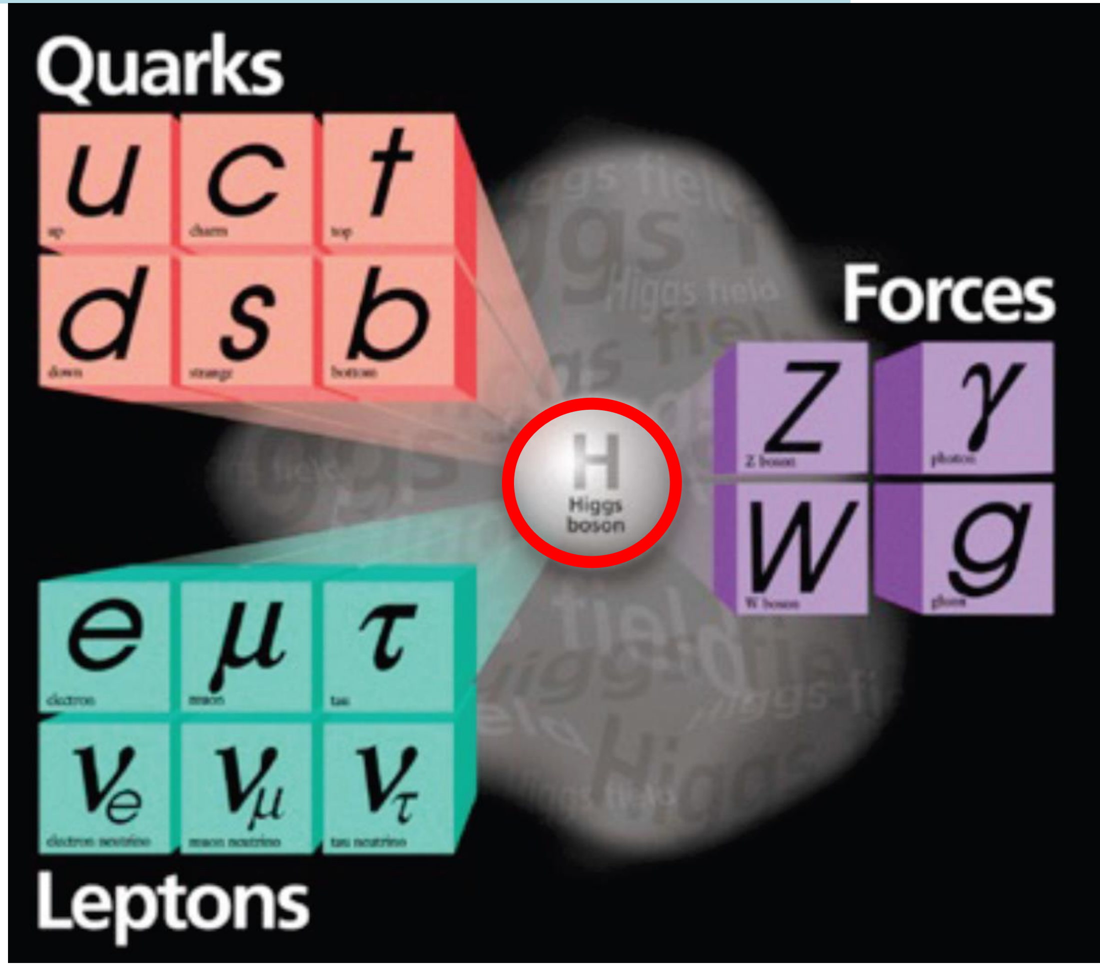
CEPC

A relative low Higgs Boson mass – makes a circular e^+e^- collider as a Higgs factory viable?

a new fundamental particle: light, weakly coupling H:
M_h=125-126 GeV, Γ<1 GeV, spin 0 (first) July 4, 2012







What is it? How does it behave? New physics?

CEPC-SppC

Phase 1: **e⁺e⁻ Higgs (or Z) factory**

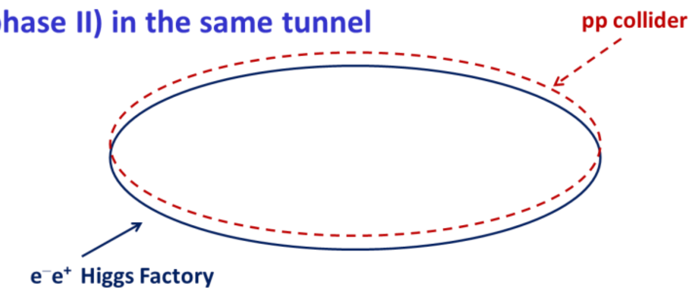
$E_{cm} \approx 240$GeV, luminosity $\sim 2\times10^{34}$ $cm^{-2}s^{-1}$, can also run at the Z-pole

precision measurements of the Higgs (Z) boson

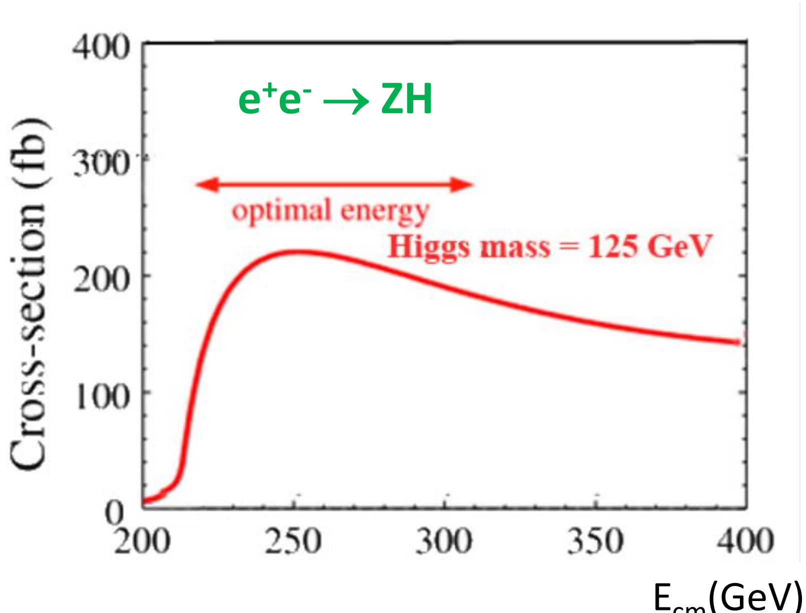
Phase 2: **a discovery machine**; pp collision with $E_{cm} \approx$ 50-100 TeV; ep option

aiming at discovery of BSM physics

- Circular Higgs factory (phase I) + super pp collider (phase II) in the same tunnel



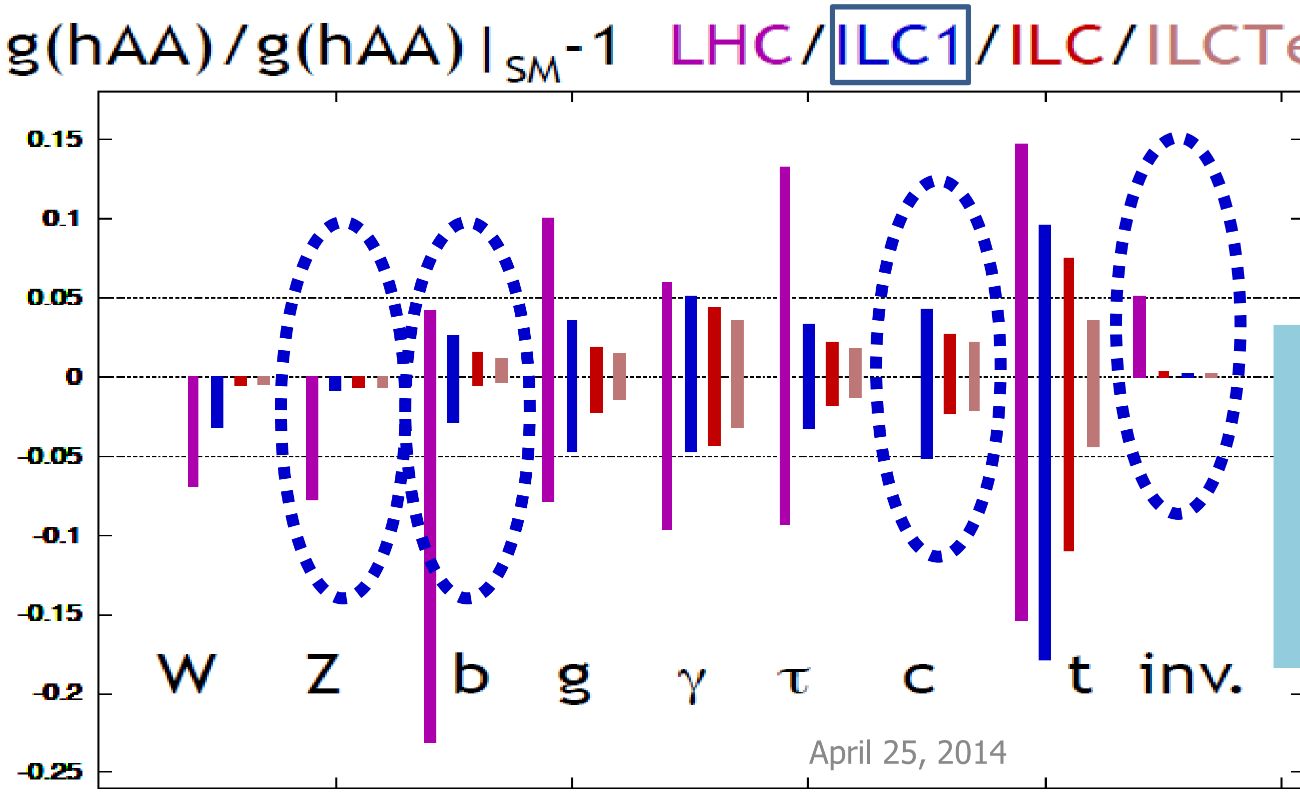
Q. Qin



Possibility for post BEPCII accelerator based HEP project in China
(other choice: τ-charm factory)

Circular e^+e^- : Precision Higgs Machine

- **e^+e^- Higgs Factory (240GeV) can more precisely measure Higgs properties than LHC: Mass, J^{PC}, Couplings, especially h-ZZ, h-bb, h-ττ, couplings, and invisible decays . It can also measure h-cc Coupling, which cannot be carried out at LHC.**
- **Most of important Precision-Higgs-Tests can be already done at HF(240GeV) , without ILC500. Higgs self-couplings'll be probed at Super pp(50-100TeV).**



M. E. Peskin, arXiv:1207.2516

CEPC comparable to ILC1(250GeV)

Need verifications (CDR,TDR)

Considerations for CEPC-SppC

- A circular Higgs factory fits our strategic needs in terms of
  - Science (great & definite physics)
  - Timing (after BEPCII)
  - Technological feasibility (experience at BEPC/BEPCII and other machines in the world),
  - Manpower reality (our hands are free after ~2020)
  - Economical scale (although slightly too high)
- The risk of no-new-physics is complement by a pp collider in the same tunnel
  - A definite path to the future
- A unique position for China to contribute at this moment:
  - Economical growth ➔ new funding to the community
  - Large & young population ➔ new blood to the community
  - Affordable tunnel & infrastructure
  - If no new project, no new resources ➔ It is a pity if we miss it

Y. F. Wang

CEPC-SppC Organization

CEPC研究项目启动

- The Chinese CEPC+SppC Study Group kick-off meeting took place Sept. 13-14,2013
- Participation by over 120 physicists
- Domestic accelerator, theoretical and experimental physicists were organized

CEPC – Web & Documentation 中文版准备中

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

- **Internal**： link to the internal Twiki
- **Events**：record of past events and announcements of future events

- **HOME**：general introduction
- **ABOUT CEPC**：introduction to CEPC
- **ORGANISATION**：organisational structure and WG activities
- **RESULTS**：publications and more
- **WHY SCIENCE**：motivations to pursue basic scientific researches
- **JOIN US**：subscribe to express interests

- **Not displayed**: job opportunities, external links, etc.

CEPC Logo your creative idea to: cepc-admin@ihep.ac.cn

PRE-CDR

PRE-CDR

A written documentation ready for China's 13^{th} 5-year plan

Pre-CDR (by end of 2014)

- main physics topics and motivations;
- initial collider design(s);
- detector technologies and conceptual configuration
- core physics sensitivity (initial)
- site requirement, reality check on civil engineering
- crude cost estimates
- etc.

Established persons in charge of the Pre-CDR writing

Theory – Hong-jian He（Tsinghua）, Shouhua ZHU（PU） and Nima Arkani-Hamed （Princeton）

Accelerator – Weiren Chou（Fermi Lab）

Detector & Simulation – Yuanning GAO（Tsinghua）

PRE-CDR

THEORY

Center for Future High Energy Physics

- Aiming at "world class particle physics"
- "CFHEP" is established at IHEP
  - Prof. Nima Arkani-Hamed is now the director
  - Many theorists (coordinated by Nima and Tao Han) and accelerator physicists(coordinated by Weiren Chou) from all the world have signed to work here from weeks to months.
  - Current work:
    - Workshops, seminars, public lectures, working sessions, …
    - Pre-CDR
  - Future works (with the expansion of CFHEP to include Exp. & more Acc.)
    - CDR & TDR
    - Engineer design and construction
  - A seed for an international lab ➔ For the world's HEP community

Center for Future High Energy Physics

Visits by foreign theorists to IHEP, ITP and universities

CFHEP

Panel discussion "Where will HEP go after the Higgs Boson has been discovered?" in Beijing

attended by > 600 people

Theory: Physics Cases for CEPC (E_{cm}≈240GeV, luminosity ~2×10^{34} $cm^{-2}s^{-1}$)

Light, weakly coupling H: M_h=125-126 GeV, Γ<1 GeV, spin ~0 (first)

- Verification the 125 GeV boson is the SM Higgs
- Precision measurement of the Higgs Boson

  mass, width, couplings to final states;

  look for deviations from the SM

- Does the Higgs decay into something unexpected?
- Are there more than 1 Higgs boson?
- Use the Higgs boson to look for new physics
- ……

Higgs(~125 GeV) physics topics being identified and developed by the Theory Group and CFHEP

Theory: Physics Cases for SppC (50-100 TeV pp collider $L \approx 2\times10^{35} cm^{-2}s^{-1}$)

By then, all all Higgs study and searches for SUSY and Dark Matter has been conducted at the HL-LHC

- **It is a discovery machine (?)**
- MSSM Higgs
- Look out for new physics beyond the Standard Model
- Search for SUSY
- Search for WIMP and dark matter
- ……

Frontier physics topics being identified and developed by the Theory Group and CFHEP

THEORY Preliminary Conceptual Design Report

Higgs Physics

- Introduction
- Theoretical Overview
- Prospects for Higgs Measurements at the LHC
- Higgs Physics at the CEPC
- High Energy Upgrades: the SppC

SM Physics

Beyond Standard Model: Supersymmetry

Beyond Standard Model: Alternatives

Flavor physics

TeV Cosmology

- Dark matter
- Electroweak baryognesis

Heavy Ion Physics

Monte Carlo Tools

What It tells us

$$V = -\mu^2|\phi|^2 + \lambda|\phi|^4$$

the only dimensional parameter allowed by SM symmetry.

The "large hierarchy":

$$m_h^2 - m_{h^0}^2 \sim -\frac{3}{8\pi^2} y_t^2 \Lambda^2$$

Michael Dine's cancelation at Planck scale:

$$m_H^2 = 36{,}127{,}890{,}984{,}789{,}307{,}394{,}520{,}932{,}878{,}928{,}933{,}023$$
$$-36{,}127{,}890{,}984{,}789{,}307{,}394{,}520{,}932{,}878{,}928{,}917{,}398$$
$$= (125\ \text{GeV})^2 \ !\ ?$$

10^{-3} fine-tune

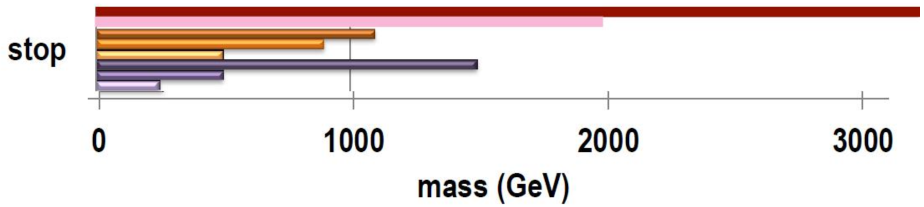
T. Han

"Naturalness" → TeV scale new physics.

Physics Cases for SppC

Naturalness

$$\epsilon \sim (125\ \mathrm{GeV}/M_{\mathrm{NP}})^2$$

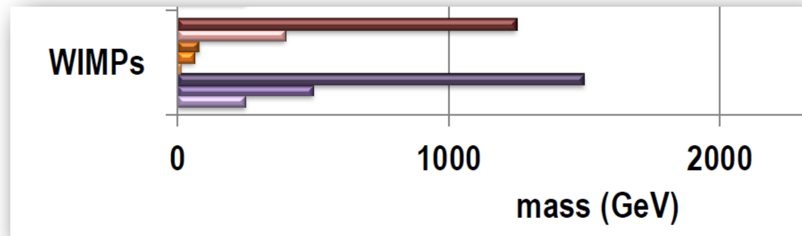


- **LHC:** TeV scale for top partner, $\varepsilon \sim 1\%$
- **HL-LHC:**
  increase the reach by 10-20%, measure top partner property
- **100 TeV VLHC:** 10 TeV level, $\varepsilon \sim 10^{-4}$
- **ILC:** $E_{cm}/2$, 1 TeV machine, $\varepsilon \sim 1\%$
  Precision measurements, multi TeV level

S. Su

Dark Matter

$$m_{\mathrm{WIMP}} \leq 2\ \mathrm{TeV} \left(\frac{g_{\mathrm{eff}}^2}{0.3}\right)$$



- Dark matter at TeV scale (Wino or Higgsino LSP)
  - ➡ can not be explored at LHC 14 with 300 fb^{-1}
  - ➡ enhanced reach at VLHC 33 or 100 TeV
- Smaller dark matter mass
  - ➡ low mass loopholes of suppressed coupling or compressed spectrum, small MET
  - ➡ e+e- collider, reach $E_{cm}/2$.

S. Su

PRE-CDR

ACCELERATOR

CEPC Preliminary Conceptual Design Report

Introduction

CEPC - machine layout and performance

CEPC – technical systems

CEPC – injectors

Upgrade to SppC

- Key accelerator physics issues
- Key technical systems
- Reconfiguration of the accelerator complex

Alternative designs

- Limited scale Higgs factory
- ep
- $\gamma\gamma$

Civil construction

Environment, safety and health considerations

R&D programs

Project plan and cost estimates

CEPC – current accelerator status

e+e- collider as a Higgs factory

- Beam energy ~ 120 GeV
- Synchrotron radiation power ~50 MW
- **50** in circumference (two options)

→ **base line**

Proton-proton collider

- Beam energy ~50-100 TeV
- 50 or 70 (100) km in circumference
- Superconducting, high-field magnets (~20T)

CEPC – current accelerator status

Main ring:

- A FODO lattice in arcs with 60 degree phase advances
- 16-folder symmetry
- RF sections distribute around the ring

  f_{rf} = 700MHz is chosen
- Pretzel scheme is adopted for multi-bunch collision
- Double ring option is under-investigation
- ATF2 type and ILC type FFS designs are currently under study

Linac:

- 6 GeV–Linac will be adopted

Booster:

- In the same tunnel of the collider (6 – 120 GeV)

CEPC – current accelerator status

preliminary parameters

Accelerator Parameters		
Beam energy [E]	GeV	120
Circumference [C]	km	53.6
Luminosity [L]	$cm^{-2}s^{-1}$	1.82E+34
SR power/beam [P]	MW	50
Bending radius [ρ]	m	6094
N_{IP}		2
n_B		50
filling factor [κ]		0.71
Lorentz factor [γ]		234834.66
Revolution period [T_0]	s	1.79E-04
Revolution frequency [f_0]	Hz	5591.66
Magnetic rigidity [Bρ]	T·m	400.27
momentum compaction factor [α_p]		4.15E-05
Energy acceptance Ring[η]		0.02
cross-section for radiative Bhabha scattering [σ_{ee}]	cm^2	1.53E-25
lifetime due to radiative Bhabha scattering [τ_L]	min	55.42
build-up time of polarization [τ_p]	min	21

input

calculated

simulation results

PRE-CDR

Detector & Simulation

CEPC – Detector Considerations

Benefit greatly from the work done with the ILC

Start with the ILD

- ✓ Adopt the detector technologies and basic layout

- ➢ detector operates without the power pulsing
- ➢ vary detector geometries

- ➢ will implement simulation to evaluate the detector performance at the CEPC and do the cost estimates

CEPC – Detector Considerations

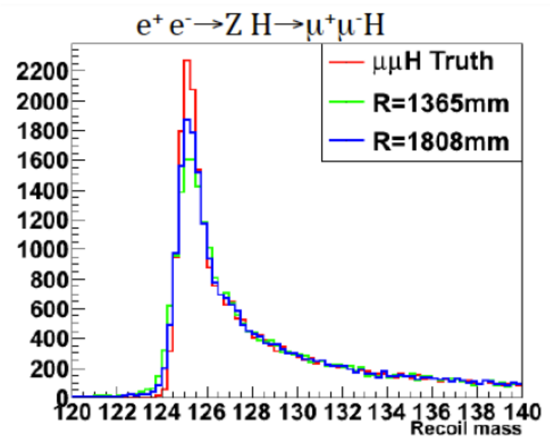
CEPC Detector: Institutes

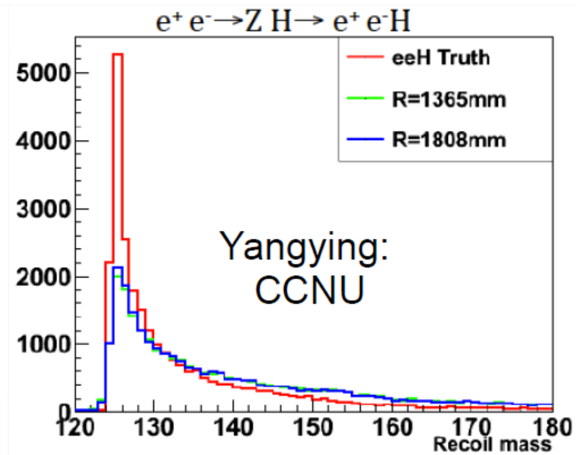
Theory

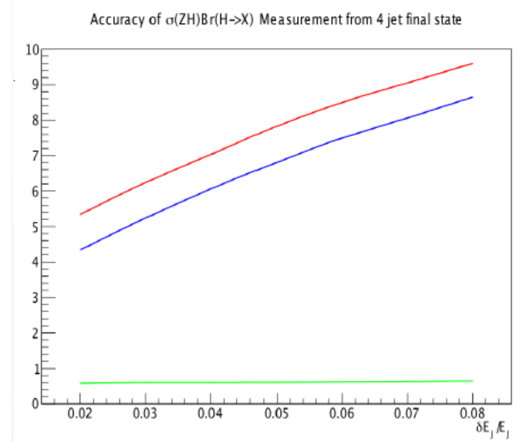
VTX	TPC	Calo	Physics Requirement
ShanDong University (SDU) IHEP …	Tsinghua University (THU), University of Chinese Academic of Science (UCAS), IHEP …	University of Science and Technology of China (USTC), Shanghai Jiaotong University (SJTU), Wuhan University (WhU), Nanjing University IHEP …	Nankai University,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

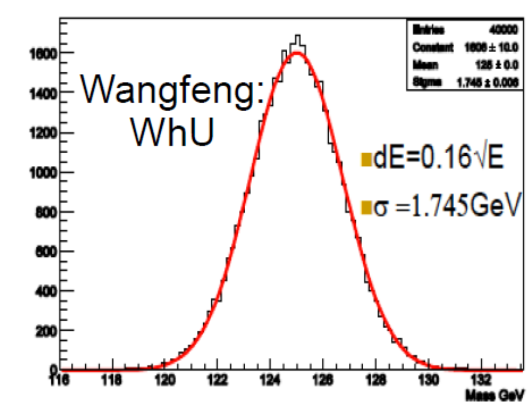
Machine

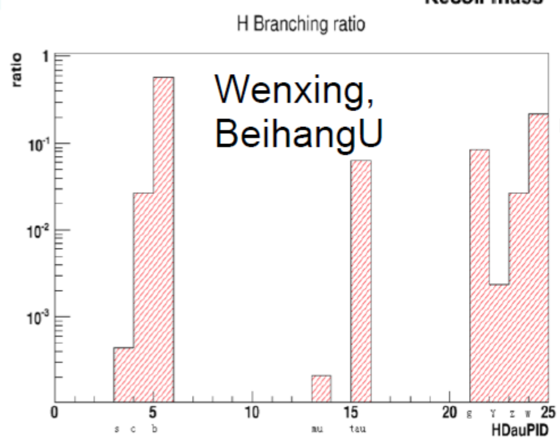
Ongoing Physics Analysis

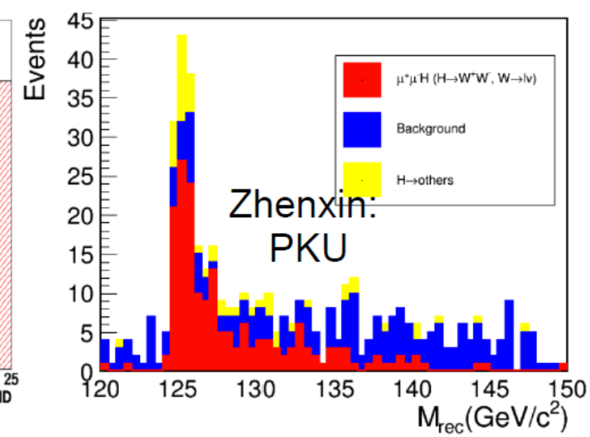












Duchun(IHEP): generator development/comparison

PRE-CDR

Site Consideration & Civil Engineering

Site Consideration & Civil Engineering

- **Current IHEP campus is too small to accommodate a large facility**
- **Is there any well suited site for a large lab (>800 acres) in northern China?**
- **Does the local government display strong support for the lab?**

IHEP management visited 14 sites in northern China (Hebei, Henan provinces)

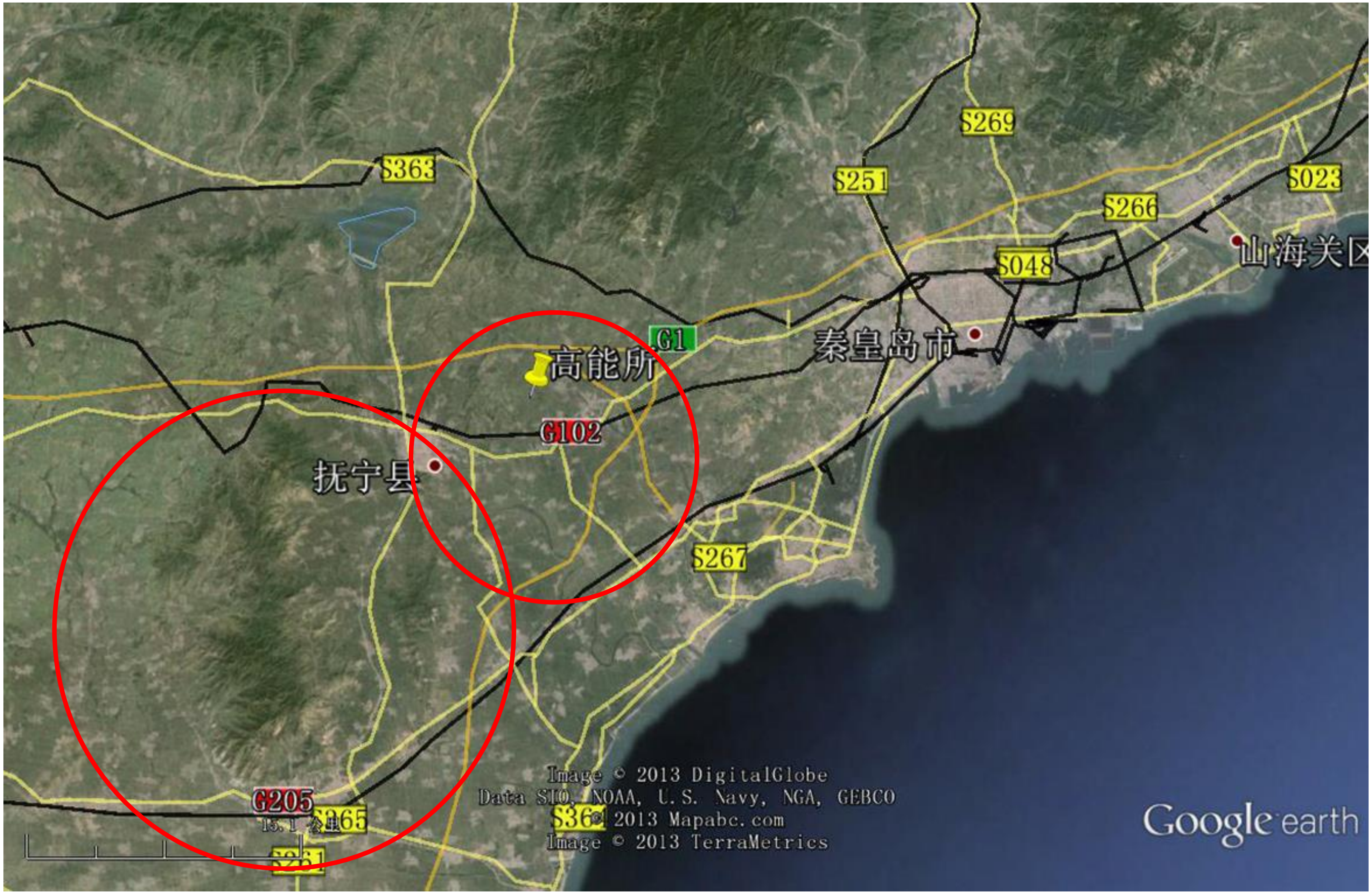
Use "Qing Huang Dao" as an example –

CEPC – Site Investigation

A good example is
Qing Huang Dao秦皇岛:

300 km from Beijing

3 hours by car; 1 hours by high speed train



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PRE-CDR Civil Engineering

Tunnel – construction plan, ventilation, caverns, etc.

Ground facilities– halls， power stations, cooling, shafts, access points, etc.

Other – green design-operation, length of construction, cost

Baseline Consideration:

黄河勘测规划设计有限公司 (private company)–

- 秦皇岛抚宁地区为概念设计地点
- C=50km圆环形隧道，截面直径R~5，7m，地下50-100m
- 倾斜度控制在4‰以内（便于排水）
- 节能减排：为节约能源，减少浪费，设法进行二次利用
- 在环形隧道地面设有5000亩办公园区 820 acres
- 隧道供电负荷、区域变电站，园区需要若干小变电站
- 使用硬岩TBM或盾构机的比较造价清单

高能所 –

- 估算与制冷机配套的冷却塔占地面积
- 安排黄河公司对CERN LHC现场考察活动
- 提供给黄河公司有关的资料

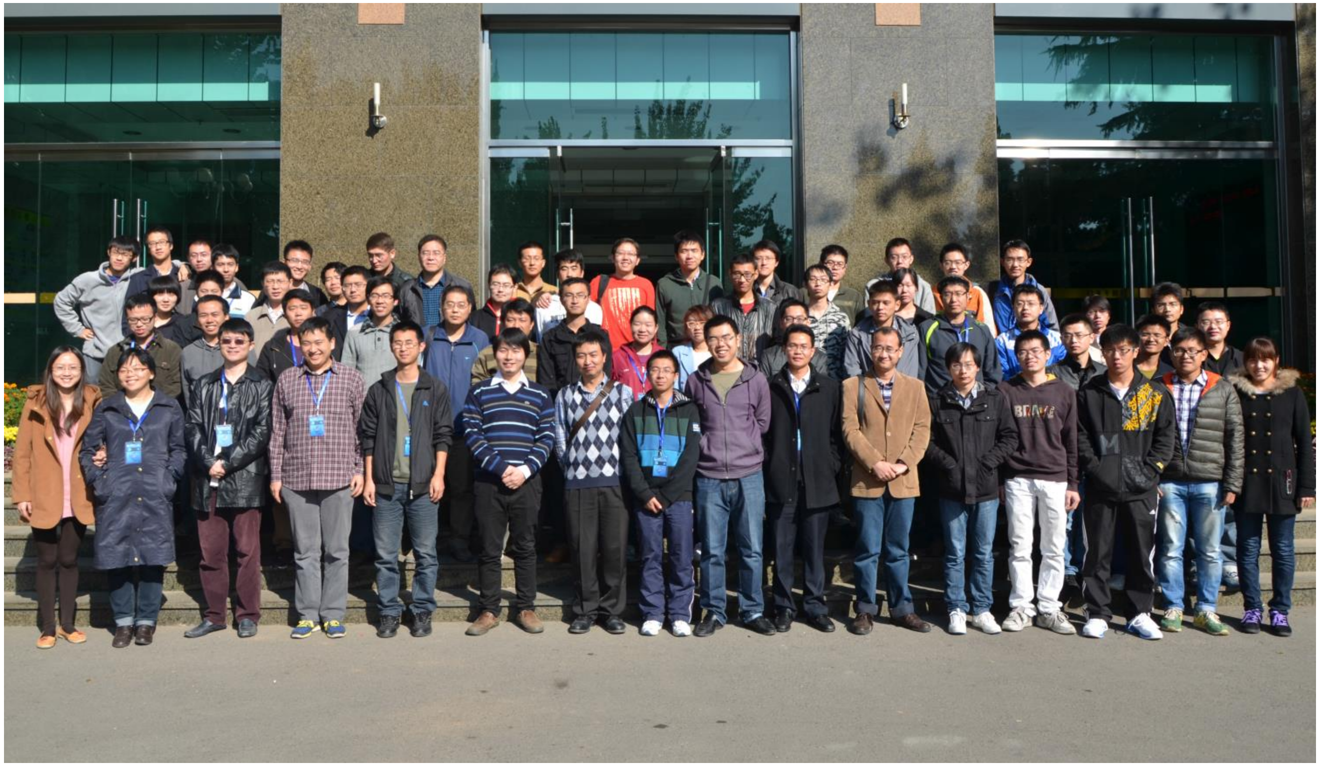
双方确定交流会，保持及时沟通

PRE-CDR

Manpower, etc.

CEPC – Manpower Considerations

- Training young people to address manpower shortage



- Recruitment: postdocs and staff at IHEP

CEPC Timeline (dream)

Pre-study, R&D and preparatory work

- **Pre-CDR** (by end of 2014) to be ready by China 13th 5-year plan
- Pre-study 2013-2015
- R&D 2016-2020
- Engineering Design 2015-2020

Construction: 2021-2027

Data taking: 2028-2035

SppC Timeline (dream)

Pre-study, R&D and preparatory work

- Pre-study 2013-2020
- R&D 2020-2030
- Engineering Design 2030-2035

Construction: 2035-2042

Data taking: 2042 –

CEPC – Prospects

Theory

➔ fully explore physics with the Higgs boson & in the energy frontier

Detector: benefits from ILC, FCC, LHC experiments + own effort

➔ excellent design, cost effective, fully functional

Accelerator

➔ cost effective, expandability

International cooperation: LHC, ILC, FCC and CEPC and others

This is part of a global effort to make sure HEP's future is very bright

Summary of Experiment

Accelerator

Magnets for Future pp Colliders – Part I Steve Gourlay
Magnets for Future pp Colliders – Part II Soren Prestemon

Detector and Experiments

Considerations for Detectors for a 100 TeV Proton-Proton Collider Peter Loch
Thoughts on Event Reconstruction & Particle Flow Richard Cavanaugh
Lesson from 8 TeV LHC – What Did We Learn? Maurizio Pierini
Panel Discussion: LHC Discovery Story F. Würthwein

Trigger

Triggering Elliot Lipeles

Simulation and Tools

DELPHES – Fast Simulation Michele Selvaggi
Parton Distribution Functions Joey Huston
MEM LO/NLO Merging with Parton Showers Stefan Prestel
Progress/status in NOL Computations for the SM and BSM Fabio Maltoni

THE ACCELERATOR

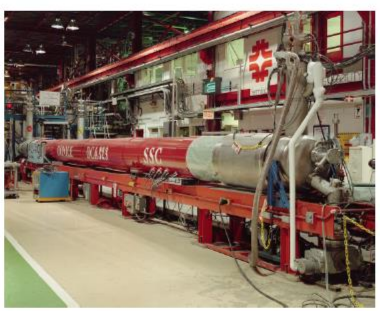
High Field Magnets

Accelerator Magnets

Then . . .

The Tevatron (Fermilab) 1983

4.4 T , NbTi, 4.2K



HERA, SSC, UNK, RHIC

And now . . .

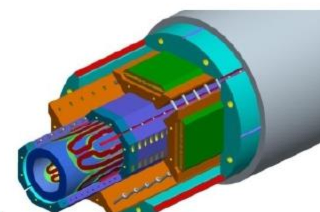
LHC 2007

8.3 T, NbTi, 1.9K

Limit of NbTi

US LHC Upgrade

Nb_3Sn quadrupoles



Operating until about 2030

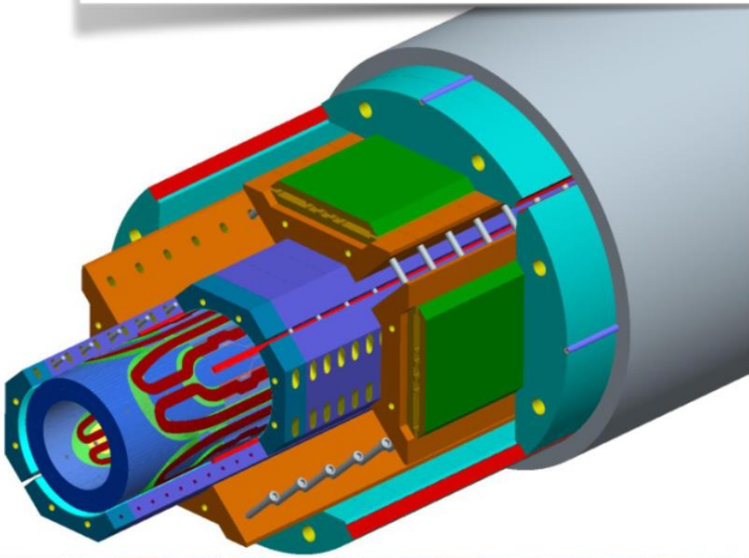
About 27 km of NbTi magnets running at 1.9K and (hopefully) 7 - 8T

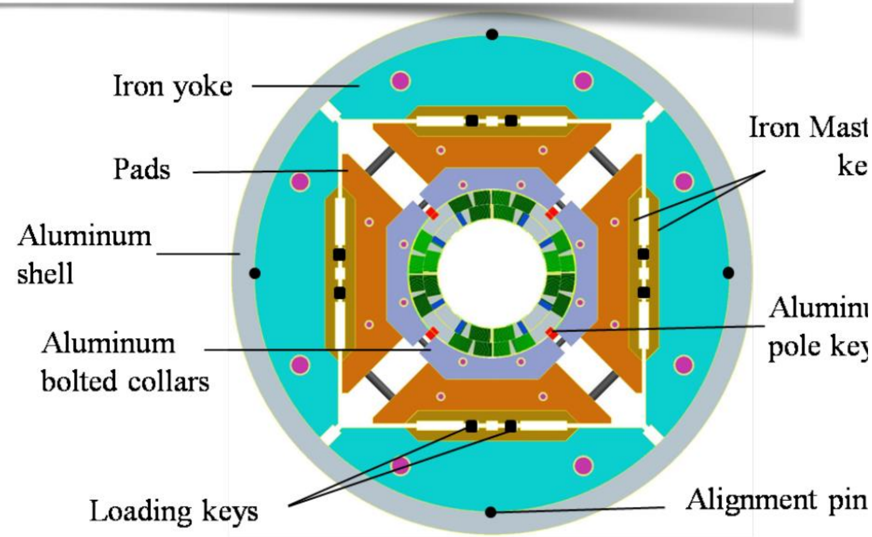
No HTS accelerator magnet has yet been built

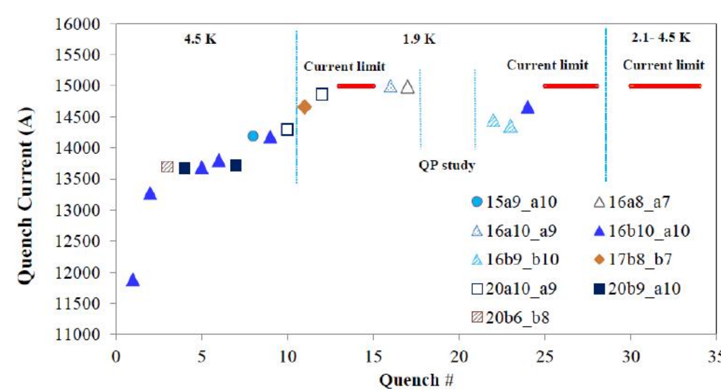
Steve Gourlay

Nb_3Sn technology is being readied by LARP: HQ ➠QXF ➠ Hi-Lumi upgrade

Design, fabrication, and test results from LARP: FNAL, LBNL, BNL



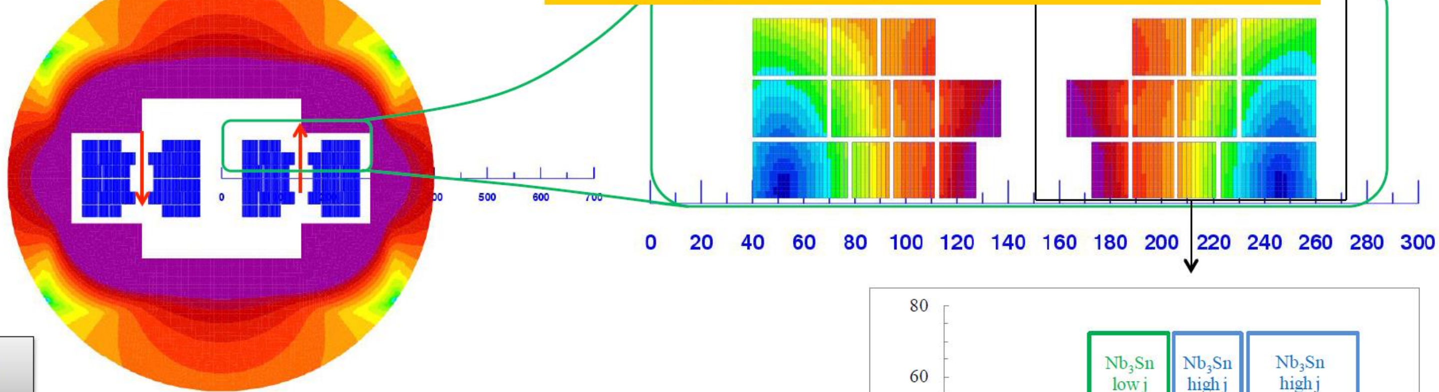




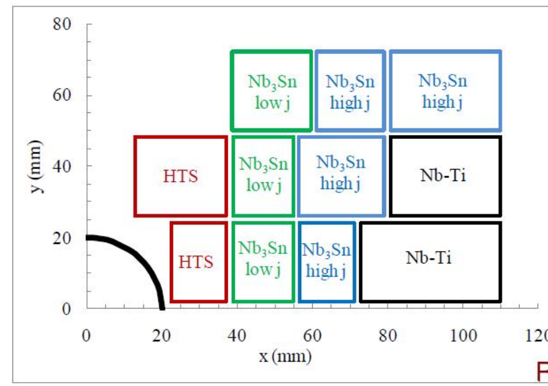
Go for 20 T

First consistent conceptual design

Using multiple SC material



L.Rossi



Material	N. turns	Coil fraction	Peak field	$J_{overall}$ (A/mm^2)
Nb-Ti	41	27%	8	380
Nb3Sn (high Jc)	55	37%	13	380
Nb3Sn (Low Jc)	30	20%	15	190
HTS	24	16%	20.5	380

20 T field!

Roy Aleksan
CERN
Feb. 22, 2013

Magnet design: 40 mm bore (depends on injection energy: > 1 Tev)
Approximately 2.5 times more SC than LHC: 3000 tonnes! (~4000 long magnets)
Multiple powering in the same magnet for FQ (and more sectioning for energy)
Only a first attempt: cosϑ and other shapes needs to be also investigated

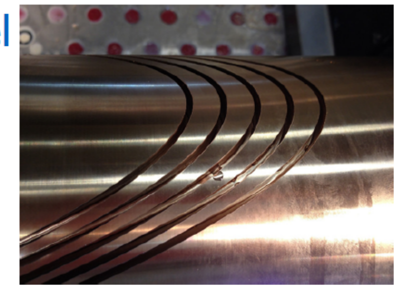
Cost of Nb_3Sn: 4 times Nb-Ti
Cost of HTS: 4 times Nb_3Sn

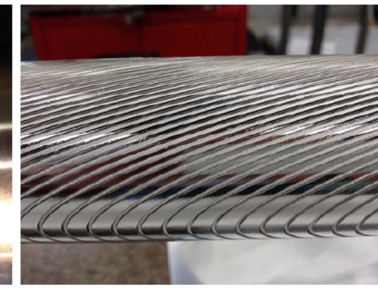
The last 2 - 3T is expensive!

Steve Gourlay

CCT appears to meet required characteristics

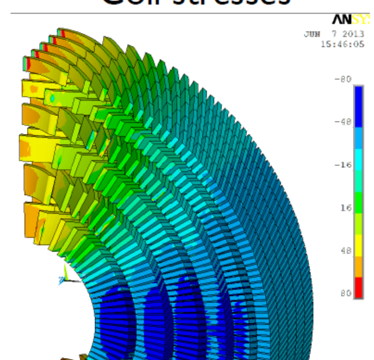
(Needs demonstration)



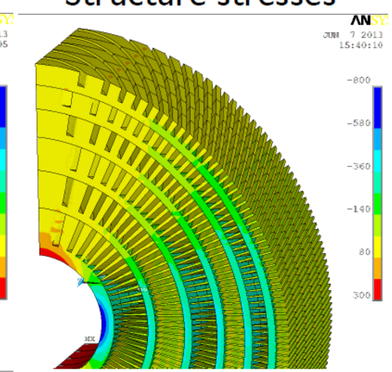


- Stress is captured by rib, transferred to mandrel
  - ➡ *No accumulation of stress on the mid plane*
  - ➡ *No stress issue with larger bore*
- Every layer can use different cable size
  - ➡ *Allows near optimal grading for conductor efficiency*
    - ✓ *Significant saving in Nb_3Sn over Cos(θ) designs*
- Conductor mass scales with bore radius only
- Excellent field quality ("for free")
- Fabrication:
  - ➡ *Minimal external structure*
  - ➡ *No spacers, end parts, etc.*
  - ➡ *Simple winding ➩ Industrialization*

Coil stresses

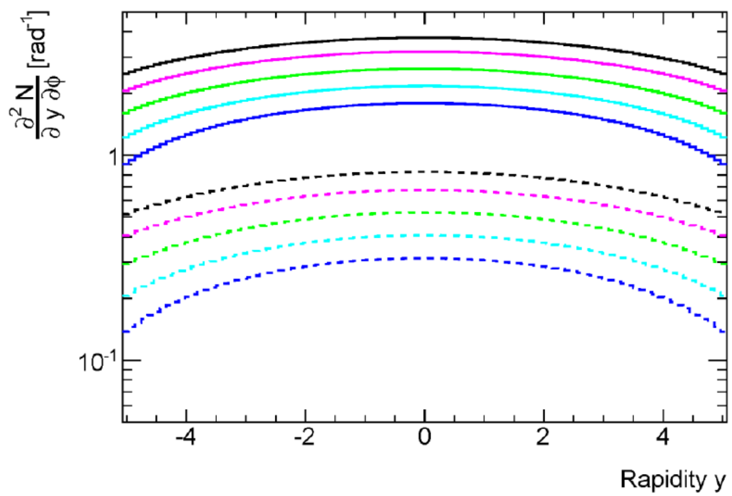


Structure stresses



THE DETECTOR & EXPERIMENTS

Multiplicities at 100 TeV



$\sqrt{s}$ = 7 TeV

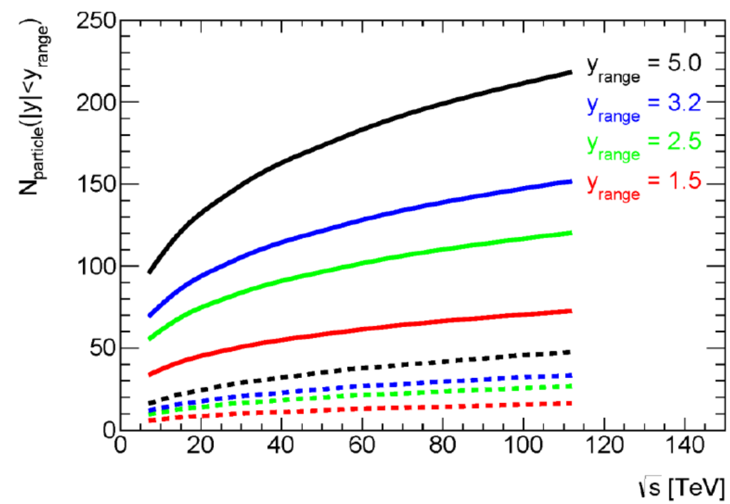
$\sqrt{s}$ = 14 TeV

$\sqrt{s}$ = 28 TeV

$\sqrt{s}$ = 56 TeV

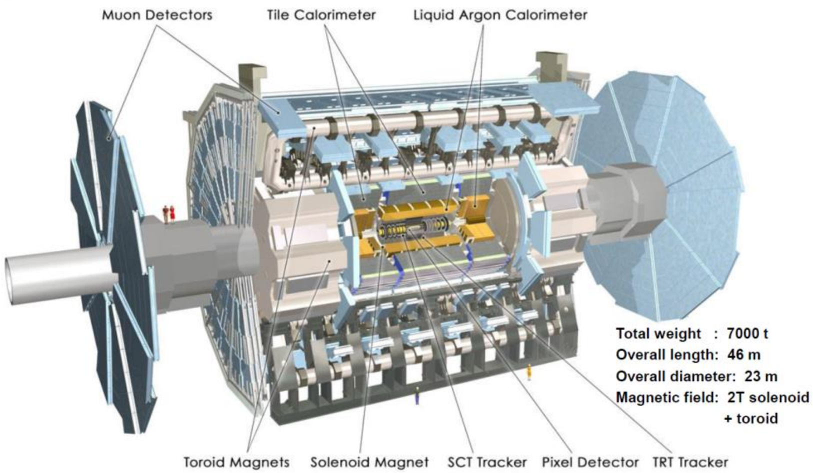
$\sqrt{s}$ = 100 TeV

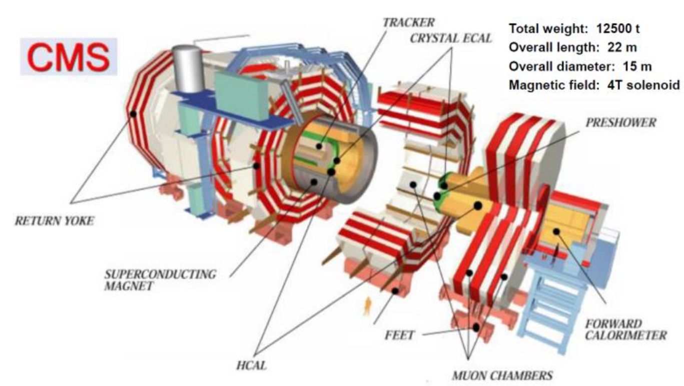
single MB interactions, charged particles with $p_T > 500$ MeV



Does experimental environment require very differer detectors?

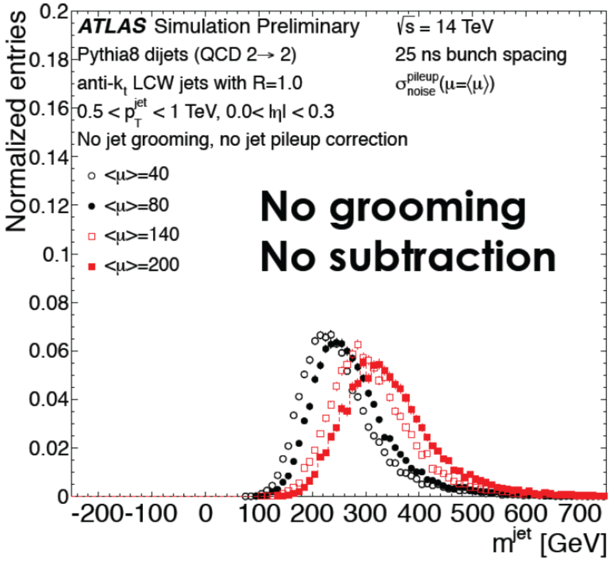
- Final states – extended phase spaces
  - Higher p_T of signal objects (leptons, photons and jets)
  - Boosted topologies of SM and BSM particle decays
  - Precision physics reconstruction at larger (pseudo)rapidities
- Experimental backgrounds – pile-up
  - Technologies for suppression and correction
  - Signal significance – lowest reliable p_T measurement for physics
  - Long term detector survival in high radiation environment





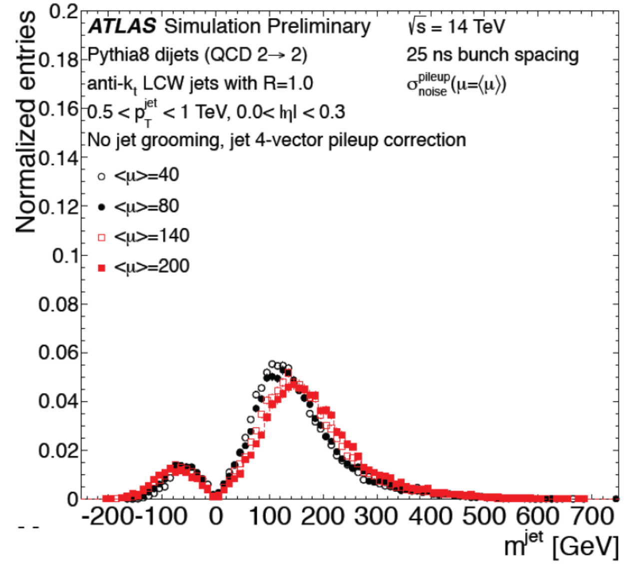
- ➢ **Use ATLAS, CMS detectors to get expectations for 100 TeV**
- ➢ **Use ATLAS,CMS full simulation for detector design for 100 TeV**

P. Loch



jet 4-vector area based pile-up subtraction

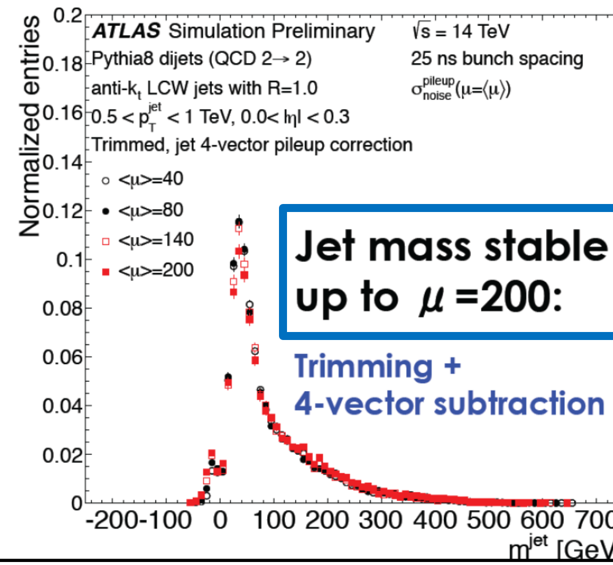
trimming



Higher energy and intensities

Detailed studies with a well-known detector useful for preparation for even higher energy scenarios

Understand effectiveness of signal definitions and jet grooming techniques



Tracking

- Resolution requirements can be stringent
  - Spatial resolution of O(10 μm) to efficiently separate O(10-100?) pile-up vertices – depending on "beam crossing diamond" size…
  - Good (transverse) momentum resolution beyond up to several 100 GeV – highly boosted jets may be too compact for calorimeter but may have stiff prongs (or core) to be resolved
  - Tracking is essential for refinement of kinematics (particle flow, leptons), in-situ calibration reference, vertex associations, pile-up suppression, …
- Operational concerns
  - Mostly radiation hardness of today's silicon pixel based trackers (best spatial resolution!) in environments with significantly higher particle fluxes
- Physics performance
  - Extend tracking to more forward regimes – today only 50% of the full detector coverage is instrumented with tracking (physics case: VBF/VBS signatures in high pile-up…)

Calorimeters (1)

Biggest concerns

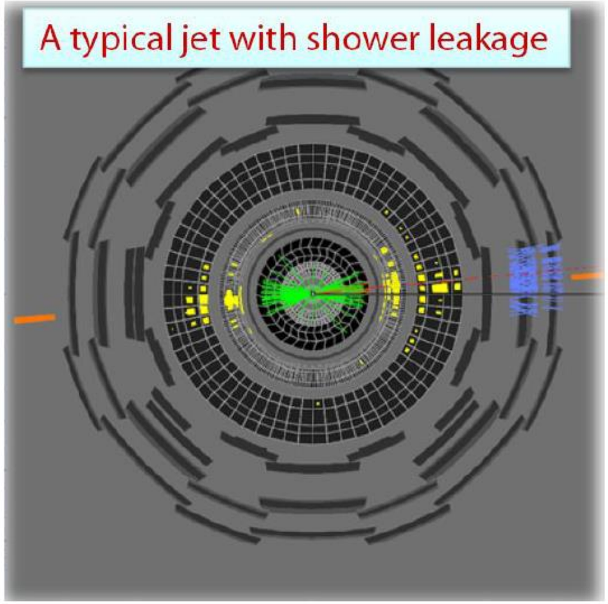
- Need to avoid tails in (jet) response to allow effective searches – avoids fake missing transverse momentum etc.
- Most uniform response across the whole acceptance in pseudorapidity

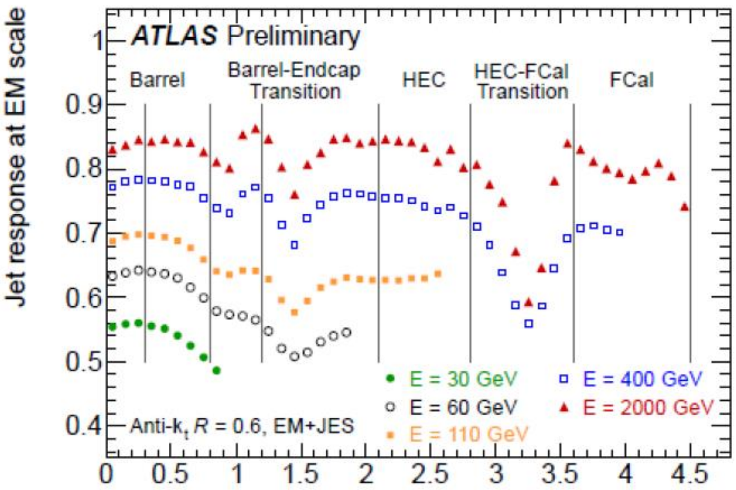
Absorption characteristics

- Depth for hadrons needs to accommodate O(10) TeV jets (energy)
- High energetic EM particles should be stopped in EM calorimetry – present day calorimeters may be a bit shallow…

Signal stability

- Highly radiative environment may affect signal yield and proportionality to deposited energy
- Need to focus on technology providing stable signals (within a few %) for

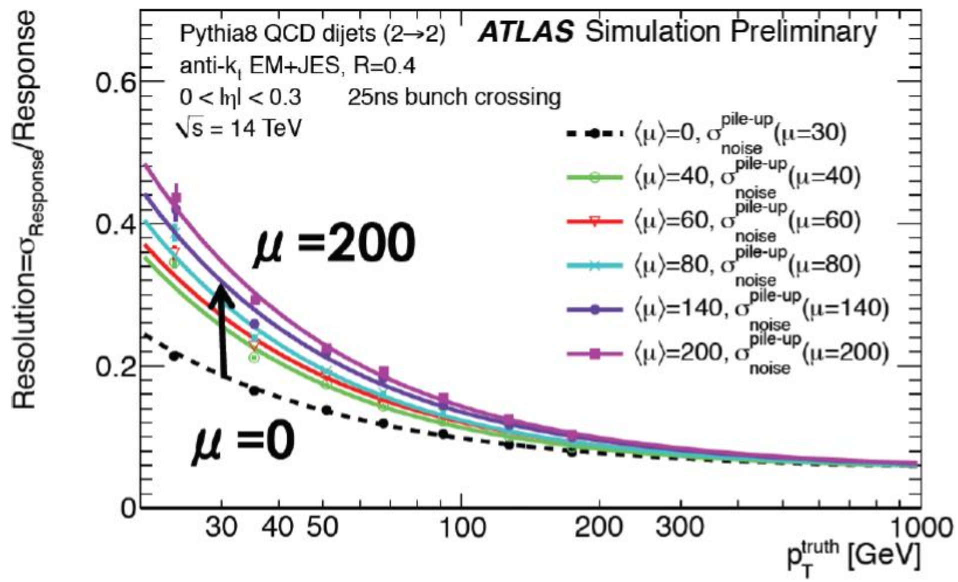




P. Loch

Calorimeters (2)

- Electron/photon energy response
  - Excellent signal linearity and resolution possible even in the most hostile environments
  - High energy resolution limit comparable to zero
- Jet energy resolution
  - Lower energies strongly affected by pile-up
  - High energy limit affected by hadronic calibration – but few % (≪10%) possible

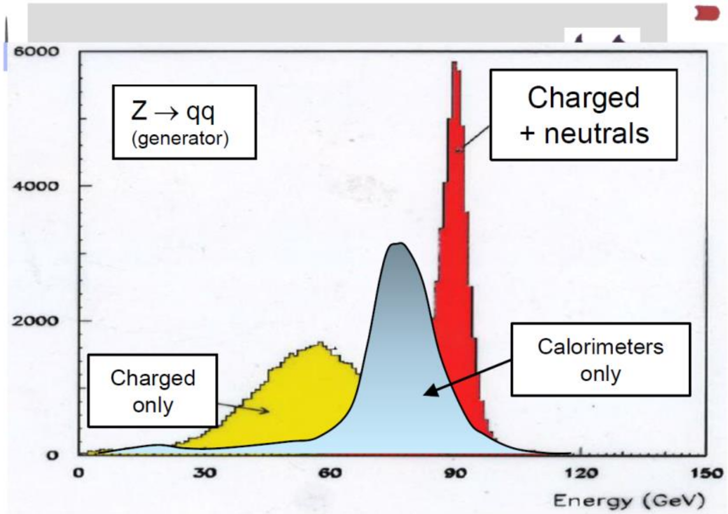


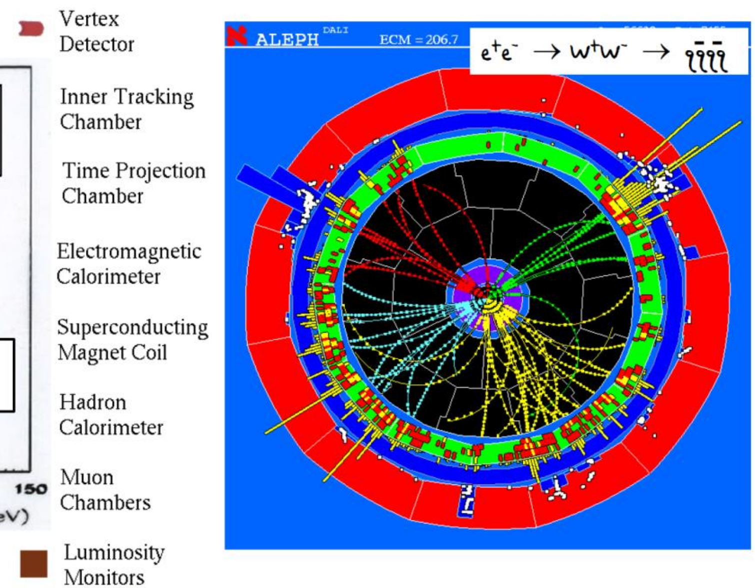
Detector design guidelines

- Consider using ATLAS/CMS full simulation to study 100 TeV collisions
  - DELPHES etc. is nice, but has limited messages which may be severely misleading concerning detector performance and capabilities – both optimistic and pessimistic…
  - Needs significant help (and resources?) from the experiments – not easy with upcoming LHC Run II and upgrades
  - Maybe a exploratory study is possible – pile-up + lepton final state signal?
- Simplify (homogenize) technologies
  - Avoid complex transition regions in calorimetry as much as possible – in particular between EM and HAD
  - Finer readout at higher pseudorapidity – only useful if shower size can be reduced…
- Explore tracking in forward region
  - Helps with jet categorization, pile-up suppression, etc. – good physics case outside VBF/VBS based searches?

P. Loch

Detector suitable for Particle Flow





Tracker:

Large Volume, Low Material, High Acceptance

Efficiency ≈ 100%; fake ≈ 0%

Solenoid:

High B-field = 1.5 T;

$\sigma(1/p_T) = 6\times10^{-4}\ \text{GeV}^{-1}$

ECAL:

Fine Granularity (3x3 cm trans; 4/9/9 X_0 long), High Accept

Good Resolution: $\sigma \approx 20\%/\sqrt{E_T}$

HCAL:

Coarse Granularity (15x15 cms trans; no long), High Accept

Low Resolution: $\sigma \approx 100\%/\sqrt{E_T}$

At 100 TeV, possible large fraction of neutrinos from radiation of W and semi-leptonic B decays.

TeV Muon Considerations

R. Cavanaugh 100 TeV Workshop, SLAC 23-26 August, 2014

electrons brem in tracker

- recovered in calorimeter

muons brem in calorimeter

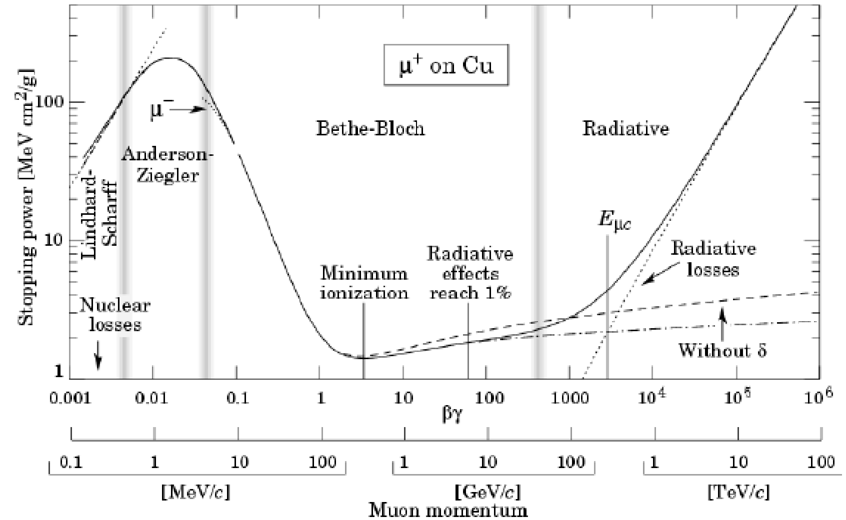
- need to ID & remove calorimeter deposits
- need to extrapolate track to muon chamber hits

Question:

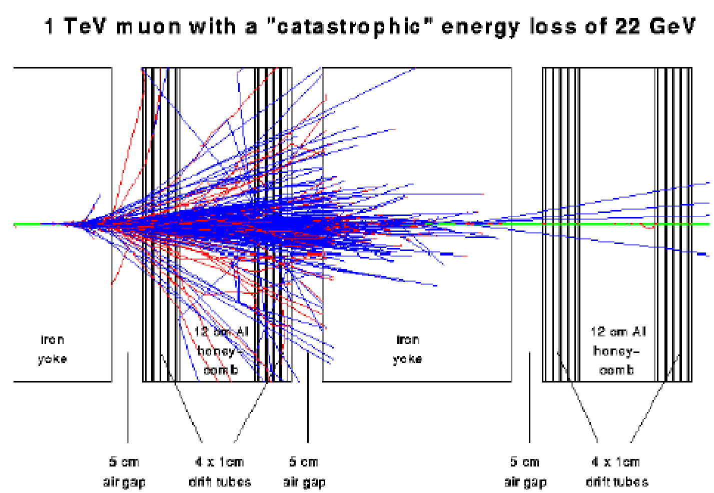
- how to do that non-isolated environment: near other e's, γ's (ECAL deposits) or π's, K_0^L's (HCAL deposits)

Partial Answer:

- use highly segmented calorimetry
- LHC is a good testbed!



Muon Induced Secondaries



See Sanjay Padhi's Talk at Beijing

Parametrized detector for 100 TeV proton collider (baseline)

1. Large Solenoid + return yoke: Magnetic Field: 5T, 24m long and 5m radius
2. Central Tracker (including pixel detector)
   - Acceptance within $|\eta| < 4$
   - Momentum resolution $\sigma/p_T \approx 1.5 \times 10^{-4} \oplus 0.005$
   - Efficiencies similar (not same) to CMS Phase-II ECFA studies
3. EM Calorimeter (PbWO4) $\sigma/E = 2.0\%/\sqrt{E} \oplus 0.5\%$
4. Hadronic Calorimeter $\sigma/E = 50\%/\sqrt{E} \oplus 3\%$
5. Forward Calorimeter (needed for VBF and other studies) up to $|\eta| \sim 6$ $\sigma/E = 100\%/\sqrt{E} \oplus 5\%$
6. Muon detector
   - Acceptance within $|\eta| < 4$
   - Momentum resolution $\sigma/p_T \approx 1\%@100\ GeV - 10\%@10s\ TeV$
   - Efficiencies similar (not same) as CMS Phase-II ECFA studies

24th Feb. 2014 "1st CFHEP Symposium on circular colliders" 20 Sanjay Padhi

Triggering at 100 TeV?

Elliot Lipeles
University of Pennsylvania

100 TeV Workshop

Apr 23, 2014

Machine Parameters

Machine Parameters are not very defined yet

Consider two main cases:

Luminosity	Bunch Spacing	Pile-up
$5x10^{34}$	25 ns	170
$5x10^{34}$	5 ns	34

Triggering Purposes

Hardware = level-1 (L1)

Goal: Reduce data volume extracted from front-end chip

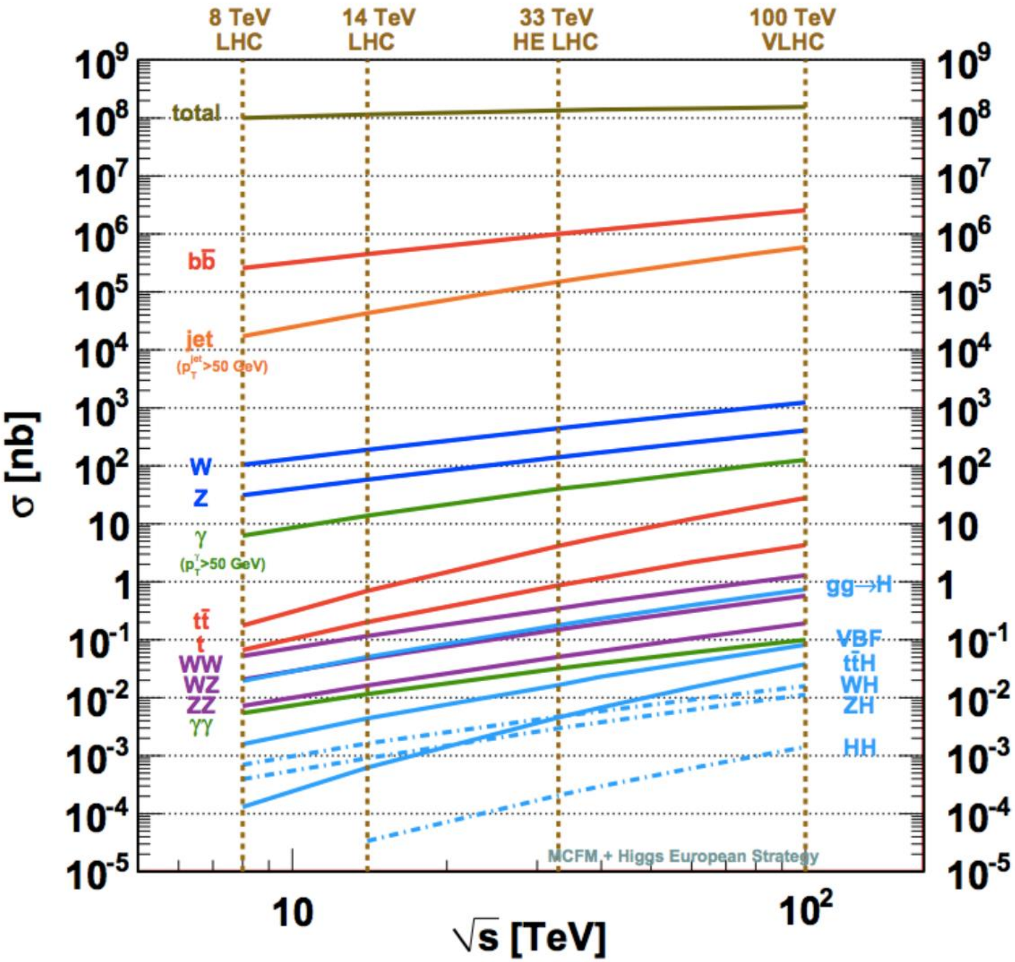
- Fundamental difference between inner detector (tracker) and outer detectors (calorimeter and muons)
- Tracker readout is necessarily in the tracker volume for a 4π detector
  - Contributions to tracker material
  - Tracker plays a big role in L1 discussion
- Outer detector readout is ~external to tracking volume
  - Assume full beam crossing rate readout and use in L1

Software = high-level trigger (HLT)

Goal: Reduce stored data volume

- PC-based with software
- Expect hardware to keep up with industry = Moore's Law?
- Expect affordable storage to scale with Moore's Law?

The Landscape



Minbias ~140 mb

~170 per crossing

Trigger Backgrounds

$b\bar{b}$ 150 MHz

~6 per crossing

~1 per crossing w/ lepton

Jets p_T > 50 GeV 25 MHz

~1 per crossing

Electroweak Physics

W+Z = 70 KHz!

Top ~30 mb

~1500 Hz

Moore's Law easily accommodates saving all the electroweak

What do we want to trigger on?

Easy stuff... core high p_T program

- Very high p_T leptons (incl τ), photons, jets, and met
- Hadronic SUSY with MET (with or without MET), Z', WW scattering, anomalous TGCs/QGCs, running of couplings

Pretty easy... single leptons

- precision/rare Higgs, top
- Many HH channels
- Much of electroweak SUSY

Challenges...

- HH to bbττ
- H to Zγ
- Monojets (+X)
- Exotics (monopoles, long lived hidden valley)
- Displaces Vertices

Challenges: Monojets

"Wino" Dark Matter

$\chi^{\pm}$
χ_0

Small $\Delta m(\chi^{\pm} - \chi_0)$

"Higgsino" Dark Matter

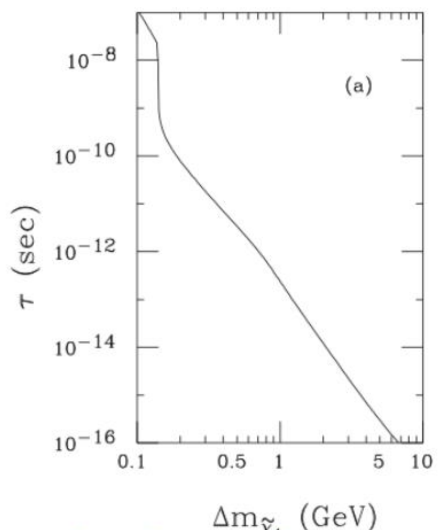
χ_2
$\chi^{\pm}$
χ_0

Small $\Delta m(\chi^{\pm} - \chi_0)$
Small $\Delta m(\chi_2 - \chi^{\pm})$

Possibly long-live

....

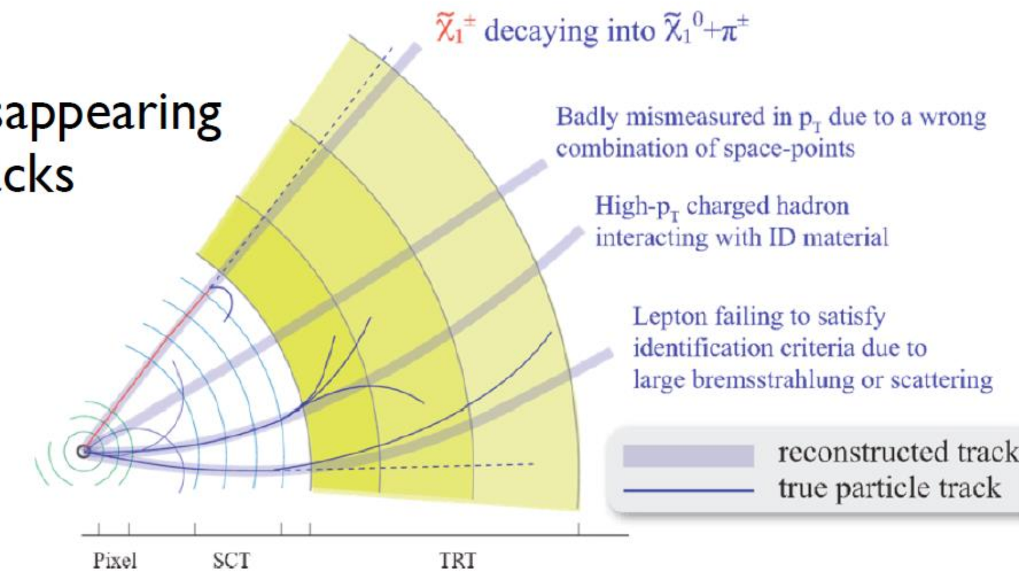
Disappearing Tracks



Chen, Drees and Gunion, hep-ph/9902309

Soft Leptons

....



Distinctive offline signature; Need to trigger on moderate MET

High χ_0 mass could mean small cross-section

Future links

Current (rad hard)
~ 10 Gbit/sec ("upgraded GBT", 65 nm)

Multilevel (should be rad hard)
~ scale by 2-4

Industry, Multiwave length (rad hard???)
~ scale by order 100+?

Unclear whether full tracker readout will be possible
Depends on rad hard link development

Reasonably Moore's law assumptions makes HLT probably CPU and storage probably not a big issue

Tracking is the core question for 100 TeV

- Difficult channels examples: HH to bb$\tau\tau$, Monojets
- RoIs or Self-seeded both good solutions for local high-p_T objects
- MET is probably the trickiest case

Full tracking at beam crossing rate technologies:

- Data extraction depends on rad hard link development
- Pattern recognition, new technologies look promising
- Correlating sensors at front-end = "Intelligent" tracking

SIMULATION & TOOLS

Good description of the SM in order to discover BSM, DM, …
Detector simulation tools, be adequate & to get the statistics

"Magnet technology has advanced considerably" – Soren Prestemon

"Technology for 16T magnets is in hand, but there is a lot of room for improvement.   And we have an idea . . . " – Steve Gourlay

"We don't know how to build the detector. "

"We need to start R&D now to not to loose the skills" – Peter Loch

"Reasonably Moore's law assumptions makes HLT probably" .
"Tracking is the core question for 100 TeV" – Elliot Lipeles

"A 100 TeV pp collider will be exploring new kinematic regions in x and Q^2, where current knowledge is just extrapolation" –Joey Huston

Thoughts –

- Start and keep strong R & D programs in key technologies and tools
- Engineering challenges: High quality components (~100 km), cost control…
- Ramp up pp energies gradually? 40, 60 80, 100 TeV, step by step?
- Keep up with the work – give our children (or grandchildren) a chance

BACKUP

International Workshop Held in Beijing Dec. 16-17, 2013

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, and will discuss critical issues in accelerator technology, detector design and in theory on the precision measurement of the Higgs and the physics with pp collision at 50-100 TeV.

- First International CEPC Workshop
- CERN FCC participation
- Jump start the international coordination

Monday, December 16, 2013

09:00 - 10:35 Session I
Convener: Prof. Xinchou Lou (IHEP, Beijing)
09:00 Welcome and Introduction 15' Speaker: Prof. Yifang Wang (IHEP)
09:15 Physics Opportunities 40'
Speaker: Prof. Nima Arkani-Hamed (Princeton)
09:55 The HL-LHC Physics Program 40'
Speaker: Dr. Takanori Kono (KEK/Ochanomizu)

10:55 - 12:05 Session II
Convener: Dr. Frank Zimmermann (CERN)
10:55 First Look at the Physics Case of TLEP 35'
Speaker: Prof. Alain Blondel (DPNC UNiversity og Geneva)

11:30 CEPC Machine Optimization and Final Focus Design 35'
Speaker: Dr. Dou Wang (IHEP)

14:00 - 15:45 Session III
Convener: Prof. Qing QIN (Institute of High Energy Physics)
14:00 Beam-beam Study of TLEP and Super-KEKB 35'
Speaker: Dr. Demin Zhou (KEK)
....

CEPC – theory effort

- Great effort by Chinese theorists, **(Hong-jian He & Shouhua Zhu)**
  - Sub-groups formed
  - Meetings
  - Document " Higgs Physics at CEPC-SPPC " in progress

Higgs Physics at the CEPC-SPPC

Ning Chen,[a] Hong-Jian He,[a] Tao Liu,[b] Shou-hua Zhu[c,d]

[a] *Center for High Energy Physics, Tsinghua University, Beijing, 100084, China*
[b] *Department of Physics, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong*
[c] *Institute of Theoretical Physics and State Key Laboratory of Nuclear Physics and Technology, Peking University, Beijing 100871, China*
[d] *Center for High Energy Physics, Peking University, Beijing 100871, China*

ABSTRACT: In this report, we survey Higgs physics in the SM and beyond, review the current measurements of Higgs physics at the LHC, and present the potential studies of Higgs physics at the CEPC-SPPC.

CEPC – Site Investigation Qinghungdao (秦皇岛)

Good geological condition

- Base rock type: granite
- Base rock depth: 0.5 - 2 m
- Seismic intensity: no more than the level 7 (some damage to houses), 0.10g
- Earth vibration(RMS, nm):

	Zhangjiakou	Huailai	Qinhuangdao	Tianjing	Huairou
1~100hz	~12	~40	~1.9	~470	~60
4~100hz	~7	~14	~0.8	~24	

Building the tunnel in granite will have the lowest cost

CEPC – Site Investigation Qinghungdao (秦皇岛)

Best beach & cleanest air
Summer capital of China

Starting point of the Great Wall

Wine yard