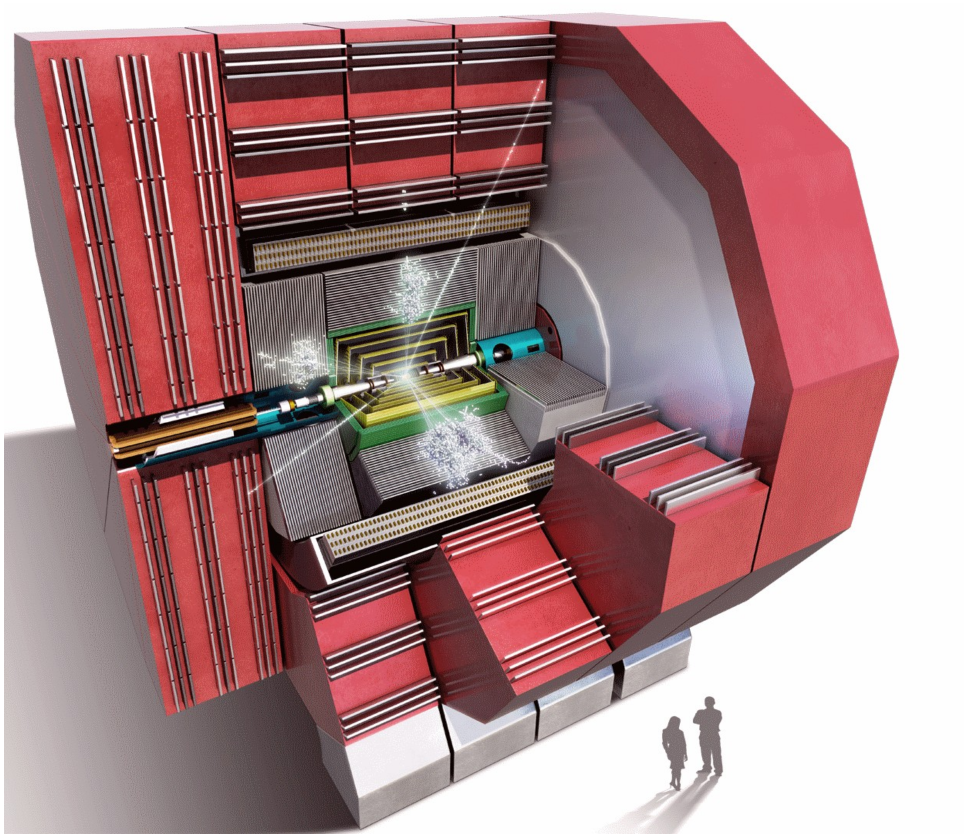
Impressions from the CLIC Detector and Physics Collaboration Meeting



Katja Krüger
ILC project meeting
15 September 2017

Introduction

- 2-days meeting 29-30 August 2017 at CERN
  https://indico.cern.ch/event/633975/
- sessions
  - Plenary
  - Physics/Analysis
  - Calorimeter R&D
  - Vertex/Tracker R&D
  - Software/Detector Validation
- remark: what I show in the following slides is my personal selection of highlights, and by no means complete

Plenary

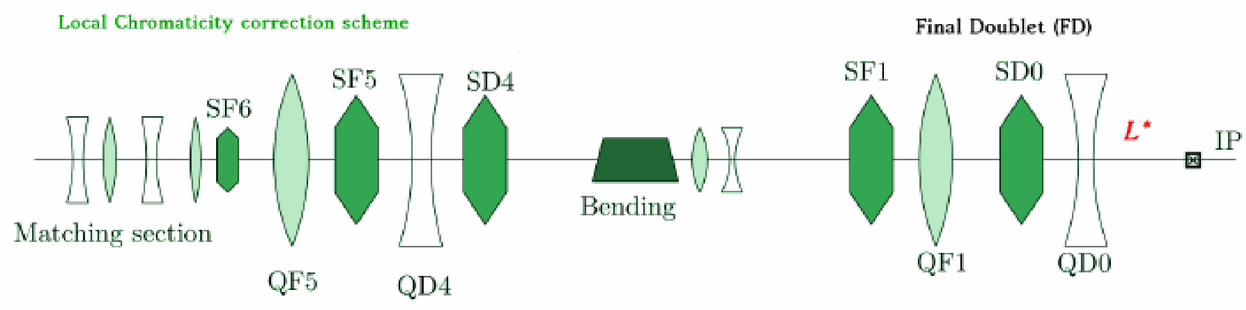
Welcome and General News	*Lucie Linssen*	
503-1-001 - Council Chamber, CERN	08:30 - 08:50	
Report from the CLIC Communication Initiative (CCI)	*Lars Rickard Strom*	
503-1-001 - Council Chamber, CERN	08:50 - 09:05	
Update on CLIC BDS tuning and luminosity performance	*Fabien Plassard*	
503-1-001 - Council Chamber, CERN	09:05 - 09:20	
Beam-induced backgrounds at 380 GeV CLIC	*Dominik Arominski*	
503-1-001 - Council Chamber, CERN	09:20 - 09:35	
Cooling of ECAL and HCAL	*Katja Krueger*	
503-1-001 - Council Chamber, CERN	09:35 - 09:55	

Report from the CLIC physics potential WG	*Jorge de Blas*
503-1-001 - Council Chamber, CERN	16:00 - 16:25
Analysis overview	*Philipp Roloff*
503-1-001 - Council Chamber, CERN	16:25 - 16:45
Report from the Speakers Committee	*Igor Boyko*
503-1-001 - Council Chamber, CERN	16:45 - 17:00
Report from the Publication Committee	*Aleksander Filip Zarnecki et al.*
503-1-001 - Council Chamber, CERN	17:00 - 17:15
Report from the Institute Board meeting	*Aidan Robson et al.*
503-1-001 - Council Chamber, CERN	17:15 - 17:30

General News

- European Strategy update
  - will take place 2019-2020
  - not much known yet about procedures
  - major strategy input (e.g. CLIC summary documents) due for end 2018 (collider baseline & Higgs physics done in 2016, new detector model in 2017, top physics planned for end of 2017, BSM physics and CLIC R&D in 2018)
- CompactLight EU proposal accepted
  - design study for X-ray FEL based on CLIC technology
  - 3 M€ EU funds requested
- new trends in searches
  - follow hints from B physics
  - more "exotic" ideas: long-lived particles
- studies of CLIC-like detector for FCC-ee
- Lucie's second term as spokesperson ends on 31st December 2017

CLIC BDS tuning and background estimates



Two FFS L^* options are explored for CLIC at 380 GeV and 3 TeV

- **Nominal L^* (CDR)** is 3.5 meters for CLIC 3 TeV and 4.3 meters for CLIC 380 GeV

  ⇒ gives **optimal luminosity** with **challenging Machine Detector Interface** (QD0 inside the experiment)

- **Longer** L^* option is 6 meters for both energy stages

  ⇒ **much more simplified MDI**

The FFS L^* option will be decisive for the CLIC Detector model!

CLIC BDS tuning and background estimates

Summary

Two L^* options for the BDS have been proposed for CLIC and fully optimized, implying significant changes in the detector model and MDI layout

CLIC BDS at 3 TeV

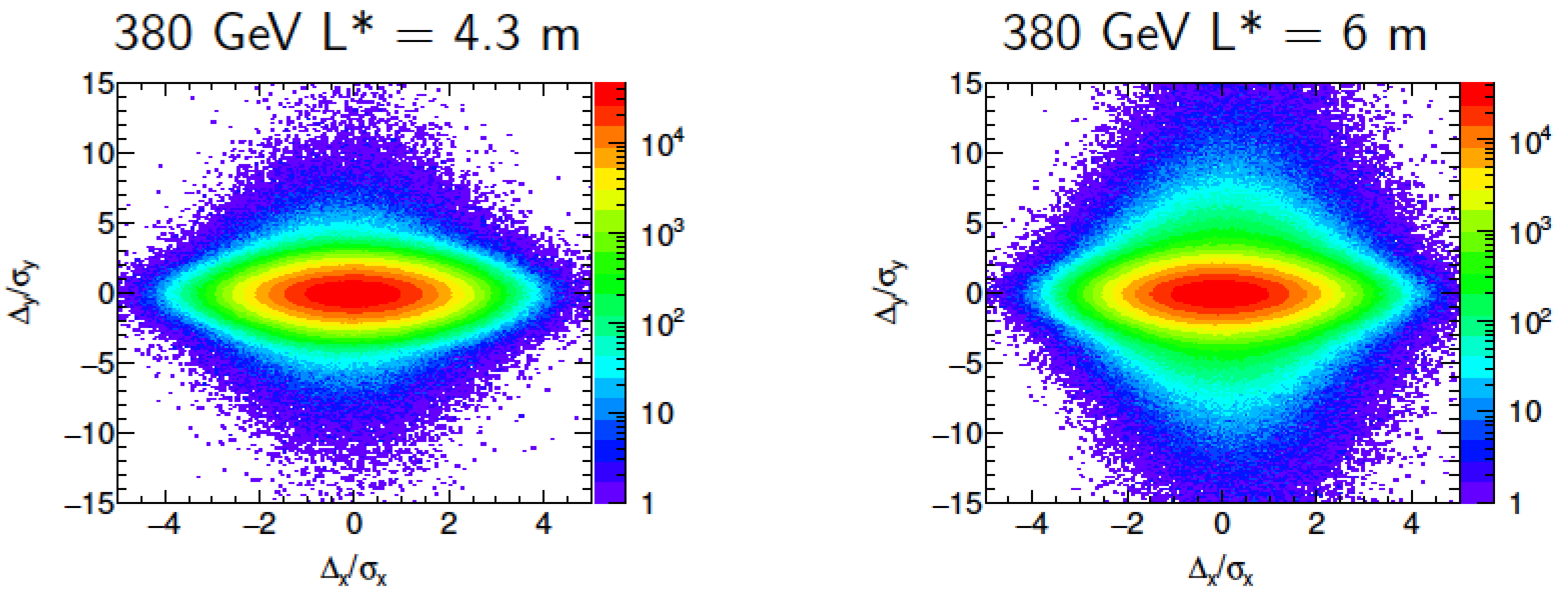
- Both L^* options reach the design requirement, with 12% of luminosity loss for the $L^* = 6$ m design compared to the nominal one
- The luminosity comparison doest not take into account the MDI simplification impact for the $L^* = 6$ m option :
  - QD0 vibration reduction
  - No field interplays between QD0 and the experiment
  - Easier access for interventions in the QD0 region
  - Simpler magnet technology for QD0 (normal conducting magnet)
  - Gain in detector acceptance
- The **tunability has been demonstrated to the same level for both L^* designs**
- The collimation depth is not tightened for $L^* = 6$ m
- Shorter designs have been optimized for $L^* = 6$ m and reach the luminosity requirements, but tunability and collimation depth needs to be studied

CLIC BDS at 380 GeV

- Both L^* have been optimized w.r.t the energy upgrade, meets the luminosity requirement and falls very close to the tuning goal under realistic error conditions

CLIC BDS tuning and background estimates

Beam distributions at IP and luminosities



design	σ_x (nm)	σ_y (nm)	$\mathcal{L}_{total}$ ($x10^{34} \frac{1}{\mathrm{s\ cm^2}}$)
baseline 380 GeV	149	2.9	1.5
PLACET 380 GeV L*=4.3 m (core)	148.6	2.9	1.5
PLACET 380 GeV L*=6.0 m (core)	150.5	3.2	1.35

- Beam transported through BDS with larger L* is 10% bigger in vertical direction which compromise reaching the total luminosity goal at this energy stage

CLIC BDS tuning and background estimates

Summary and outlook

- All major types of beam-induced backgrounds have been presented for lower energy stage of CLIC along with the relevant energy depositions
- The main sources of direct background are incoherent pairs and $\gamma\gamma \to$ hadrons events
- The most irradiated subdetector is BeamCal with 0.8 mW of power coming from incoherent pairs
- The longer L* results in luminosity lower by 10% from the nominal value but offers a lower yield of direct background coming from unwanted $\gamma\gamma \to$ hadrons events

Future works:

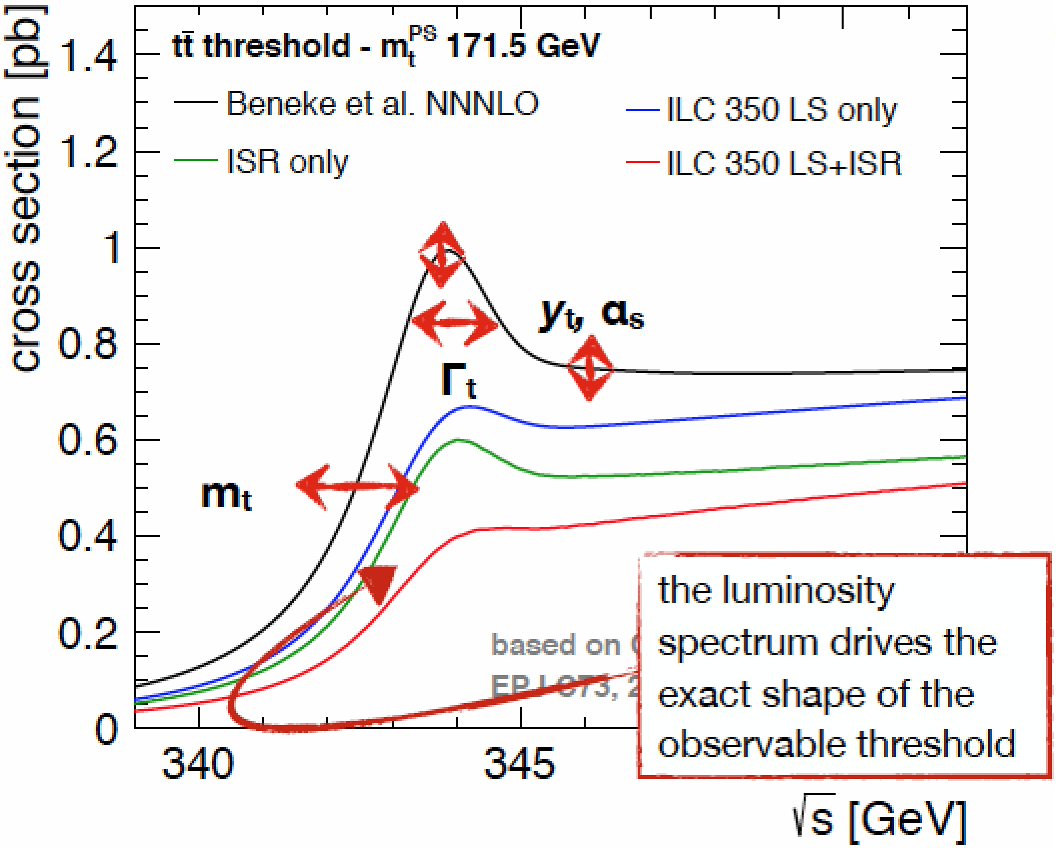
- Study energy depositions of backgrounds in the CLICdet with the longer Beam Delivery System, and arising occupancies in further detail
- Analyze the synchrotron radiation production in FFS at 380 GeV including the possible reflection against the beampipe and its impact on the detector design

Physics/Analysis

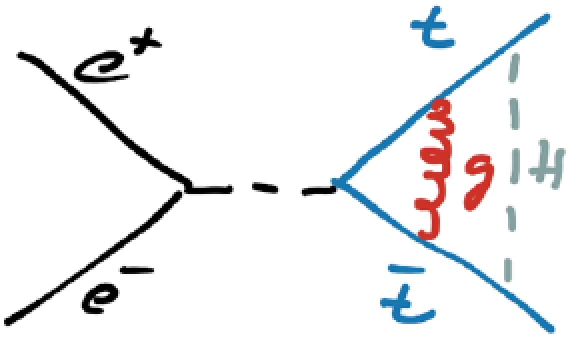
Limits on top FCNC decay t->cH from CLIC at 380 GeV	*Aleksander Filip Zarnecki*	
503-1-001 - Council Chamber, CERN		10:30 - 10:50
Update on FCNC t->c gamma at 380 GeV	*Naomi Van Der Kolk*	
503-1-001 - Council Chamber, CERN		10:50 - 11:10
Status of ee -> gamma gamma analysis	*Igor Boyko*	
503-1-001 - Council Chamber, CERN		11:10 - 11:25
BSM Hidden valley searches	*Marcin Kucharczyk*	
503-1-001 - Council Chamber, CERN		11:25 - 11:45
The Higgs couplings and self-coupling in the EFT framework	*Jiayin Gu*	
503-1-001 - Council Chamber, CERN		11:45 - 12:00

Top Yukawa coupling measurement at 1.4 TeV at CLIC	*Mr. Yixuan Zhang*	
503-1-001 - Council Chamber, CERN		16:30 - 16:45
WW/ZZ separation and timing cut comparison for old and new CLIC detector model	*Sascha Simon Dreyer et al.*	
503-1-001 - Council Chamber, CERN		16:45 - 17:05
Top forward-backward asymmetry with boosted reconstruction methods at multi-TeV CLIC	*Lars Rickard Strom*	
503-1-001 - Council Chamber, CERN		17:05 - 17:25
The top-antitop threshold in WHIZARD	*Maximilian Stahlhofen*	
503-1-001 - Council Chamber, CERN		17:25 - 17:45
A Top Threshold Scan with with Luminosity Spectrum of the 380 GeV Machine	*Frank Simon*	
503-1-001 - Council Chamber, CERN		17:45 - 18:00

Introduction: Top Threshold Scan



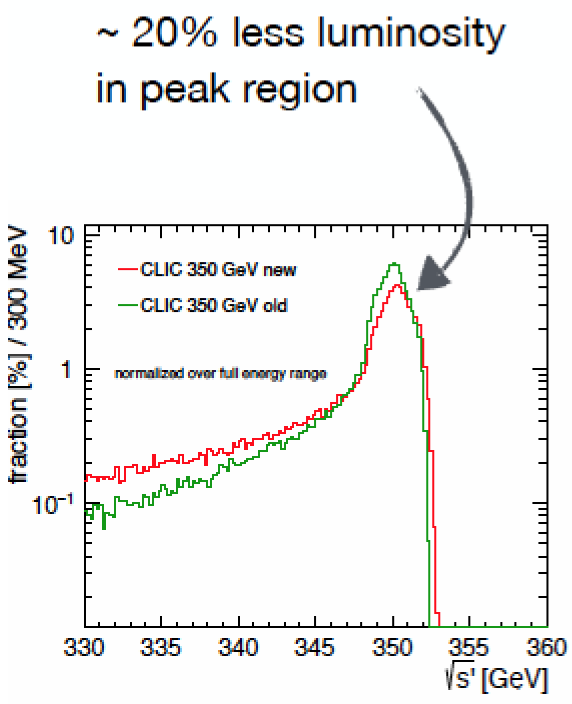
- The cross-section around the threshold is affected by several properties of the top quark and by QCD
  - Top mass, width, Yukawa coupling
  - Strong coupling constant

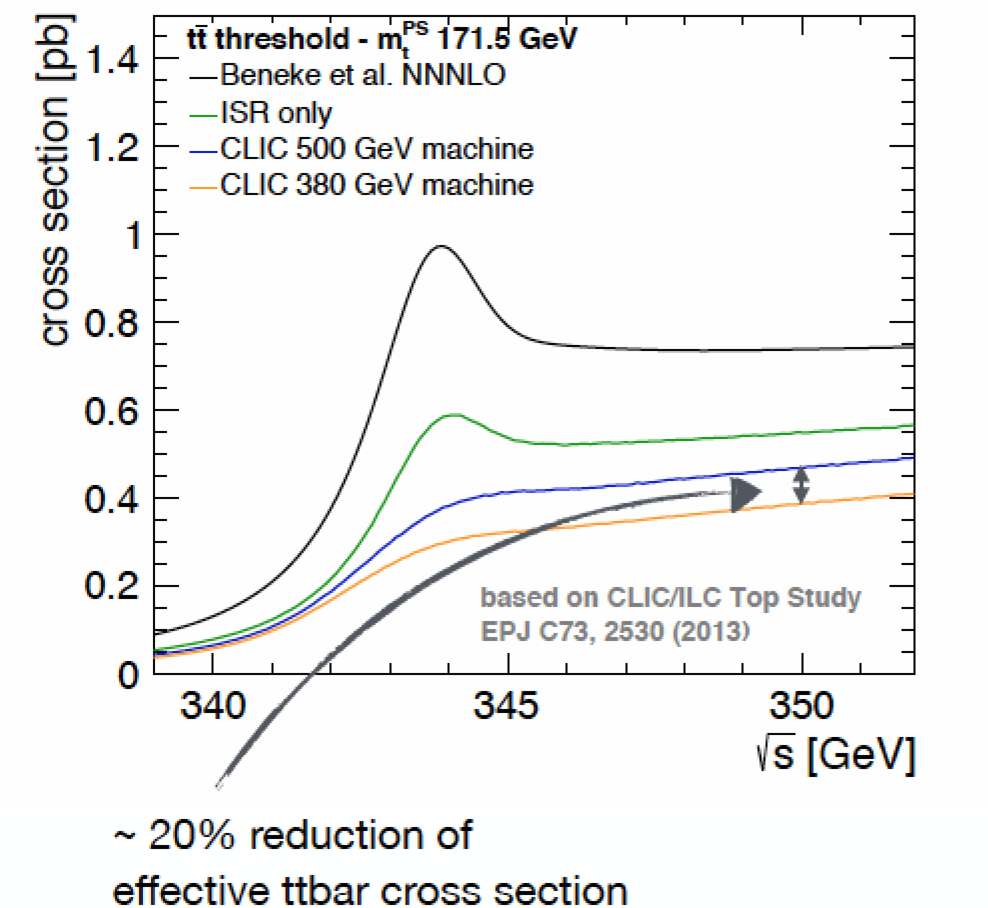


- Effects of some parameters are correlated; dependence on Yukawa coupling rather weak - precise external α_s helps

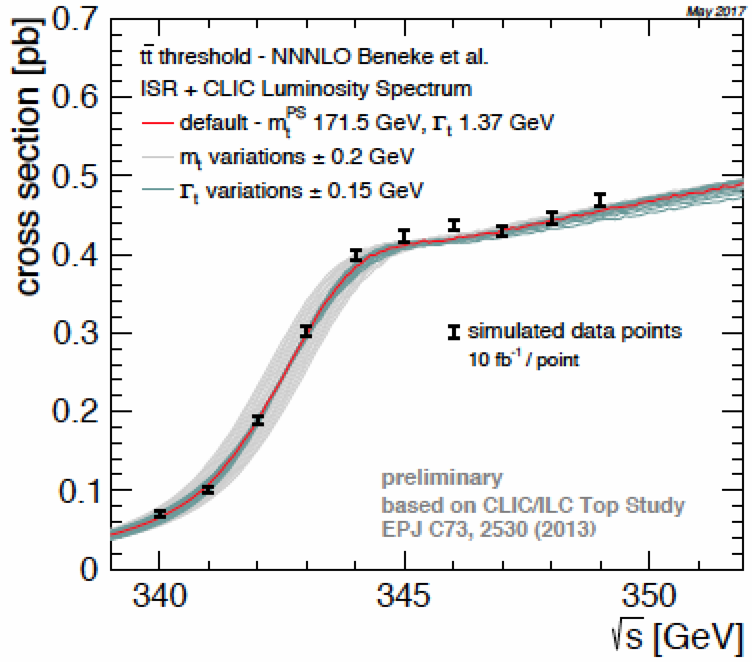
Top threshold scan

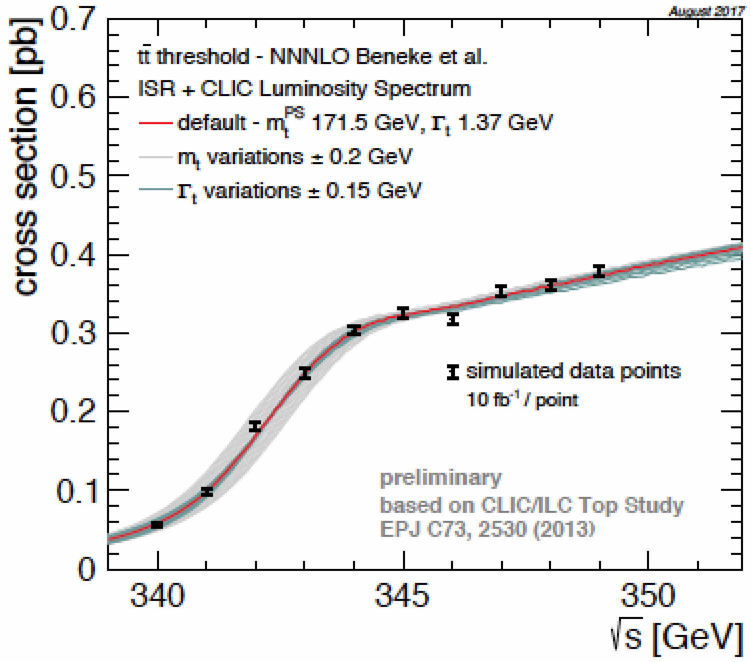
- CLIC machine optimised for 380 GeV but run at 350 GeV has a different beam spectrum than 500 GeV machine run at 350 GeV
- significant effect on effective ttbar cross section





Consequences for the Mass Measurement





- With the 500 GeV Machine:
  - Δm_t^{PS} = 19.4 MeV (stat)
- With the 380 GeV Machine:
  - Δm_t^{PS} = 23.8 MeV (stat)

To compare: ILC: ~ 18 MeV, FCCee ~ 16 MeV

⇨ The luminosity spectrum of the 380 GeV machine has a substantial impact: The statistical uncertainties of CLIC are now much bigger - a 10% - 20% effect turned into a 30% - 40% effect

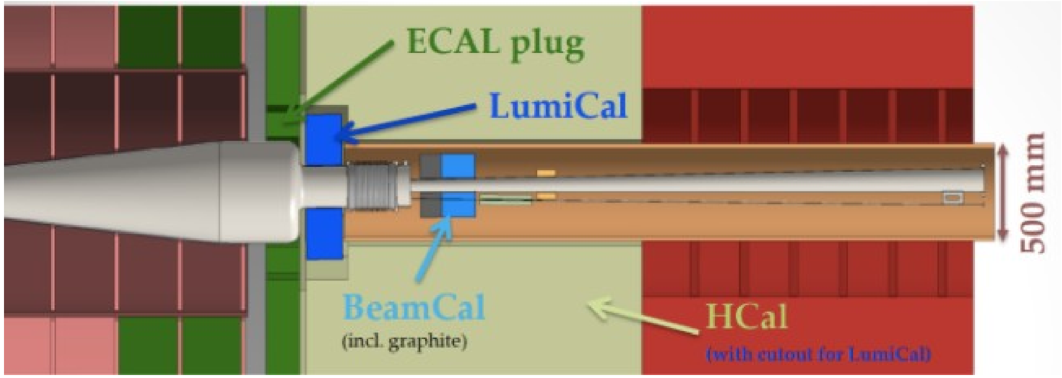
- 1D width fit uncertainty from 51 MeV -> 66 MeV

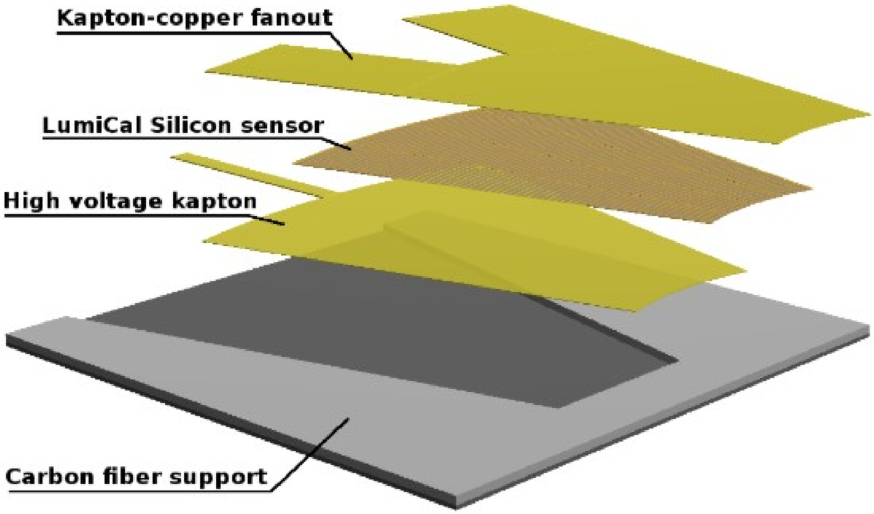
Calorimeter R&D

FoCal: MAPS digital calorimetry	*Naomi Van Der Kolk*	
503-1-001 - Council Chamber, CERN		14:00 - 14:23
The CALICE AHCAL: Progress with the Technical Prototype	*Felix Sefkow*	
503-1-001 - Council Chamber, CERN		14:23 - 14:46
The CMS HGCAL Testbeams	*Thorben Quast*	
503-1-001 - Council Chamber, CERN		14:46 - 15:09
Beam test of a compact LumiCal prototype	*Maryna Borysova*	
503-1-001 - Council Chamber, CERN		15:09 - 15:26
LumiCal performance in combination with a tracking detector	*Oleksandr Borysov*	
503-1-001 - Council Chamber, CERN		15:26 - 15:43
New developments of the BeamCal	*Oleksandr Borysov*	
503-1-001 - Council Chamber, CERN		15:43 - 16:00

LumiCal: Testbeam results

- extreme requirements on compactness (keep showers small)
  - containment
  - shower separation





Layer	Thickness
Fan-out	120
Adhesive	10
Si sensor	320
Adhesive	15
HV Kapton	70
Adhesive	15
Support	100
Total:	650 μm

LumiCal: Testbeam results

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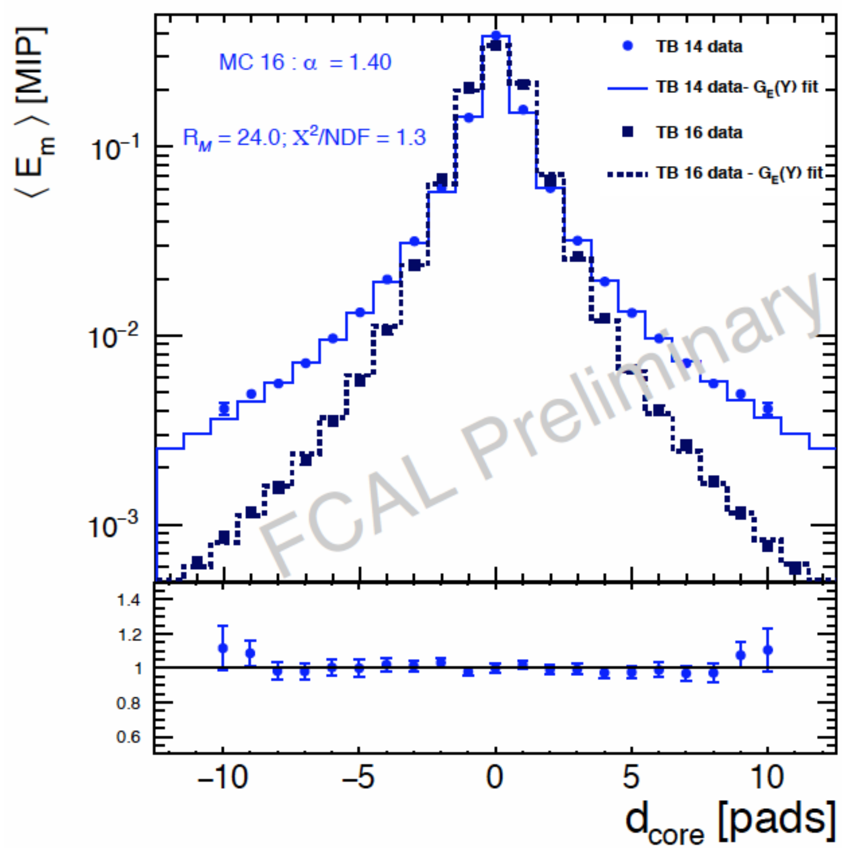
  - shower separation



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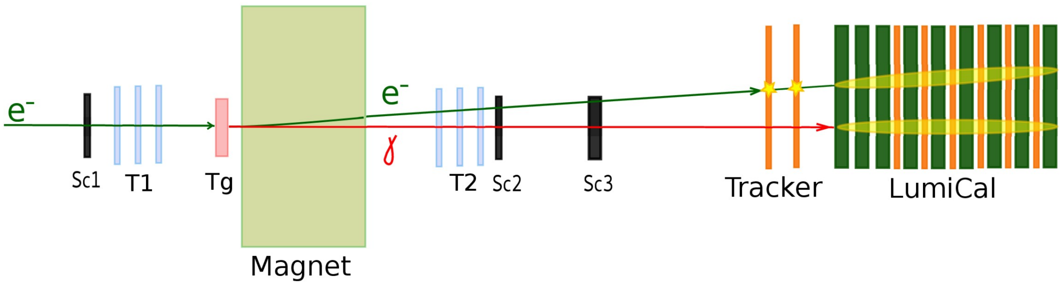
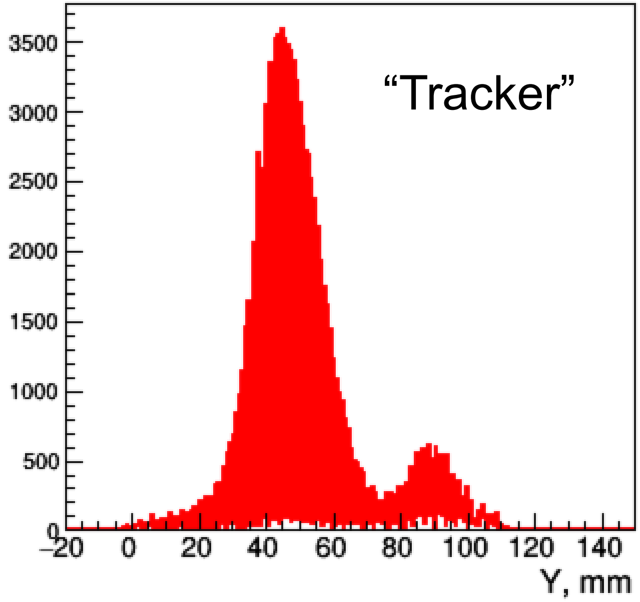
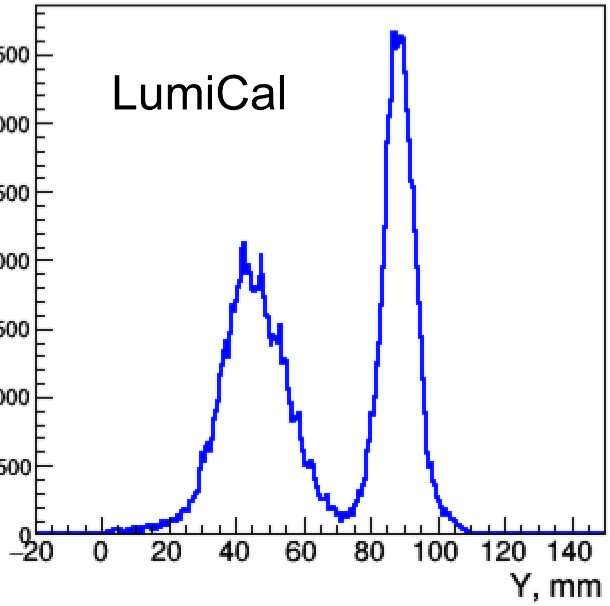






Vertex/Tracker R&D

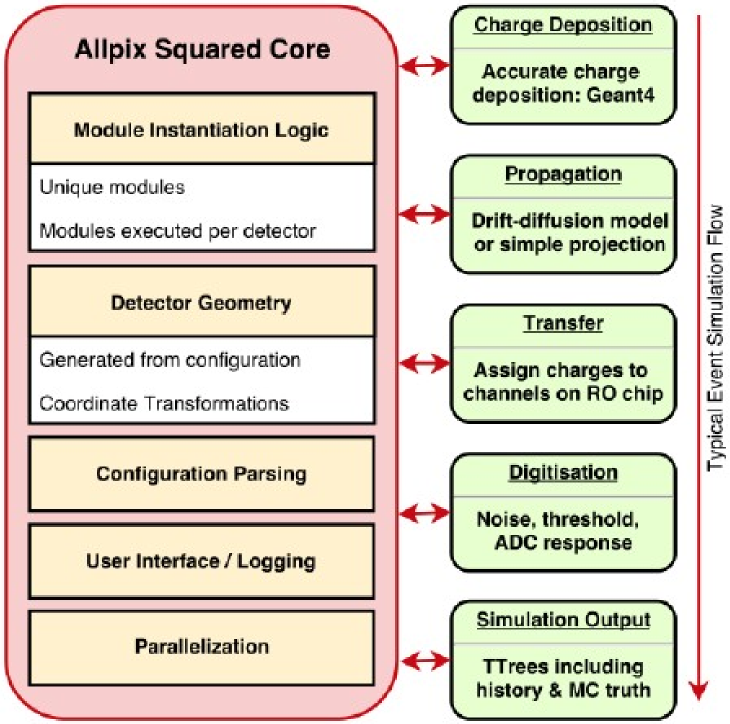
The Allpix2 Simulation Framework	*Koen Wolters*	
503-1-001 - Council Chamber, CERN	08:30 - 08:50	
SOI test beam and irradiation studies	*Roma Bugiel et al.*	
503-1-001 - Council Chamber, CERN	08:50 - 09:10	
Analysis & Simulations of the Investigator Chip	*Ruth Magdalena Munker*	
503-1-001 - Council Chamber, CERN	09:10 - 09:30	
Simulations and Glue Studies for Capacitively Coupled Sensors	*Mateus Vicente Barreto Pinto*	
503-1-001 - Council Chamber, CERN	09:30 - 09:50	

Analysis & Simulations of CLICpix+CCPDv3 Assemblies	*Matthew Daniel Buckland*
503-1-001 - Council Chamber, CERN	11:30 - 11:50
Characterization of Capacitively Coupled HR/HV-CMOS Sensor Chips	*Iraklis Kremastiotis*
503-1-001 - Council Chamber, CERN	11:50 - 12:10
Status of the CaRIBOu DAQ System	*Adrian Fiergolski*
503-1-001 - Council Chamber, CERN	12:10 - 12:30
Lab & Test Beam Charactierization of the CLICpix2 Chip	*Andreas Nürnberg et al.*
503-1-001 - Council Chamber, CERN	12:30 - 12:50

The Allpix2 Simulation Framework

Allpix Squared

- Framework in modern C++
- Modular structure
  - Slim core
  - Independent modules
- Intuitive configuration



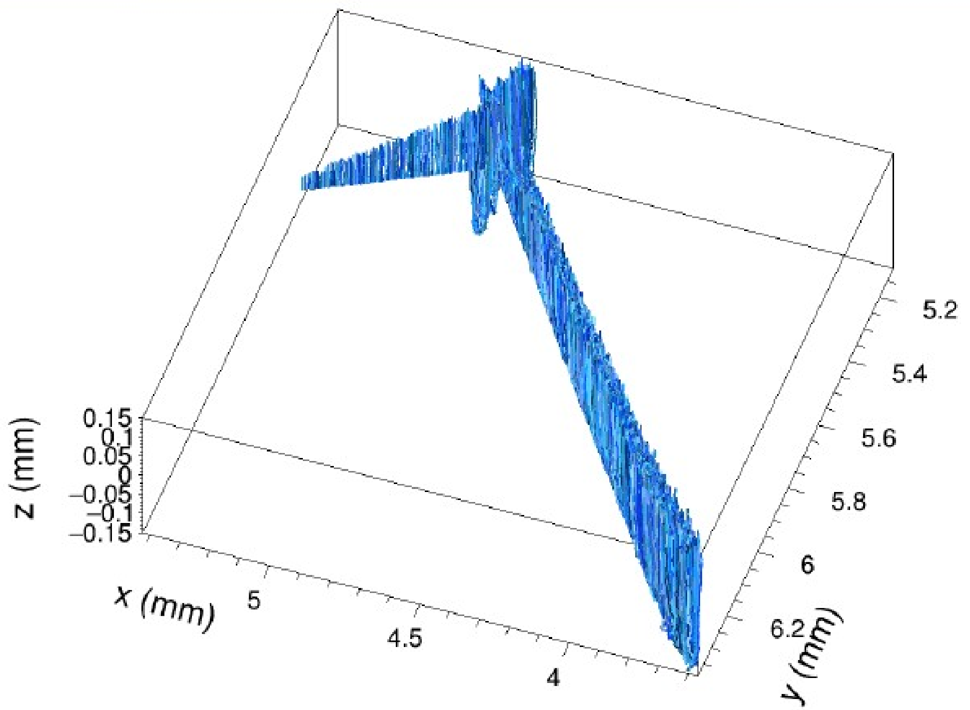
30.08.17 Allpix Squared 4

The Allpix2 Simulation Framework

Charge propagation

- Interaction within sensor
- Multiple tracks
- Only electron propagation enabled

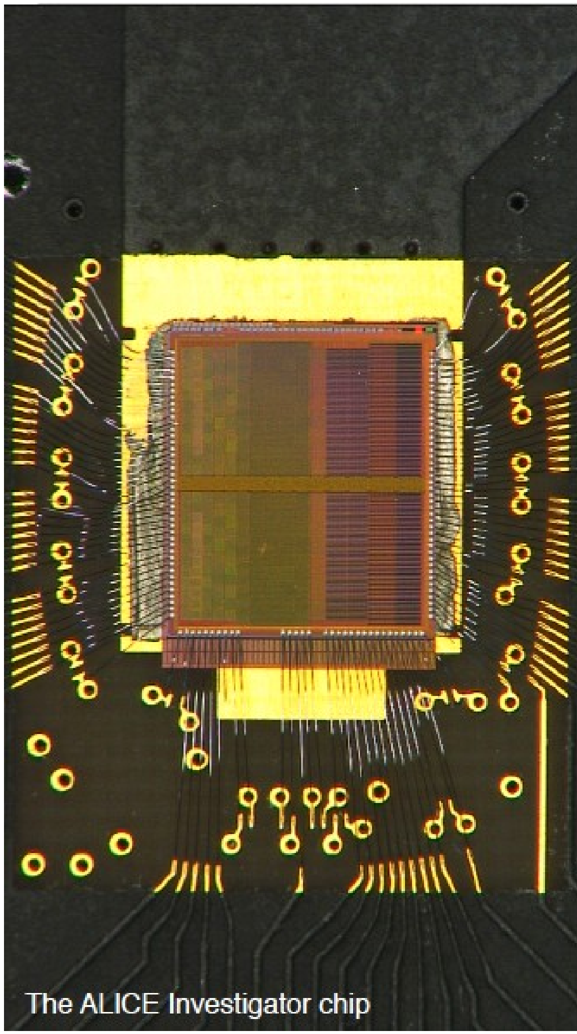
- Large cluster of pixels hit



30.08.17 Allpix Squared 12

The ALICE CMOS investigator chip

Motivation of monolithic technology for the CLIC tracker


The ALICE Investigator chip

Large surface silicon tracker planned for CLIC (~ 100m²):

- Need of large scale production

Benefit from monolithic technologies:

- Electronics integrated in sensor
- No separate readout chip
- No need of bump bonding
- Reduced material budget

Benefit from synergies with ALICE collaboration:

- Test-chip developed within ALICE collaboration to investigate full analogue performance of monolithic technology chosen by ALICE
- Interesting to study feasibility of technology chosen by ALICE with respect to CLIC tracker requirements (time slicing of 10 ns, single point resolution of ~ 7 µm)

p. 1

The ALICE CMOS investigator chip

Summary and outlook

Comparison of different processes for 28 µm pitch, 25 µm epitaxial layer, bias voltage – 6 V:

Modified process:	Standard process:	
• Spatial resolution ~ 5.5 µm • Timing resolution ~ 5 ns *(limited by external readout)* • Efficiency > 99 % *Seed threshold ~ 160 e⁻* *Neighbor threshold ~ 50 e⁻*	• Spatial resolution ~ 5.5 µm • Timing resolution ~ 6 ns *(limited by external readout)* • Efficiency > 99 % *Global threshold ~ 160 e⁻*	Meeting requirements for the CLIC tracker Used as input for design of fully integrated chip for the CLIC tracker

- Performance of modified and standard process comparable
- Slight differences observable in timing observables, as expected from more diffusion in standard process

Sub-pixel studies gives us access to impact of process details on global performance:

- Naïve picture of larger cluster size => better spatial resolution not always valid for Investigator standard process

Note on analysis, reconstruction and some results currently under collaboration review:
https://cds.cern.ch/record/2280799

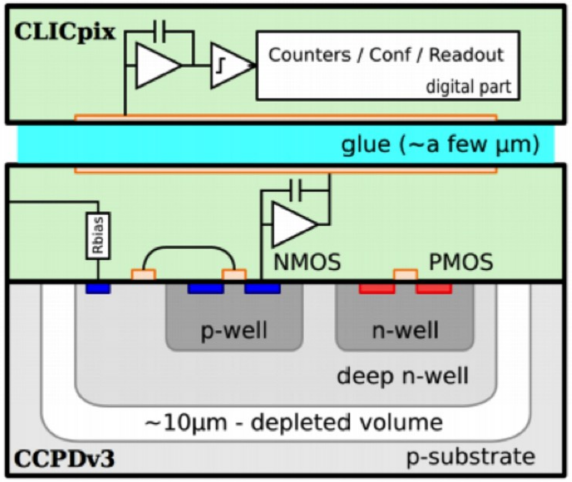
Vertex detector studies

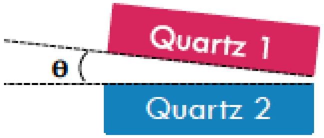
- many demanding requirements:
  - Ultra low mass, 0.2% X0 per layer
  - Single hit resolution of ~3 μm
  - Time-stamping of 10 ns
- one option: capacitively coupled pixel detector (CCPD), using a High-voltage CMOS (HV-CMOS) sensor
- small pitch (25μm), no bump-bonding
- many nice studies & testbeam measurements
- here: glueing investigations

first test

1,11	1,09	1,07	1,12	1,19	1,34	1,62	2,1
1,23	1,22	1,23	1,24	1,31	1,46	1,76	2,25
1,45	1,41	1,39	1,42	1,51	1,69	1,99	2,49
1,86	1,77	1,75	1,83	2,06	2,4	2,83	3,3
2,58	2,4	2,37	2,56	2,97	3,73	4,70	5,5
4,64	4,07	3,96	4,32	5,18	7,28	10,7	16,7

Capacitance [pF]





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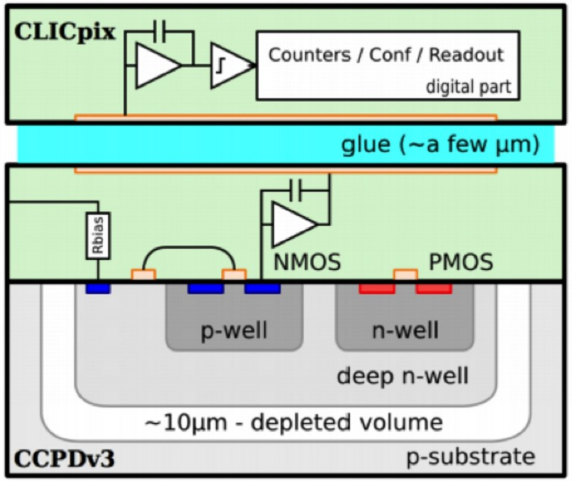
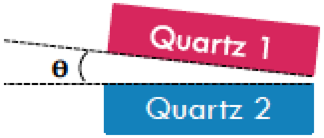


improved procedure

5,3	5,27	5,36	4,92	5,16	5,15	5,06	5,08
5,02	4,81	4,69	4,24	4,08	4,18	4,39	4,93
5,1	4,4	4,41	4	3,65	3,82	4,34	5,11
5,39	5,24	4,77	4,36	8,64	4,61	4,8	5,19
5,42	5,35	5,02	4,76	4,72	5,34	5,23	5,32
4,92	5,5	5,71	5,59	5,5	5,63	5,52	5,54

Capacitance [pF]



Software / Detector Validation

iLCDirac Status	*Marko Petric*	
503-1-001 - Council Chamber, CERN	10:30 - 11:00	
Software Status	*Andre Sailer*	
503-1-001 - Council Chamber, CERN	11:00 - 11:30	

Tracking Validation	*Daniel Hynds et al.*
503-1-001 - Council Chamber, CERN	14:00 - 14:25
Impact Parameter Resolution	*Peter Winkel Rasmussen*
503-1-001 - Council Chamber, CERN	14:25 - 14:40
Flavour Tagging	*Mr. Ignacio Garcia Garcia*
503-1-001 - Council Chamber, CERN	14:40 - 15:05
Calorimeters and Pandora Performance	*Matthias Artur Weber*
503-1-001 - Council Chamber, CERN	15:05 - 15:30

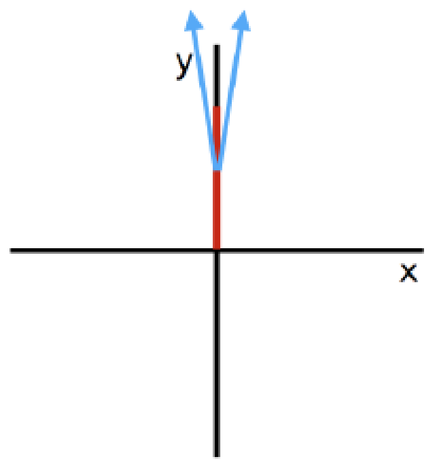
Tracking Validation

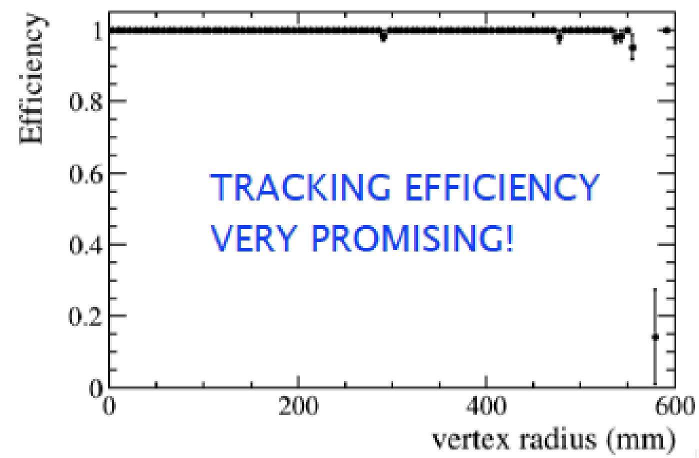
Summary and news

- ✓ Single muons are reconstructed with an efficiency of 100% down to 100MeV/c and in the full phase space down to 10 (170) deg
- ✓ Momentum resolution achieved: 2×10^{-5} for high energy (500GeV) muons in the central barrel
- ✓ Z=>uds events at 91GeV are reconstructed with a tracking efficiency larger than 90% (and around 99% above 1GeV/c)
- ✓ ttbar events @ 3TeV are reconstructed with a tracking efficiency larger than 90% (and around 99% between 1 and 100GeV/c)

FIRST LOOK AT DISPLACED TRACKS

- ☆ 100GeV displaced muons generated in $0 < y < 1$m
- ☆ $80° < \theta, \varphi < 100°$ to point away from IP
- ☆ cuts tuning optimized to reduce execution timing

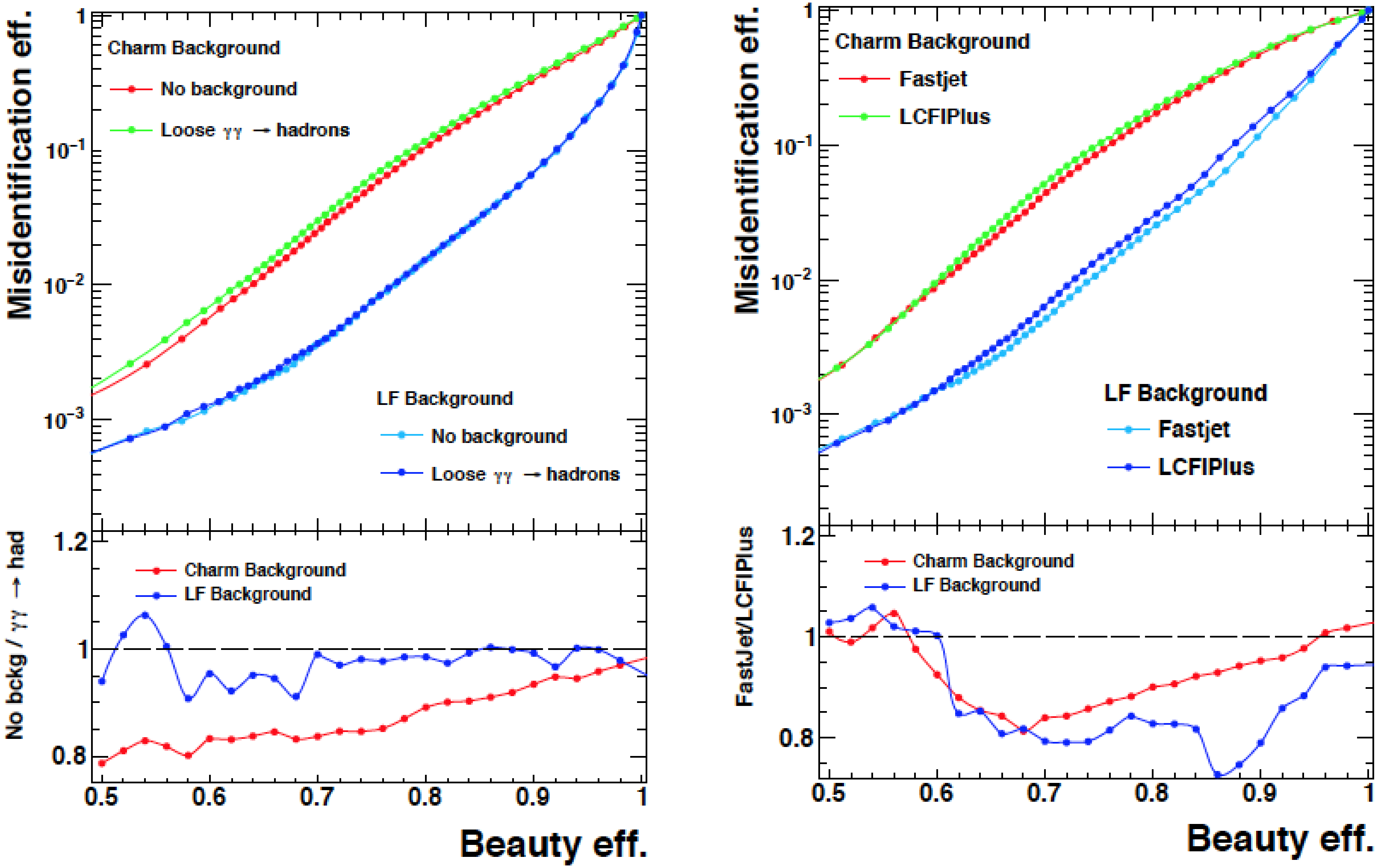




- ☆ next major step foreseen: background (γγ->hadrons, incoherent pairs) overlay

Flavour Tagging

- study influence of timing cuts for γγ removal and jet clustering and vertexing on flavour tagging



Flavour Tagging

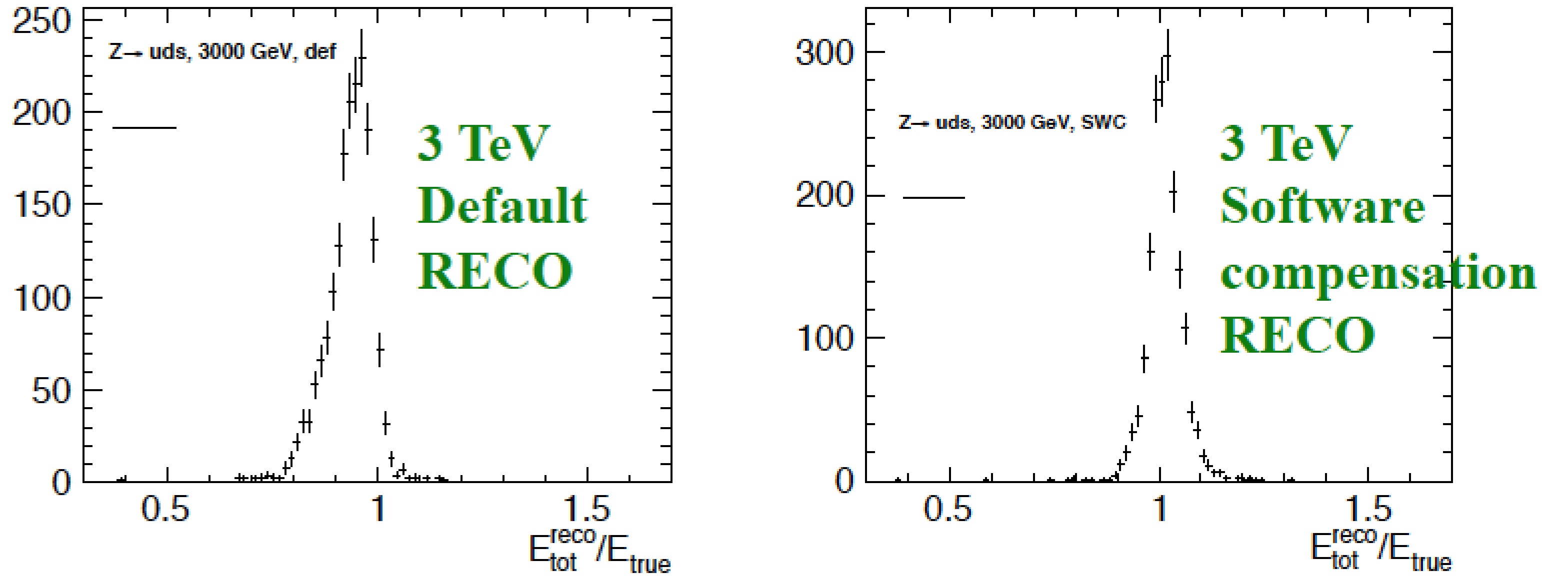
Summary

- Flavour tagging performance is better for lower energies and in the central region of the detector, severally degraded in the most forward region
- The impact of the $\gamma\gamma \rightarrow$hadrons on the flavour tagging performance translates into an increase of the fake rates up to 10% even using Loose timing cuts
- A robust algorithm against $\gamma\gamma \rightarrow$hadrons like Valencia jet algorithm performs slightly better than the classical Durham algorithm
- Vertex reconstruction and jet clustering strategy matters, being significantly better the FastJet + LCFIPlus strategy for b-tagging. Reduce the impact of $\gamma\gamma \rightarrow$hadrons before vertex reconstruction
- Future work:
  - Test flavour tagging performance at TeV scale (1.5TeV, 3TeV), much larger impact of $\gamma\gamma \rightarrow$hadrons expected
  - Compare the performance assuming different single point resolutions for the pixel sensor
  - Try new deep learning techniques for flavour tagging

Jet Energy reconstruction / Pandora

Compare the reconstructed energy using the different settings

total event energy



This behavior is gone with the software compensation (MHHHE removed), mean of reconstructed energy distribution within 1 % of true energy for all energy points considered, symmetric distribution

Move to new default PandoraSetting in clicReconstruction

- Recover energy response deficit of 5 %, mainly a result of removed cut on HCAL hit energy for hadrons with impact on high energetic showers
- Software compensation enabled → started work on CLIC specific weights

Summary

- very interesting workshop
- preparation for European strategy update
  - collider baseline fixed
  - new detector model fixed, simulation being validated
  - physics studied ongoing and being written up
  - detector R&D on silicon tracker and (very ambitious) silicon vertex detector
- CLIC workshop 2018: Monday Jan 22nd to Friday Jan 26th
  https://indico.cern.ch/event/656356/overview

Backup