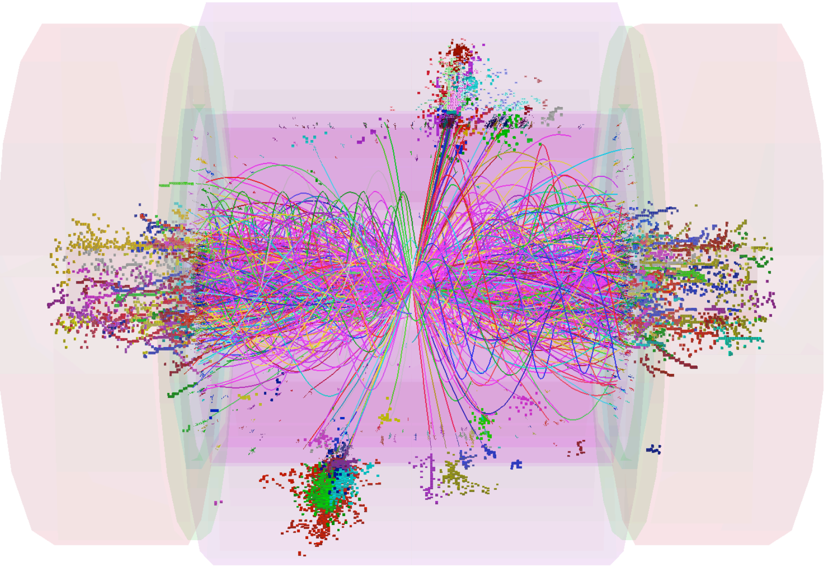
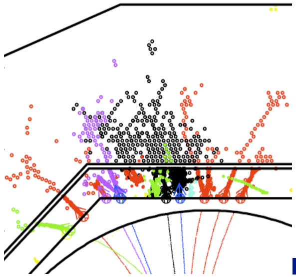
Physics and Detector studies for CLIC

Felix Sefkow

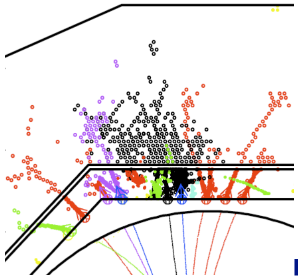


ALCPG 11
Eugene, OR, March 19-23, 2011

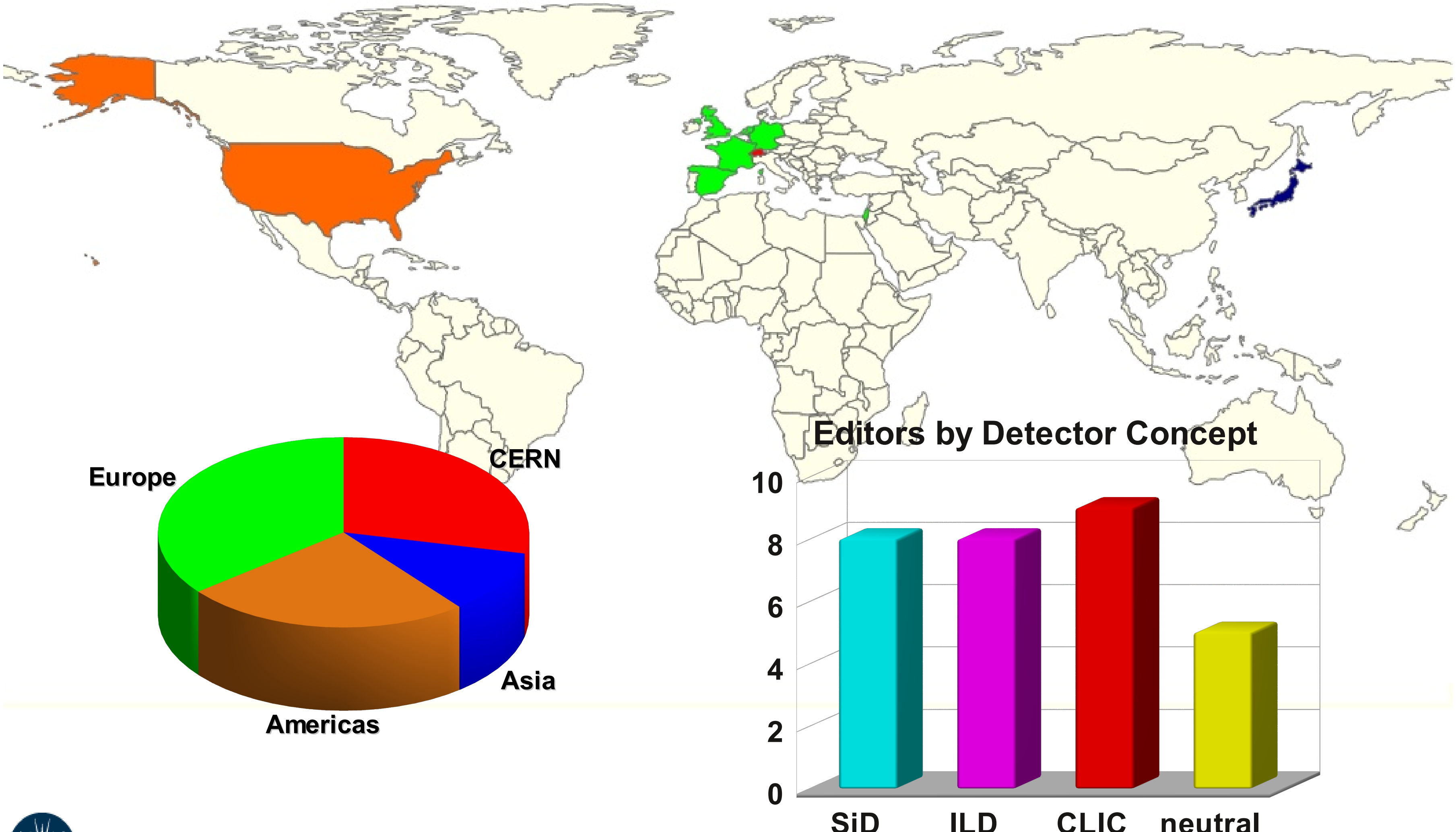


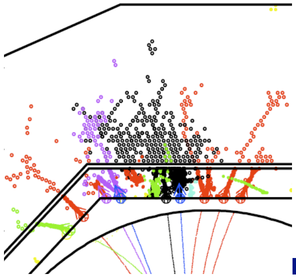
Context

- Physic results from the first round of LHC data are expected to guide the choice of energy for a future linear collider
- The LC community prepares a CLIC Conceptual Design Report, due in fall 2011, as input to strategy discussions worldwide, e.g. the CERN council European strategy to be updated in 2012
- The goal of the physics and detector studies for CLIC is to establish feasibility of experimentation in the multi-TeV range, and to identify and tackle critical R&D issues
- The studies cover the full energy range, with focus on 3 TeV, but include 0.5 TeV and a recently added 1.5-2 TeV intermediate stage



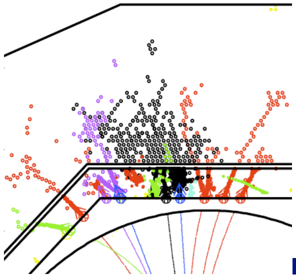
CLIC CDR Phys & Det editors





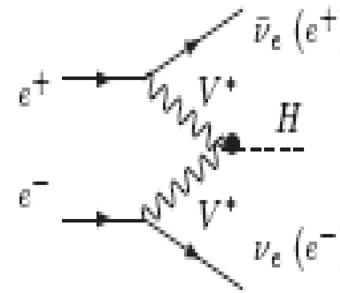
Outline

- Physics and background
- Simulation and reconstruction
- Engineering and R&D
- Thank you very much for input:
  - T.Barklow, D.Dannheim, K.Elsener, L.Linssen, A.Lucaci, J.Marshall, A.Muennich, J.Nardulli, S.Poss, A. Sailer, F.Simon, M.Stanitiski, M.Thomson
  - and those whose slides I have stolen without asking



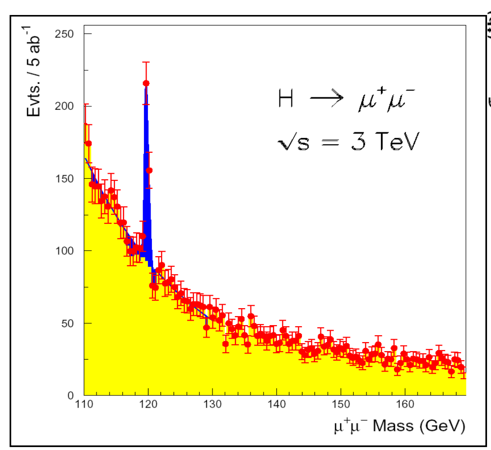
e^+e^- Physics at 3 TeV

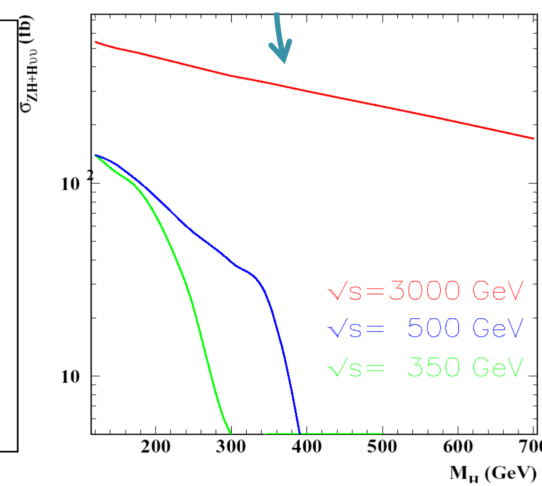
- Establish physics case
  - ≠ benchmarking
- Discovery and precision
- In view of early LHC results
- Physics groups
  - Higgs
  - Susy
  - Alternatives
  - Precision
- Example Higgs physics:
  - benefits from high fusion cross section
  - H → μμ
  - triple Higgs

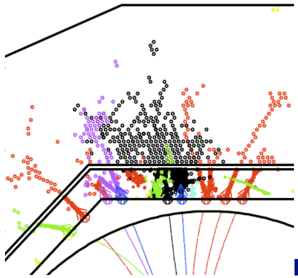


$\sigma \propto 1/s$

$\sigma \propto \log(s)$



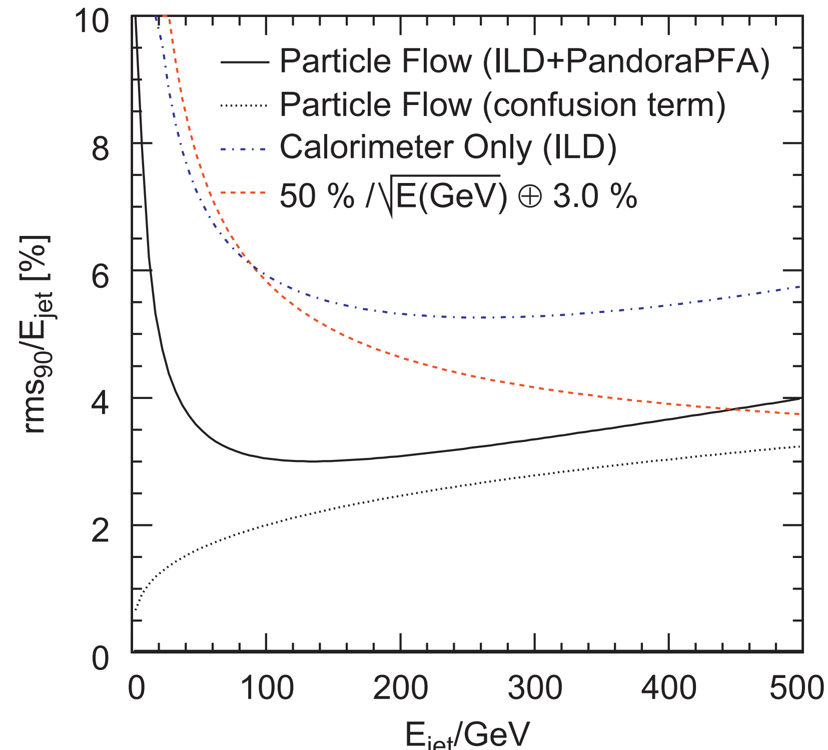


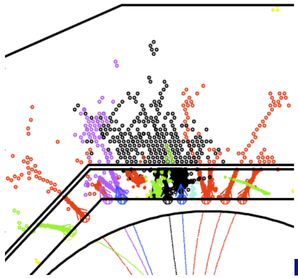


Experimental conditions

- Physics final states are not that different from the ILC
- Particle flow approach shown to work at high energy
- ILC like detector concepts are an excellent starting point for 3 TeV, too
- But: at CLIC need to tackle
  - higher energies
  - shorter bunch spacing
  - harsher backgrounds

√s	#fermions	Jet energy
250 GeV	4	~60 GeV
500 GeV	4 – 6	80 – 125 GeV
1 TeV	4 – 6	170 – 250 GeV
3 TeV	6 – 8	375 – 500 GeV

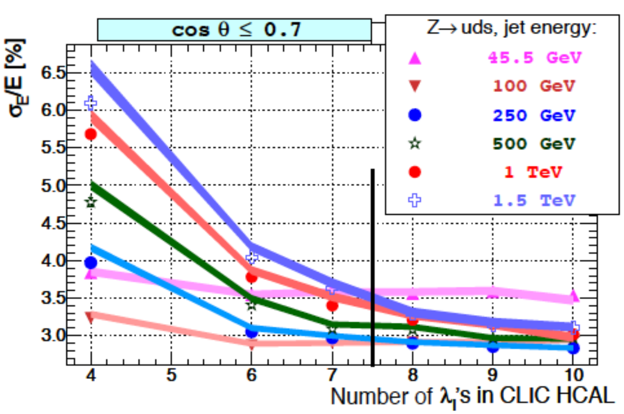


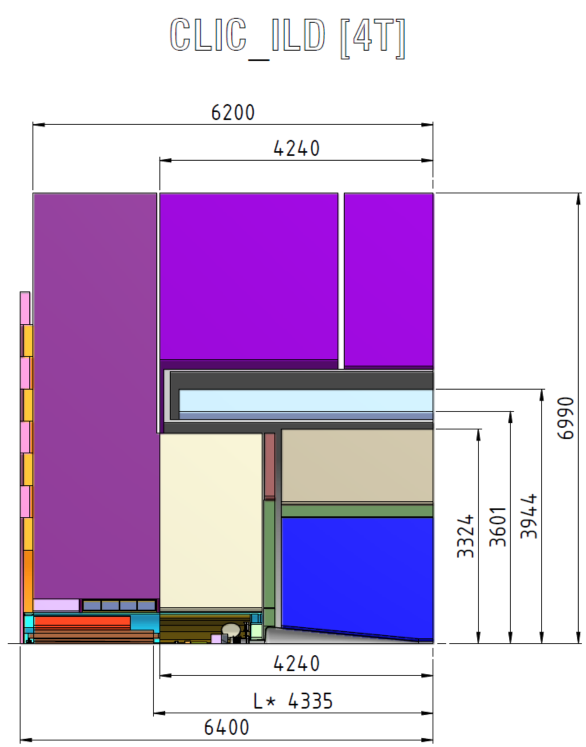


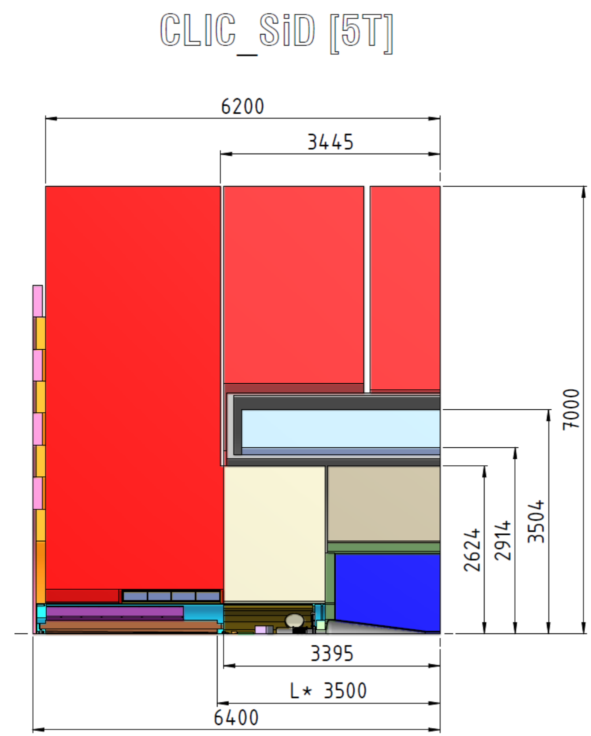
CLIC detector versions

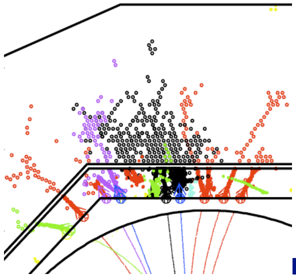
- Need to cover the physics potential of the full energy range, including the demanding precision requirements at 500 GeV
- No full new concepts, but modifications of ILD and SiD
  - VX to 2.5-3cm, HCAL 7.5 λ, W barrel, B = 4-5T, redesign FWD
  - tracking and ECAL unchanged

Pandora based optimization



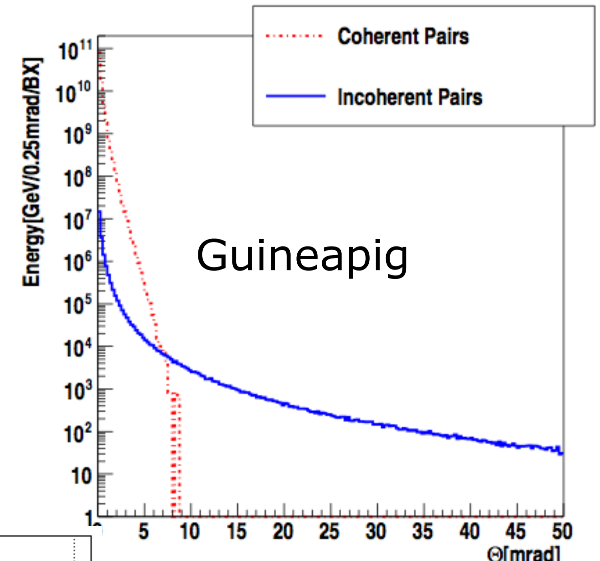


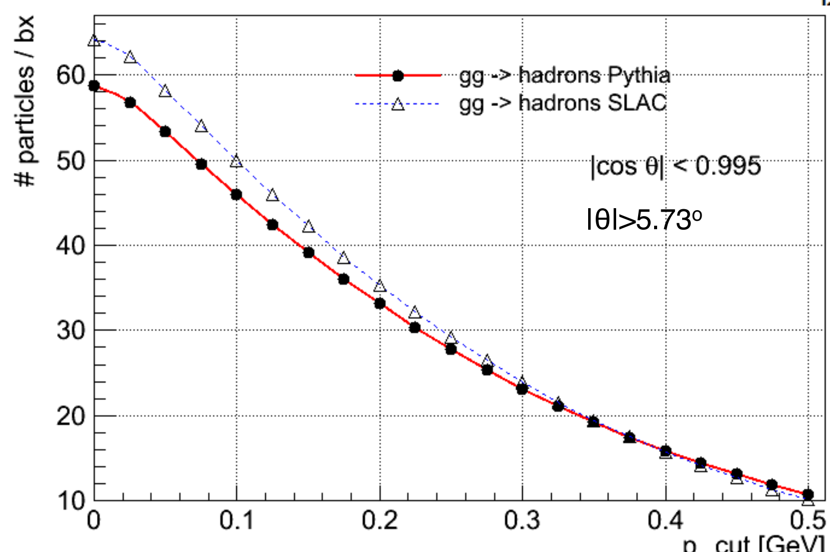


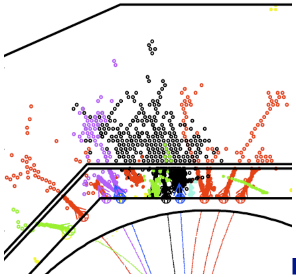


Backgrounds at 3 TeV

- 6 x 10^8 coherent particles / bx
- 3 x 10^5 incoherent particles / bx
  - but larger radii → detector sim
- 3.2 γγ → hadron events / bx
  - calculations cross-checked
- radiation damage still no issue
  - < 10^{10} 1 MeV n equiv / y except beamcal



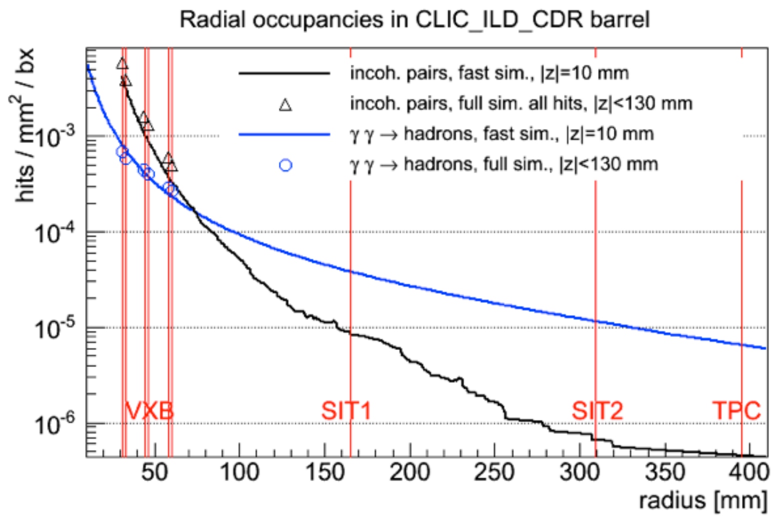




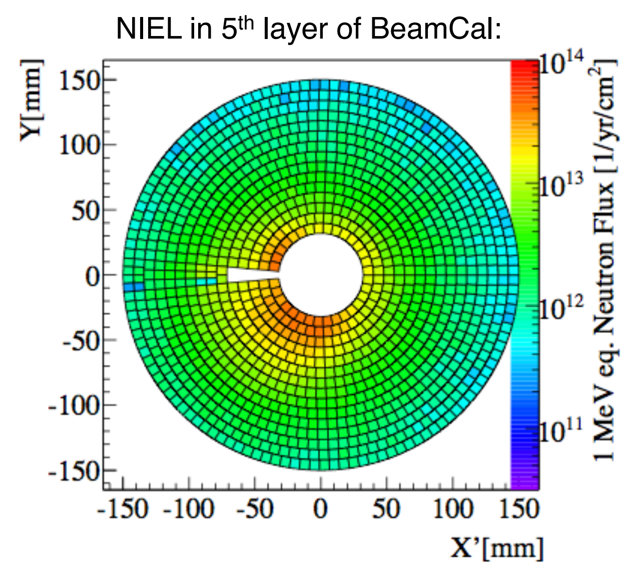
Detector occupancies

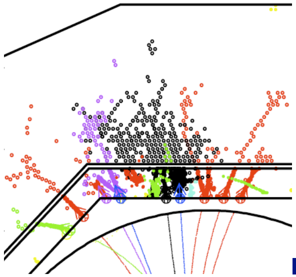
Pythia 2010 sample (D. Schulte) 3.2 events / bx

Section	CLIC_ILD_CDR E_{vis}/bx [GeV]	CLIC_SiD_CDR E_{vis}/bx [GeV]
LUMI-CAL	101.5	120.2
CAL-Endcap	35.4	45.3
CAL-Barrel	3.6	4.4
CAL-all	37.8	47.5



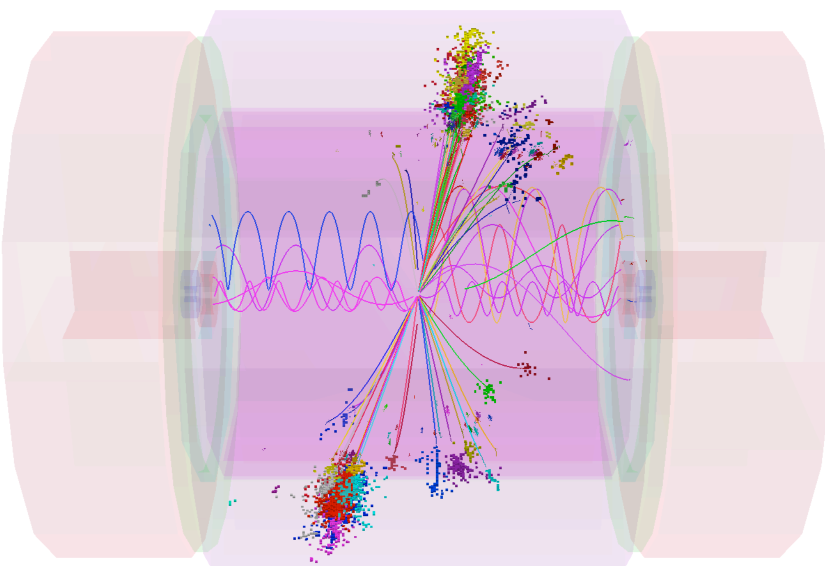
- fast sim validated with full sim
- 12-15 TeV / train in calorimeter
  - mainly γγ
- 2 hits / mm^2 / train in vertex
  - mainly incoherent pairs
- challenge for read-out electronics and reconstruction



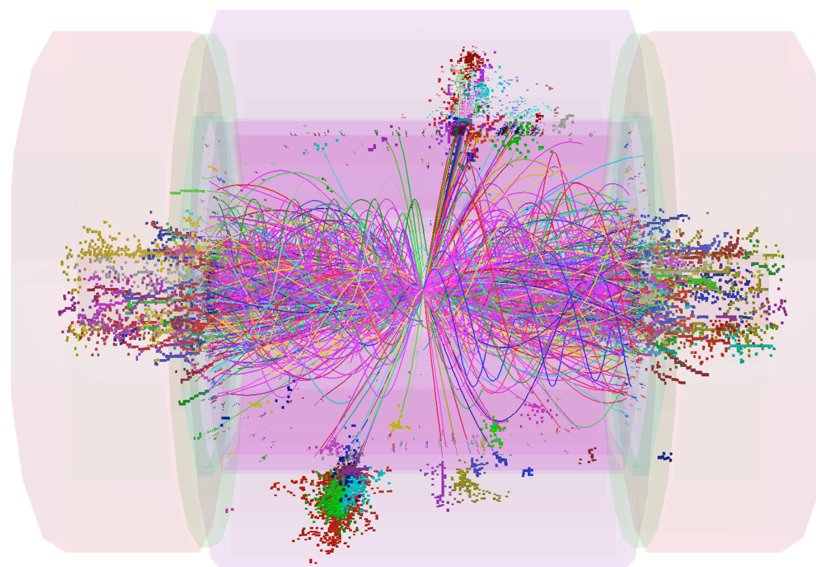


Sim & reco with background

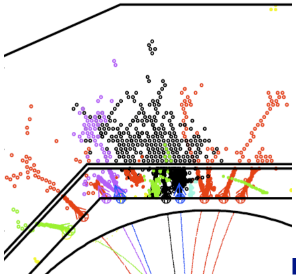
- Overlay γγ events from 60 BX
- take sub-detector specific integration times, multi-hit capability and time-stamping accuracy into account
- apply pt and timing cuts on cluster level (sub-ns accuracy)



Z @ 1 TeV



+ 1.4 TeV BG (reconstructed particles)



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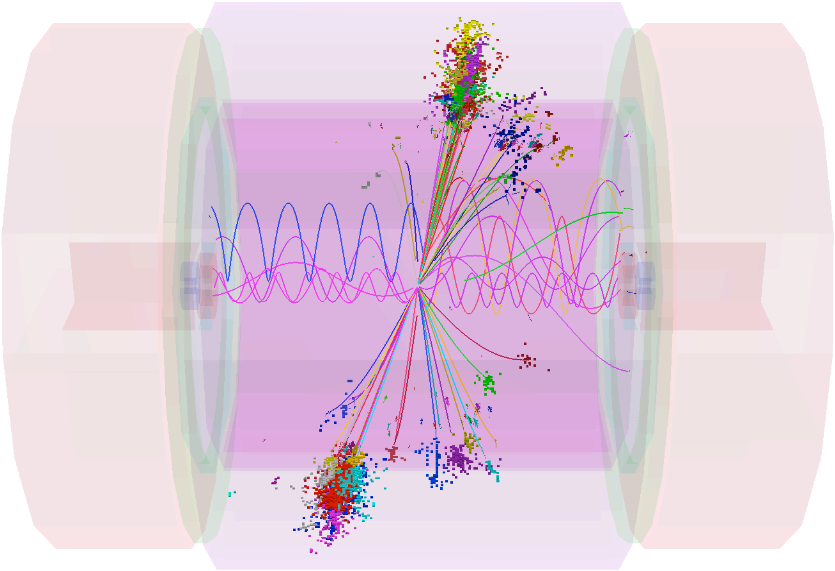

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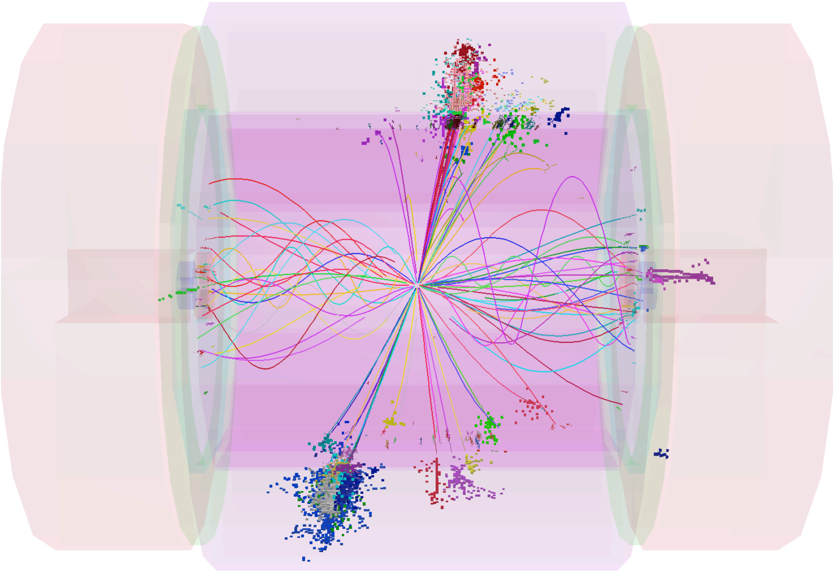

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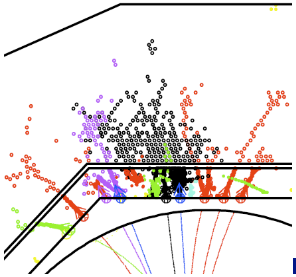

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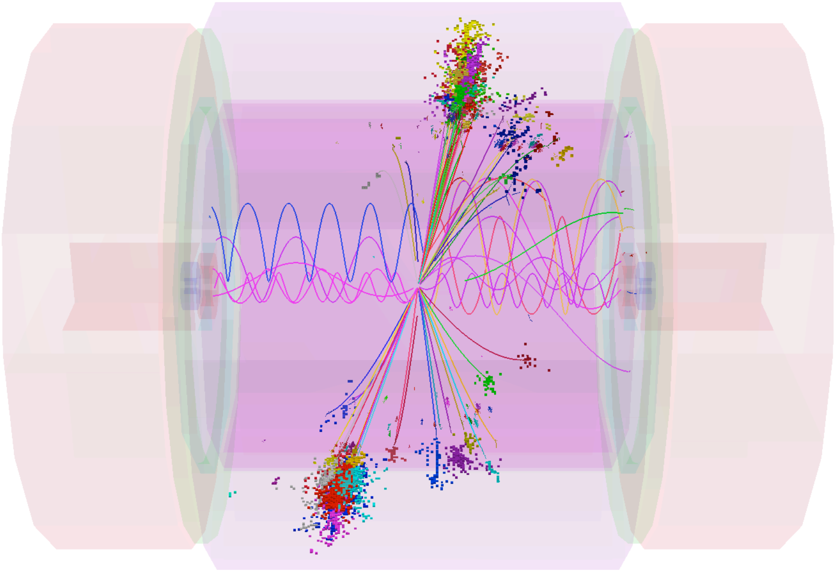

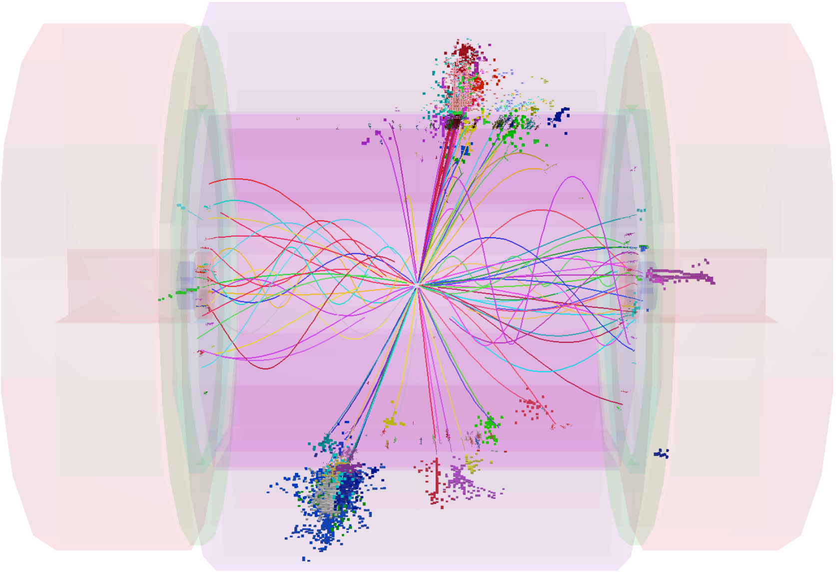

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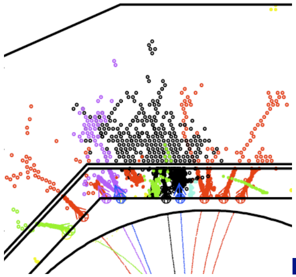
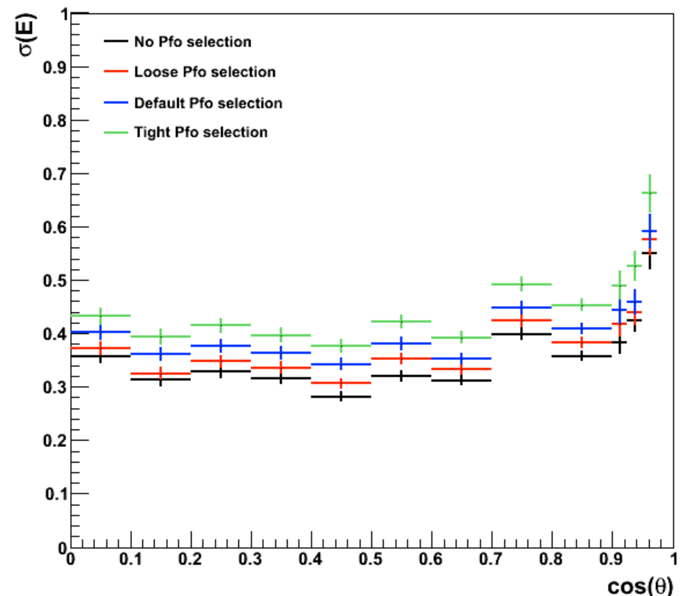
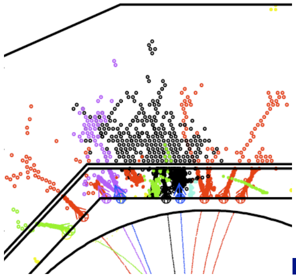


Jet energy validation

- **full sim & rec chain validated**
- study effect of cuts on signal
- some degradation, tuning not final
- no background included yet
  - but there was not too much left
- application to physics studies started

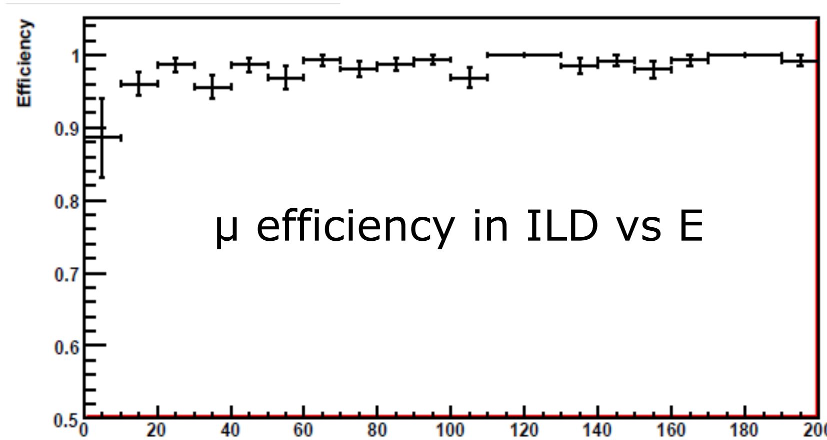


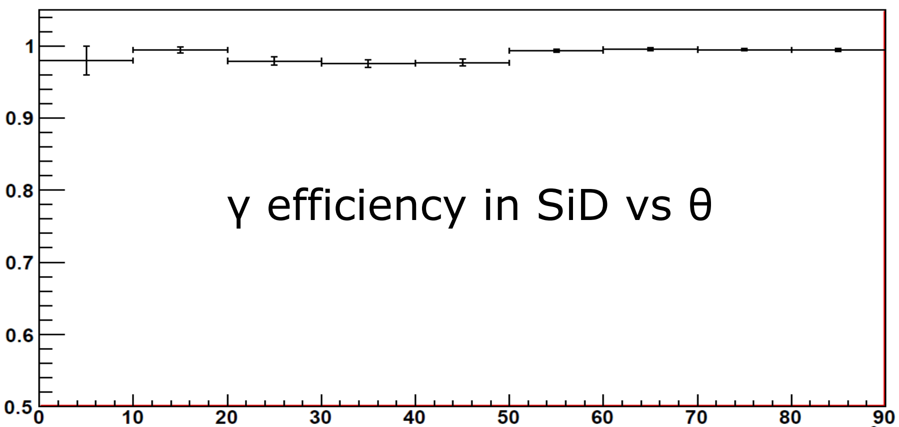
E_j	45GeV	100GeV	250GeV	500GeV
CLIC_ILD_CDR, v01-11, new config	3.74 ± 0.05	3.02 ± 0.04	3.00 ± 0.04	3.20 ± 0.06
CLICTrackSelector, 50ns cut	3.90 ± 0.05	3.13 ± 0.04	3.03 ± 0.04	3.21 ± 0.06
CLICPfoSelection, loose	4.40 ± 0.06	3.34 ± 0.04	3.12 ± 0.04	3.27 ± 0.06
CLICPfoSelection, default	5.18 ± 0.07	3.65 ± 0.05	3.20 ± 0.04	3.30 ± 0.06
CLICPfoSelection, tight	6.00 ± 0.08	3.99 ± 0.05	3.35 ± 0.04	3.37 ± 0.06

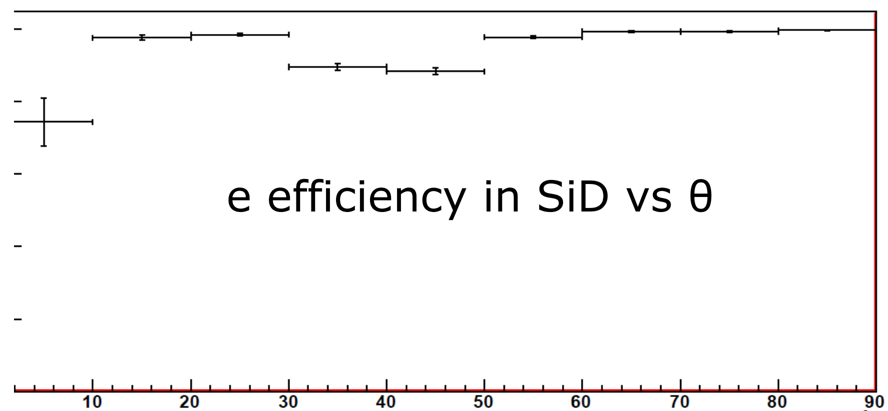


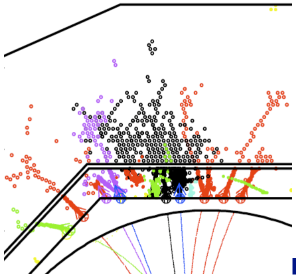
Particle ID

- use particle gun
- reconstruct PFOs and match with MC truth
- good efficiencies, further tuning possible
- influence of backgrounds and jet environment to be studied





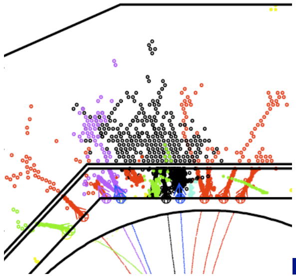




Detector benchmarking

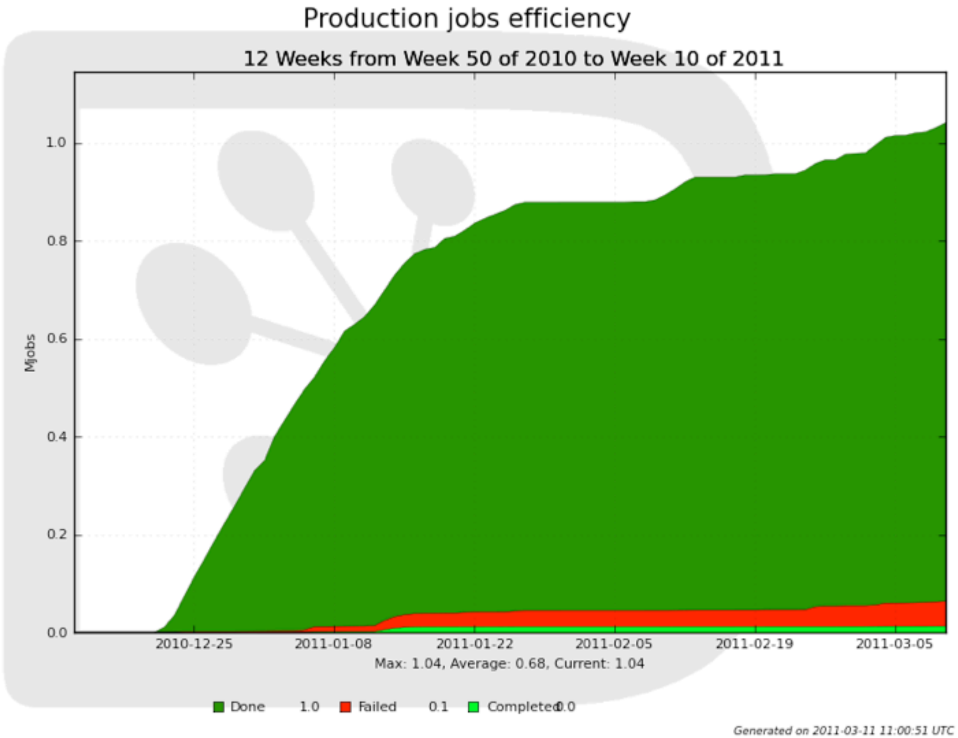
- Purpose: show that the 3 TeV physics can be done
  - do not confuse with physics case
- At 3 TeV:
  - light 120 GeV Higgs, H → μμ, bb
    - p (μ), fwd trk, jets
  - heavy 900 GeV Higgses H^+H^-, H^0A^0 → tbtb, bbbb:
    - b tag, multi-jet, Mjj
  - squark pairs, m = 1.1 TeV
    - high Ejet, missing E
  - slepton pairs, m = 1 TeV
    - high p reco, e, μ ID, missing E
  - chargino, neutralino pairs, various masses
    - Mjj at high Ej, multi-jet, missing E
- At 0.5 TeV:
  - tt production - ILC physics under CLIC conditions
    - multi-jet, b tag, with background

Teams active for
all 6 channels;
data production started

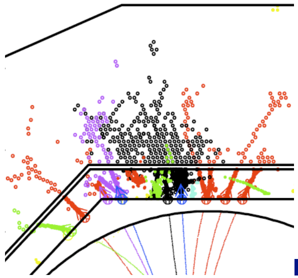


DIRAC production

- ILCDIRAC system
  - inherited from LHCb
  - ILCsoft: Mokka, Marlin, SLIC,...
- user-friendly GRID interface
  - automatic job re-submission
- SM production: 5 M ev / channel in about 2 weeks
  - incl. background
  - gen, sim, rec
  - 500 fb-1 / y x4
- 1 tt-bar event at 3 TeV takes 2 hours...

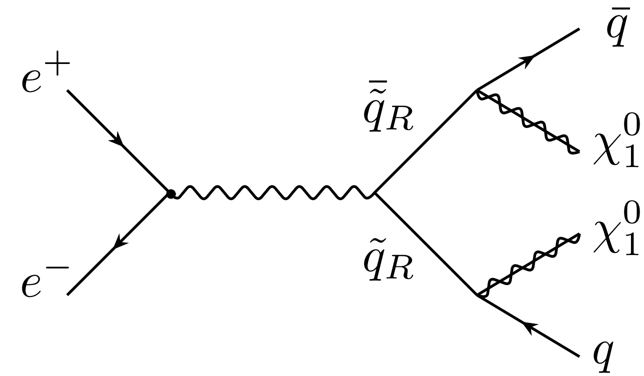


includes code instabilities



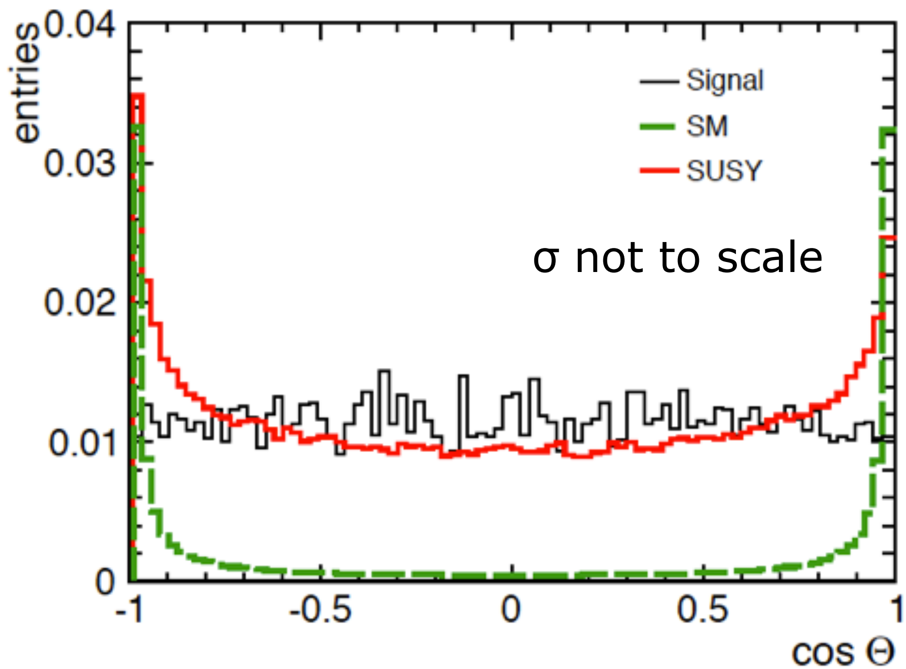
Squark production

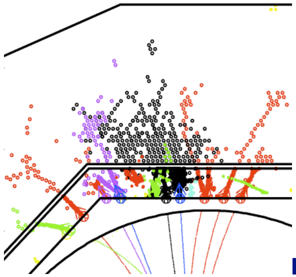
- Right-handed . u,d,s,c,b squarks
- M = 1.12 TeV, σ = 1.7 fb at 3 TeV
- Main background: SM 4f, σ~ 10 pb



2 jets +
missing E

- Benchmark barrel calorimeter and tracking
- CLIC-ILD



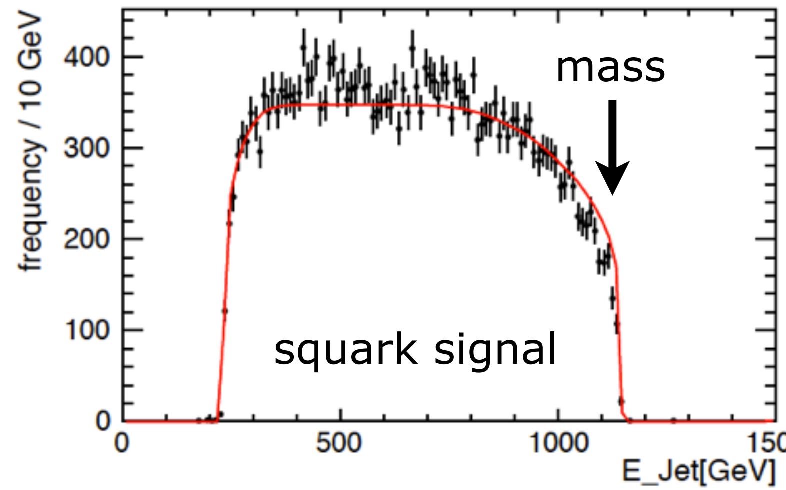


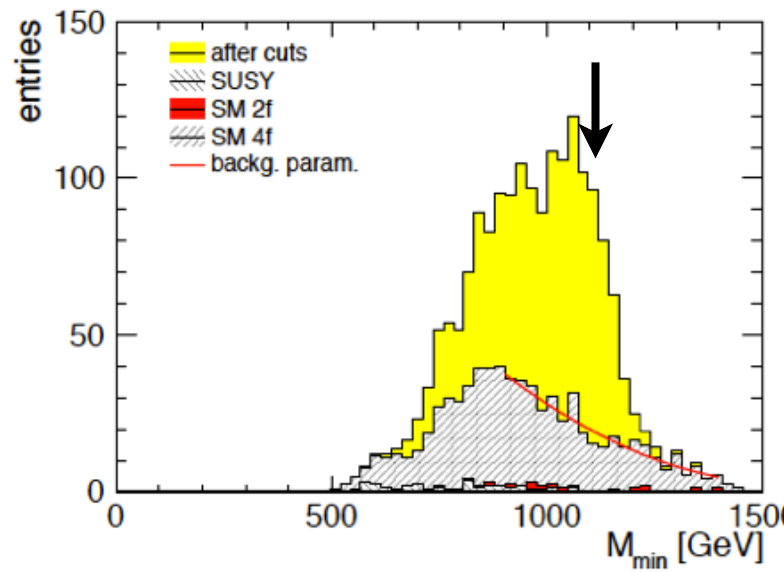
Squark mass measurement

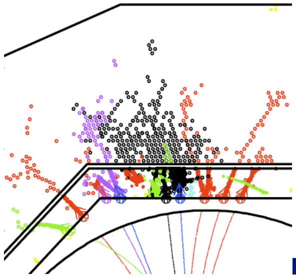
- Edge of E_{jet} distribution
- distorted by
  - beamstrahlung, ISR
  - background

- Selection cuts
  - missing E_T, cos θ
  - acolanarity, event & jet shapes

- Mass extraction
  - use neutralino mass, kinematics
  - clean edge
- Next: add γγ background







Chargino, neutralino production

Signal: $e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$ σ=10.5 fb

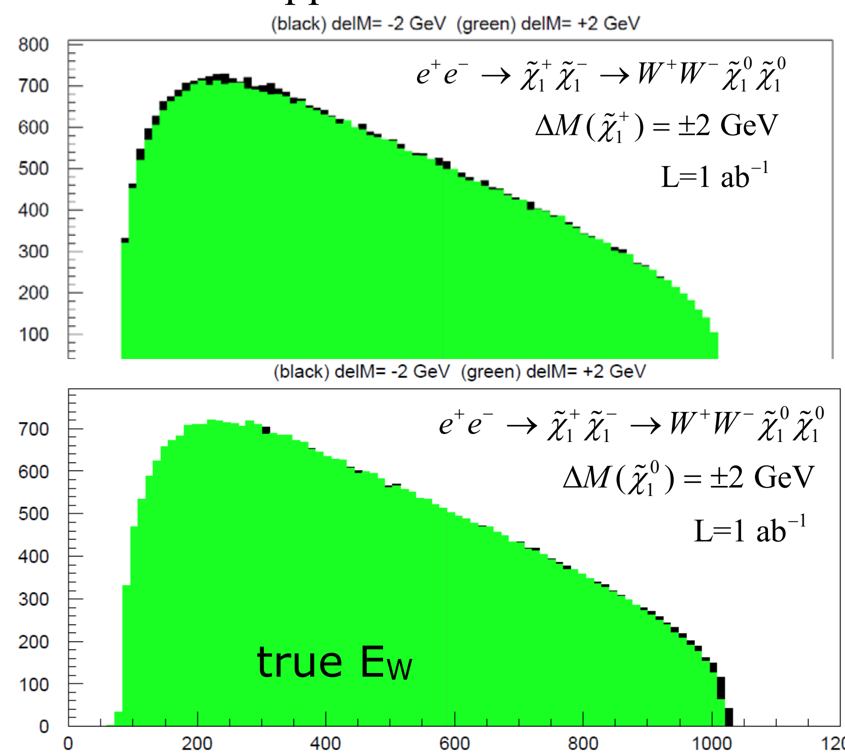
Backgrounds: $e^+e^- \to \tilde{e}_L^-\tilde{e}_L^+ \to \tilde{\chi}_1^+\tilde{\chi}_1^-\nu_e\bar{\nu}_e \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0\nu_e\bar{\nu}_e$

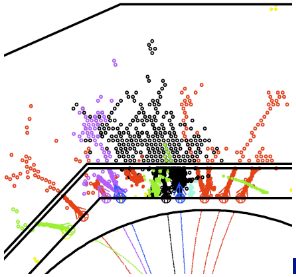
$+\tilde{\mu}_L^-\tilde{\mu}_L^+ \to \tilde{\chi}_1^+\tilde{\chi}_1^-\nu_\mu\bar{\nu}_\mu \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0\nu_\mu\bar{\nu}_\mu$ σ=1.4 fb

$e^+e^- \to W^+W^-\nu\bar{\nu} + ZZ\nu\bar{\nu} \to \mathrm{q}\bar{\mathrm{q}}\nu\bar{\nu}$ σ=55.7 fb

- 5 par fit (masses and X-sections) to W energy distribution
- study sensitivity to chargino mass
- benchmark jet energies
- CLIC_SiD
- also studied with same technique: neutralinos:

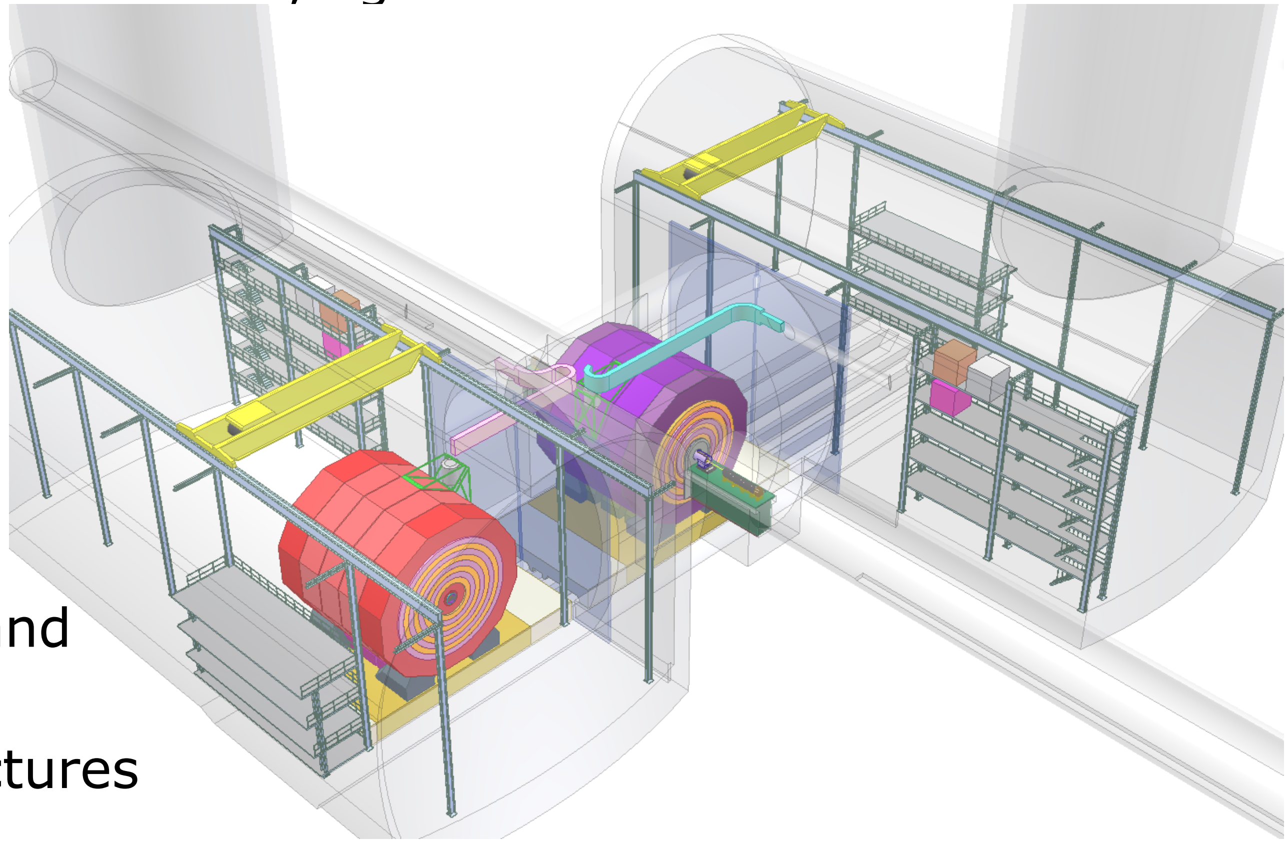
$$e^+e^- \to \tilde{\chi}_2^0\tilde{\chi}_2^0 \to h^0h^0\tilde{\chi}_1^0\tilde{\chi}_1^0$$



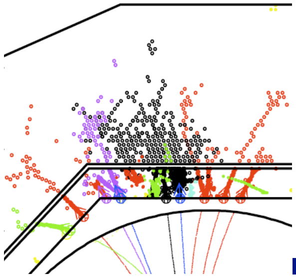


Engineering

- Push-pull experimental hall design
- Solenoid design and SC cable R&D
- Costing with ILD and SiD, agreed unit costs

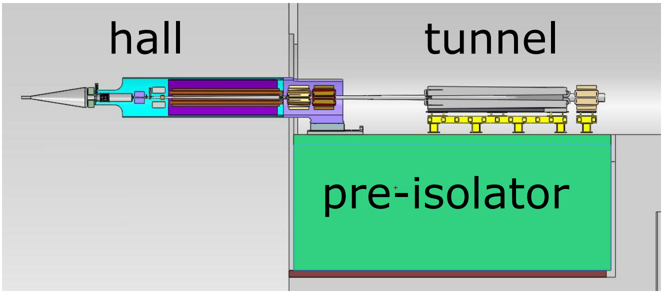


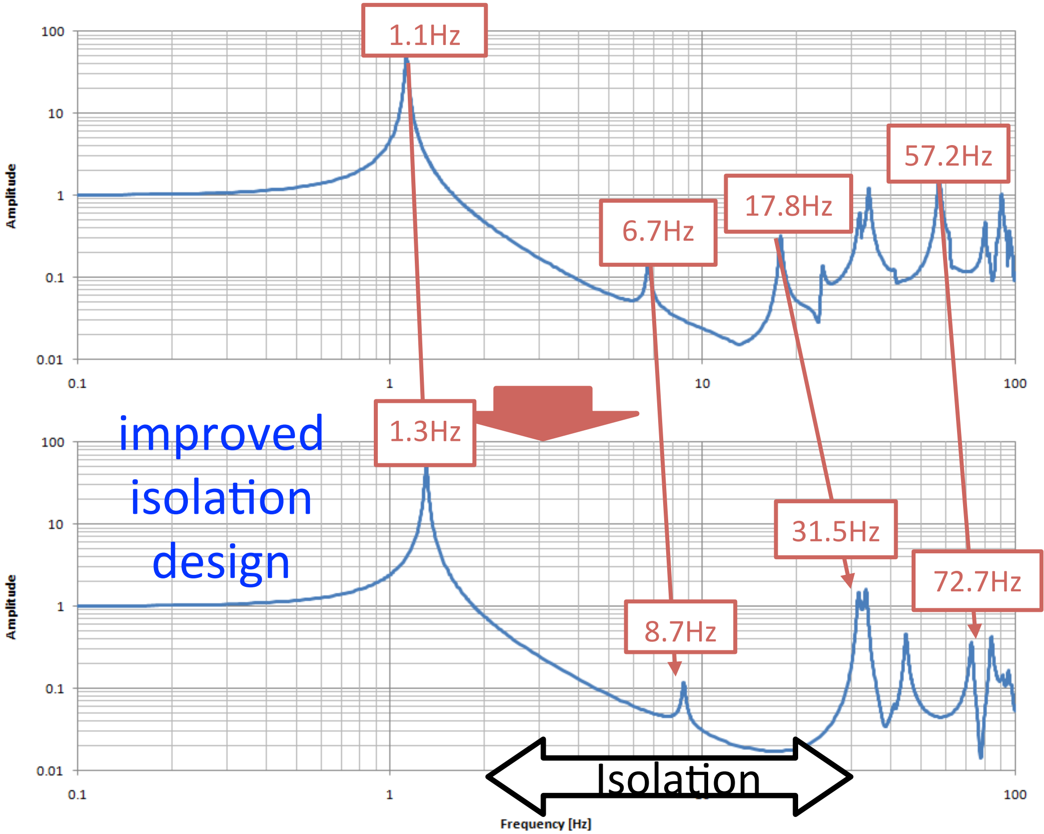
- QD0 magnet and support
- tungsten structures

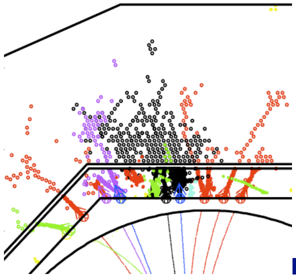


QD0 stabilization

- Isolating the QD0 magnet from ground motion is a major engineering challenge
- Test set-up built in order to validate calculations
  - not a prototype







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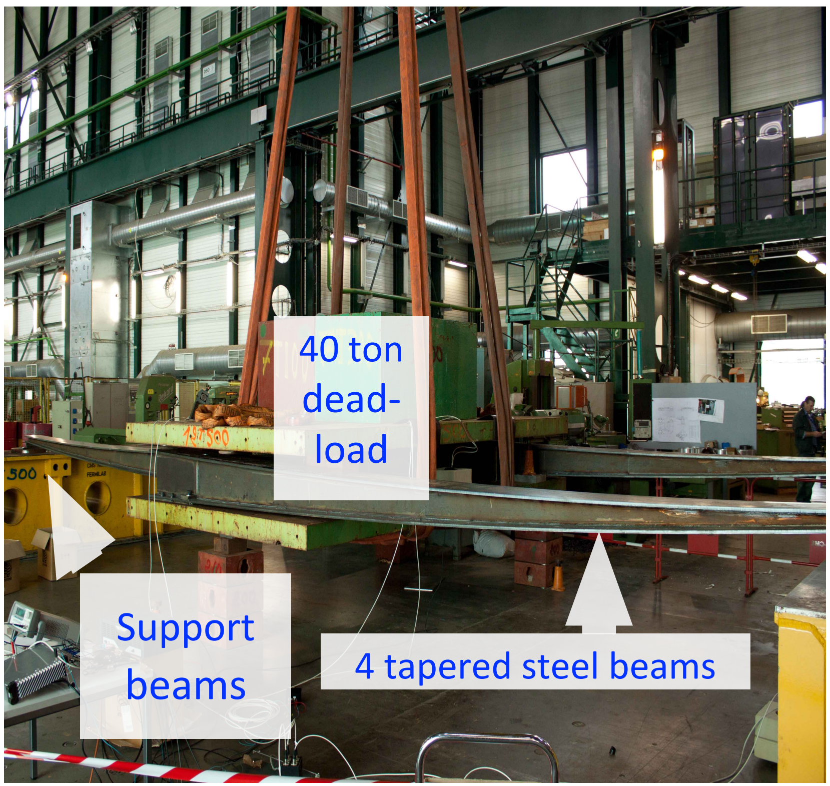
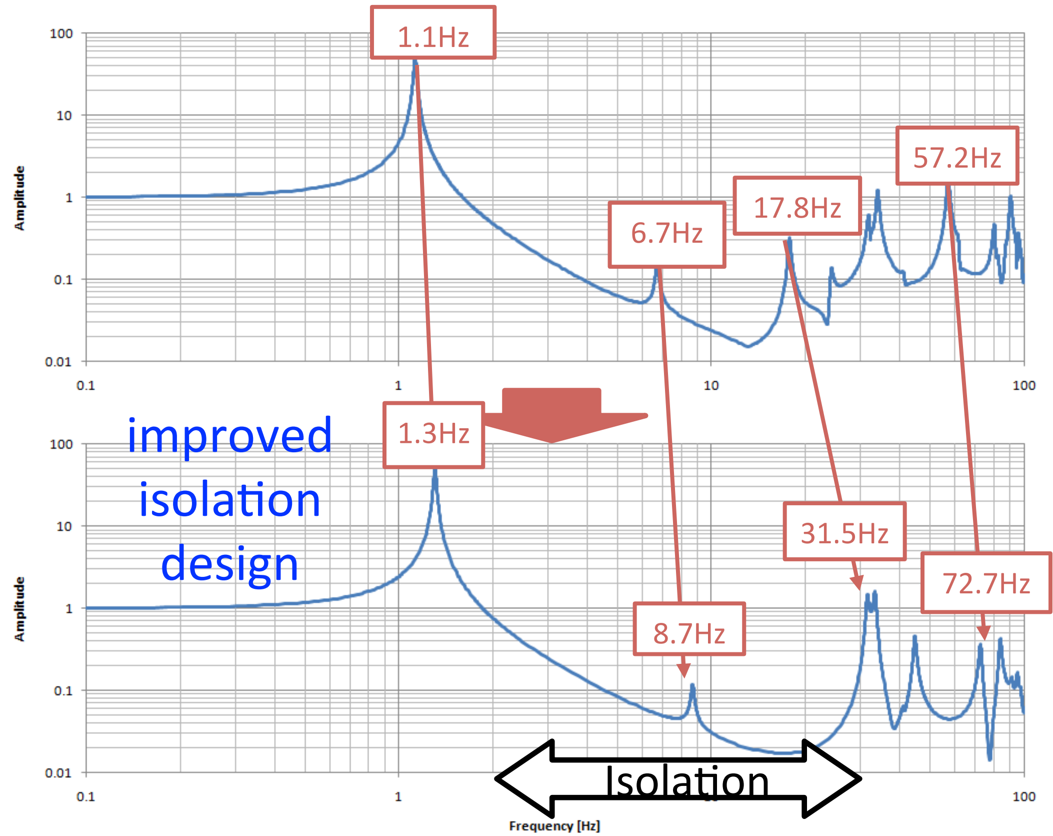
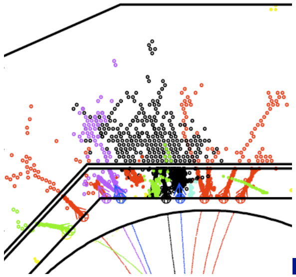
- Test set-up built in order to validate calculations
  - not a prototype

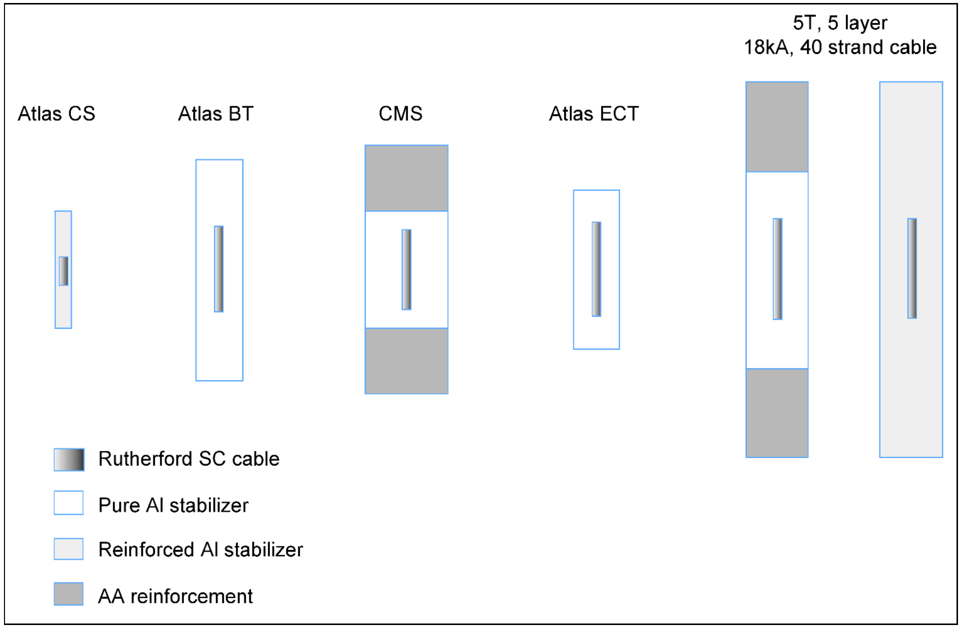




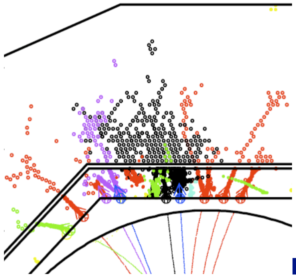


SC cable extrusion test

- Main challenge of 5T (and a 3.5 T) solenoid: forces on the SC cable (100 bar pressure)
- Extrapolate ATLAS CS reinforced aluminum design
  - micro-alloy increases mechanical strength without degrading conductivity
- Collanoration between KEK and CERN, involving Swiss industry

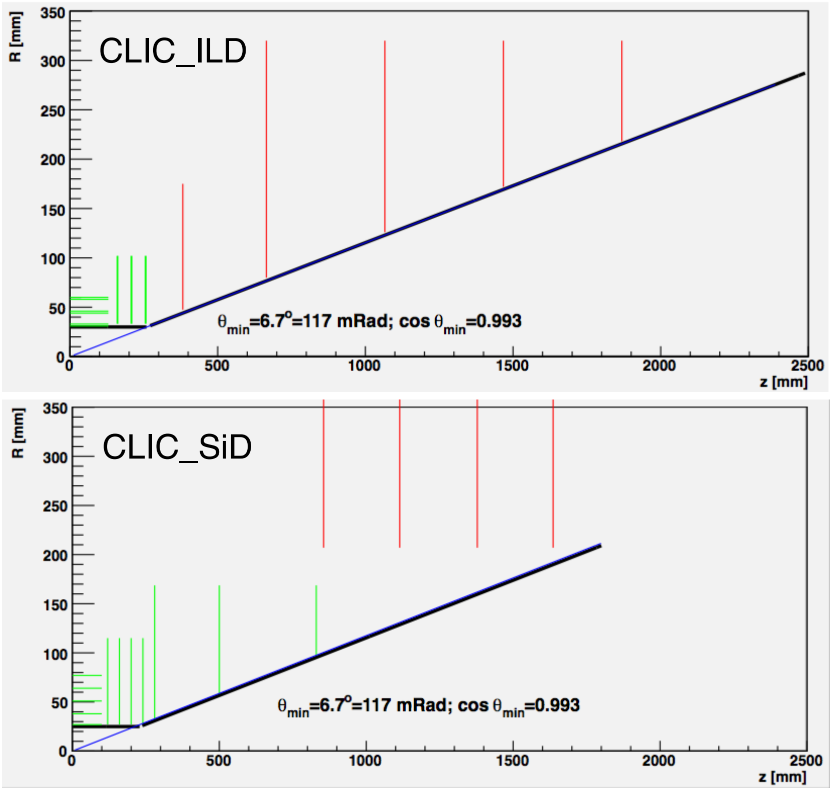


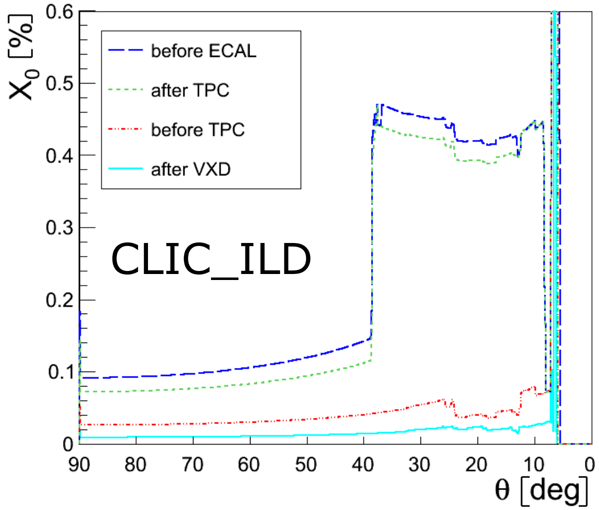
Co-extrusion

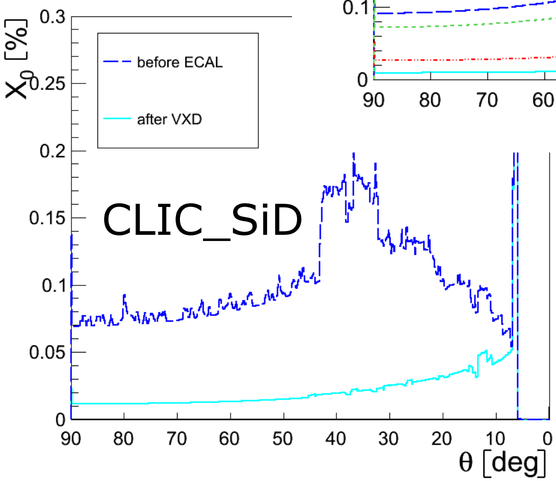


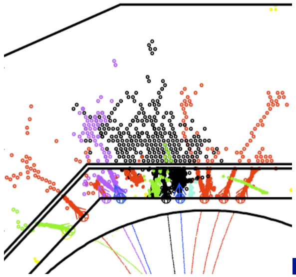
Vertex detector design

- ILD and SiD vertex region re-optimized and re-designed
- similar acceptance and performance
- now material budget checked in full simulation



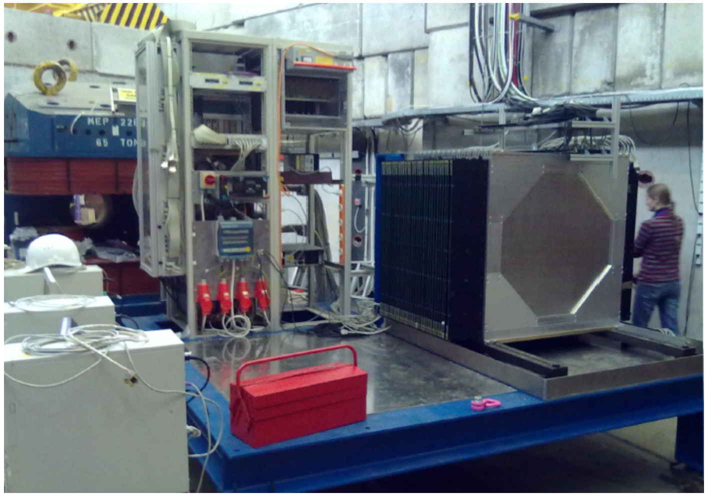


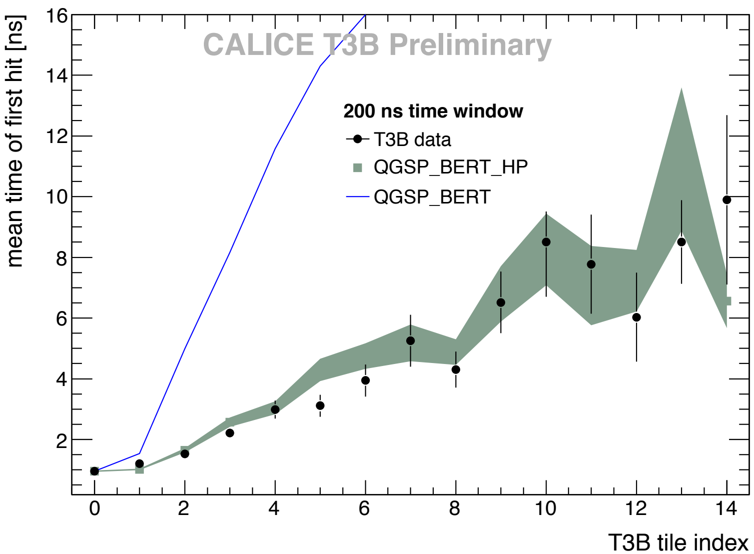


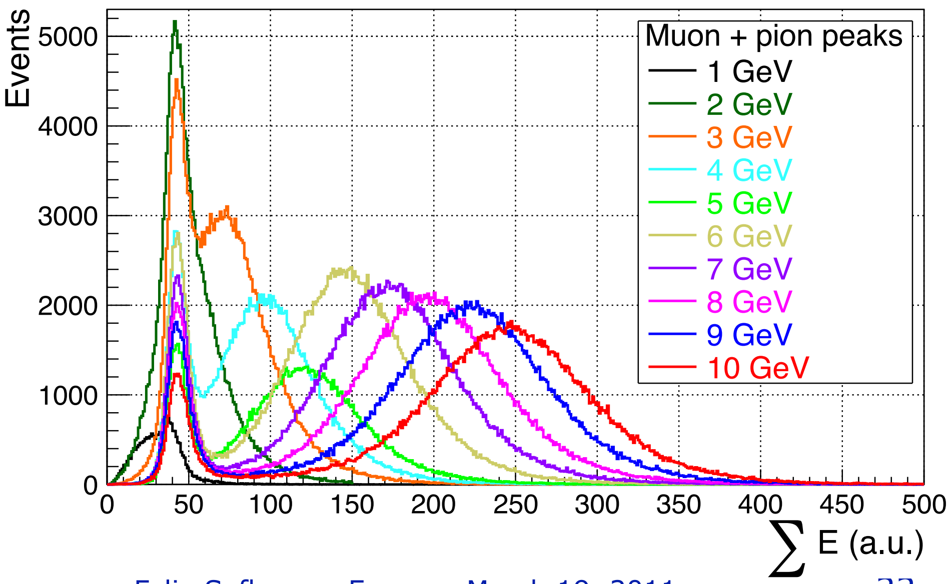


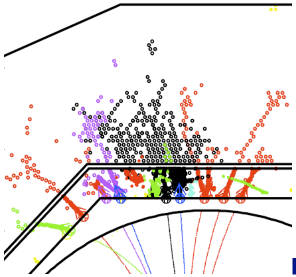
W HCAL tests

- test simulation of neutron-rich response and time structure
- Test beam in 2010 with 30 W absorber and scint active layers
- 2011: add 10 layers and tail catcher
- analysis in progress
- T3B: tiles with picosecond electronics: first results









Conclusions

- CDR effort extends the LC physics and detector studies to the multi-TeV region
- Detector: particle flow driven, standing on ILD and SiD shoulders but facing some additional challenges
- Benchmarking: incorporate backgrounds in simulation and reconstruction → realistic assessment of the physics potential
- Engineering and R&D: focussed on some critical items and on issues common with ILC detectors
- Altogether: broaden the LC case and strengthen community

Back-up slides