CLIC_ILD tracking
(technology + performance)

Review of CLIC physics/detector CDR

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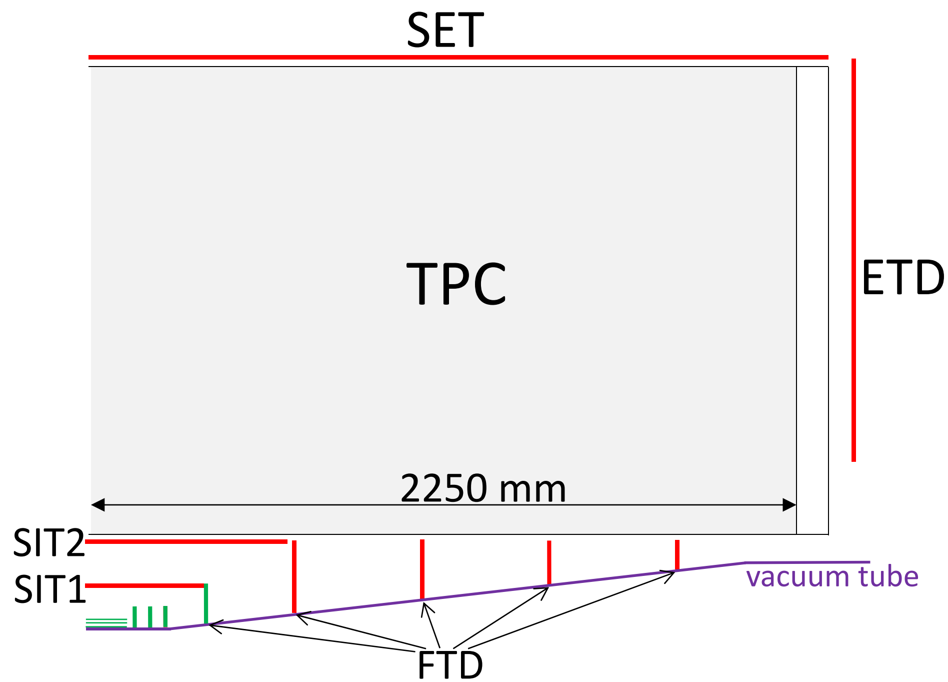
CLIC_ILD tracking

- Large TPC (329 < R < 1808 mm) for highly redundant continuous tracking (~ 200 measured points)
  - Particle ID through dE/dx
  - Little material in tracking volume (5% X_0); <25% X_0 in endcap
- Complemented by silicon tracking system:
  - Independent tracking at low angles (FTD)
  - Silicon tracking layers surrounding TPC for timing and precision points (SIT, SET, ETD)



- TPC acceptance (10 measurement points) down to 12^0
- SIT acceptance down to 25^0
- FTD acceptance down to 7^0

TPC design parameters & performance goals

- Dimensions: R_{in} = 329 mm; R_{out} = 1808 mm; Z_{max} = 2250 mm
- Solid angle coverage: $12^o < \theta < 168^o$ (10 pad rows)
- TPC material budget: to ECAL R ~ 0.05 X_0 ; endcaps ~0.20-0.25 X_0

- Momentum resolution (B=4T):
  - TPC only : $\delta(1/p_T) \sim 8.\ 10^{-5}$ /GeV
  - SET+TPC+SIT+VTX: $\delta(1/p_T) \sim 2.\ 10^{-5}$ /GeV

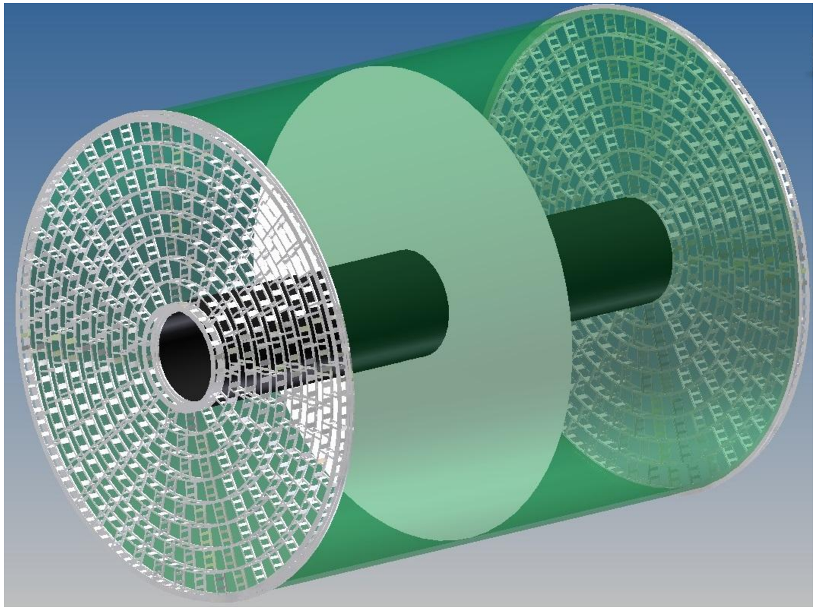
- #pads/#time buckets: ~2.10^6 / 1000 per endcap
- Pad size/#pad rows: ~1 mm x 4-6 mm / ~200 (standard readout)

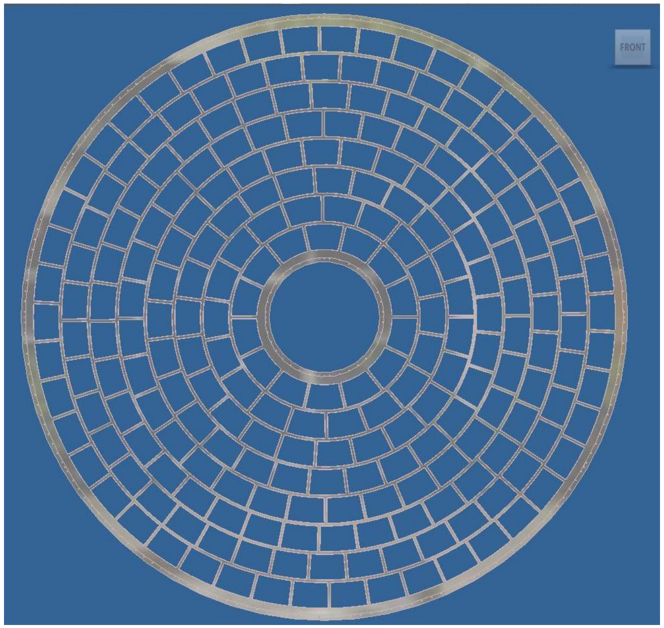
- Point resolution: in rϕ: < 100 μm ; in rz: ~ 0.5 mm
- 2-hit resolution: in rϕ: ~ 2 mm ; in rz: ~ 6 mm
- dE/dx resolution: ~ 5% (based on LEP TPC experience)

TPC design (1)

- Lightweight fieldcage with resistor chain for potential rings: drift field homogeneity $\Delta E/E \sim 10^{-4}$
- Central HV cathode (up to 100 kV)
- 2 endcaps each with some 240 Micropattern Gas Detector (MPGD) modules: Micromegas or GEMs
- TPC integrates charge over full CLIC bunch train -> foresee ion gate
- Use gas mixture like (T2K gas) $Ar/CF_4/iC_4H_{10}$ (95/3/2%) for large suppression of transverse diffusion at B=4T
- B field has to be mapped out to relative precision of 10^{-4}
- Laser system for monitoring calibrations/distortions

TPC design (2)



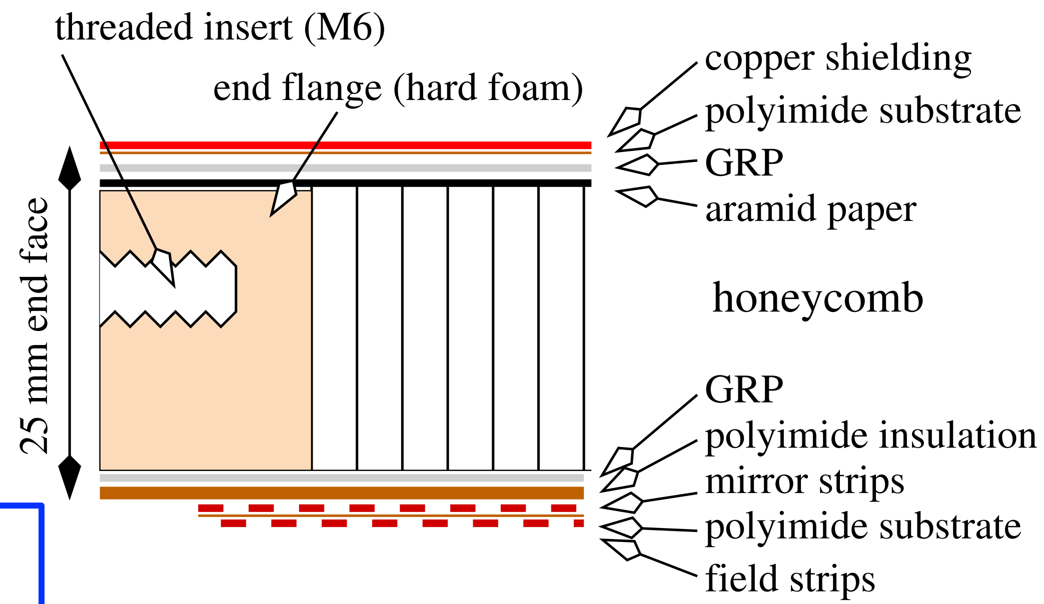


- Endcaps made with spaceframes
- Allows stable positioning of detector modules to <50 μm
- Deflection under 2.1 mbar over-pressure is 0.22 mm
- Mass is 136 kg/endplate

- 10 m^2 per endcap
- 8 rows of MPGD detector modules; module size ~ 17 x 22 cm^2
- 240 modules per endcap
- Endplate is 8% X_0
- Readout modules+electronics 7% X_0
- Power cables 10% X_0

TPC design (3): fieldcage wall

- Lightweight fieldcage
  - 1% X_0 inner wall
  - 3% X_0 outer wall
  - 1% X_0 gas



Large Prototype (LPTPC):
- Radius ≈ inner radius CLIC TPC
- 1.21% X_0
- Material samples tested up to 30 kV
- (simple) extrapolation would allow 70 kV

TPC design (4): modules + electronics

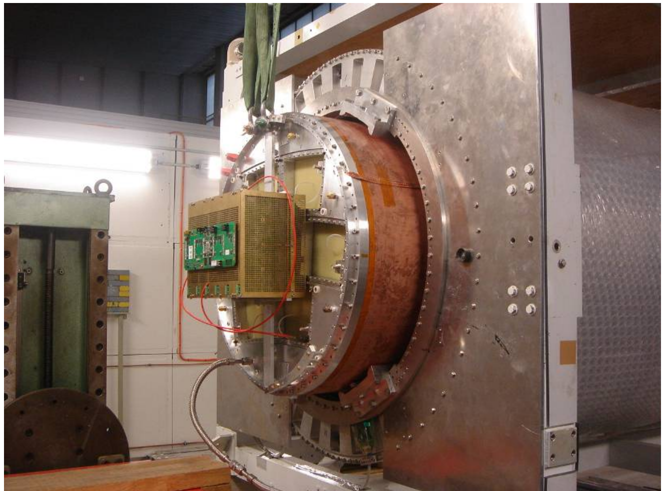
- Double and triple GEM stack modules
- Bulk Micromegas with resistive anode modules
- Extensively tested at LPTPC, with similar resolution (at zero drift distance) of ~60 μm
- Resolution at larger drift distance (up to 60 cm) follows expected diffusion
- Smaller prototypes in B=5T field show ≤ 100 μm resolution when extrapolated to 2.25 m drift

- Deep-submicron electronics integration of 16-channels of full Alice chain under test; 64-ch ASIC under investigation
- Power-pulsing will be needed (gain factor 25-50)

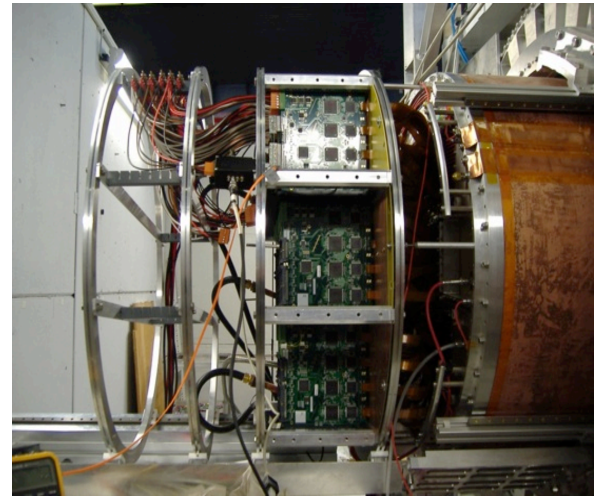
- New concept of combined gas-amplification + pixelised readout (Ingrid) under further development; needed(?) in high-occupancy regions

Several beam tests at DESY with LP (2008-2011) by LCTPC collaboration

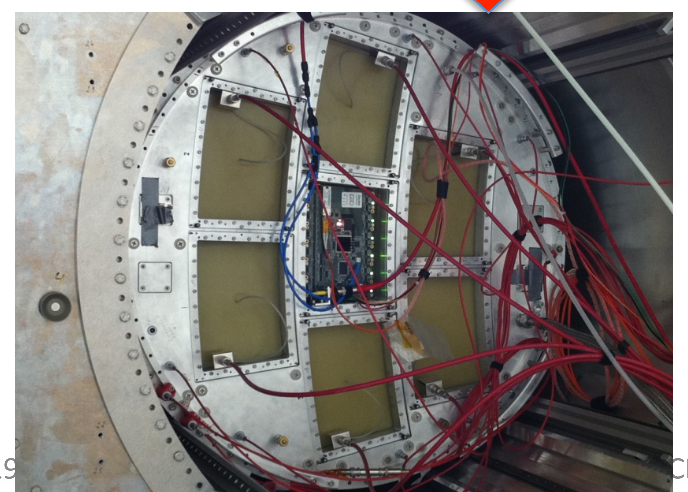
Micromegas (T2K readout)



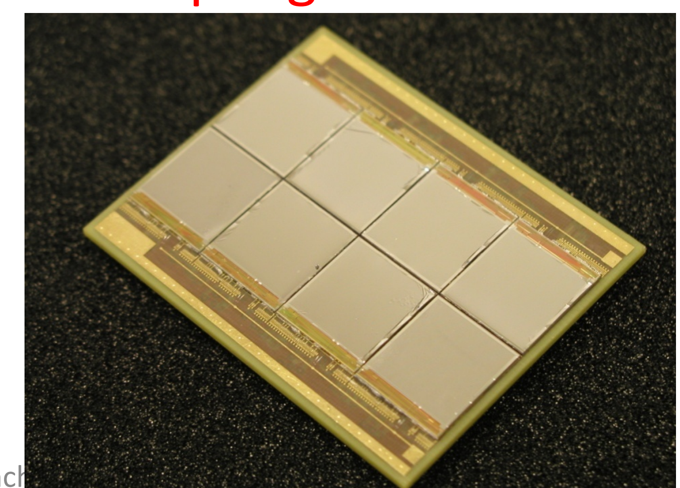
GEMs (Altro readout)



Integrated version

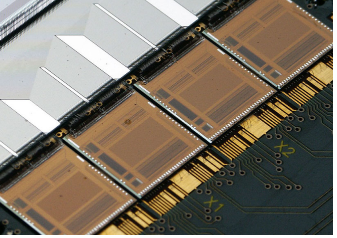


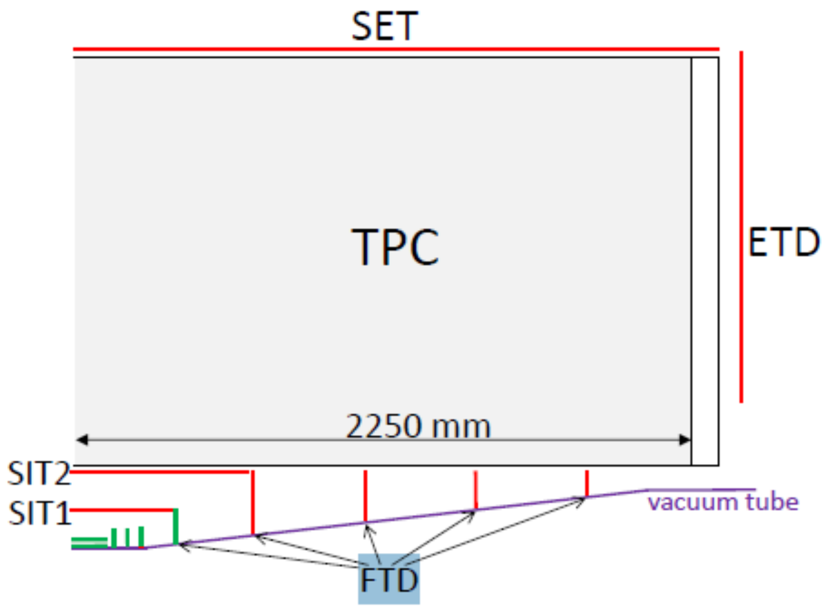
8-chip Ingrid module



R&D by LCTPC collaboration

- Construction of advanced endplate for LP (2012)
- Improved 2nd fieldcage for LP (2012?)
- Further development of endplate modules with (integrated) electronics for GEMs and Micromegas (2012) and for Ingrids (late 2012-2013)
- Testbeams at 5 GeV electrons at DESY (2012)
- Gating device studies
- CO2 cooling studies
- Power distribution and power pulsing
- High-energy hadron testbeams (2013 -





Silicon Tracking at CLIC

- same performance requirements as ILC ILD:

$\Delta(1/pT) = 8x10^{-5}$ (TPC only)

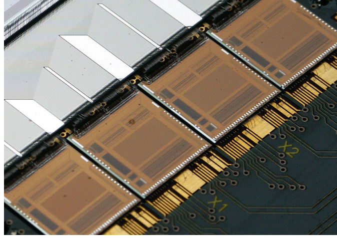
$\Delta(1/pT) = 2x10^{-5}$ (TPC + Si)

(H->μμ takes over from Higgs-strahlung recoil mass analysis, high pT leptons BSM sources)

In a harsher environment → differences of CLIC_ILD with respect to ILC design:

- Forward region becomes more important (many-fermion final states, t-channel, ISR)
- γγ → hadrons yields less steep background density vs. radius. Outer tracker design must be more robust.
- Barrel vertex detector coverage extends down to "only" 26 degrees
- Standard micro-strip detectors are no longer capable of single BX time stamping

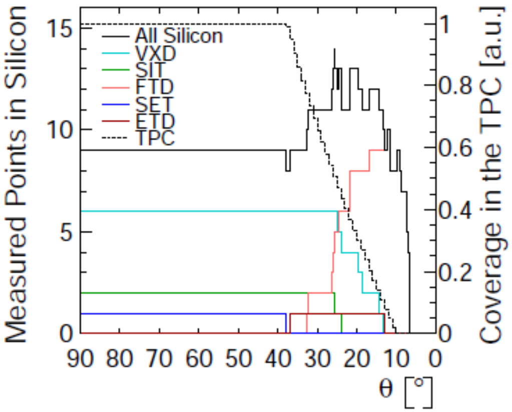
Forward Tracking

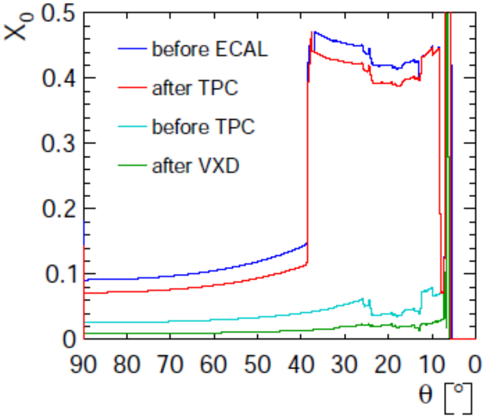


TPC has full coverage down to 40 degrees.
Barrel VXD and SIT down to 25 degrees. Below that:
- VXD-endcap (see, talk by Dominik Dannheim yesterday).
- Forward Tracking Disks.

At least 8 silicon hits down to 10 degrees.

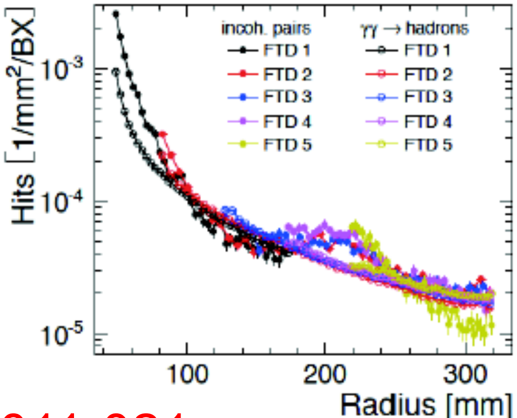
#hits vs. polar angle.
Note that here VXD-EC is accounted for in FTD)





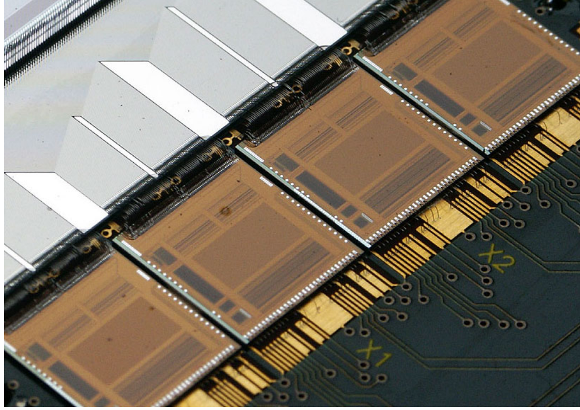
Relatively little material in Silicon tracking

Inner rim of FTD tracking disks see a lot of background, more than a “standard” micro-strip detector can cope with → Replace with pixels or μ-strips with ns-level time stamp and multi-hit storage capability.



FTD1 (100mm strips): 10 hits/train LCD-Note-2011-021

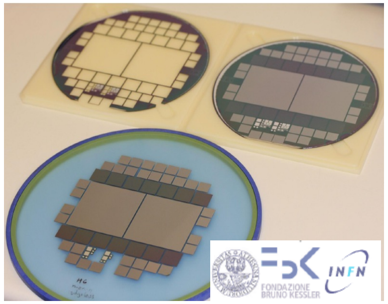
Silicon Tracking R&D

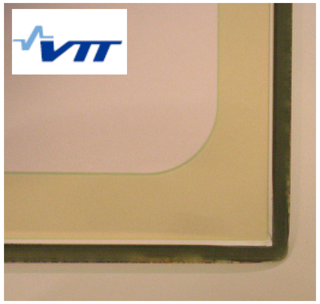


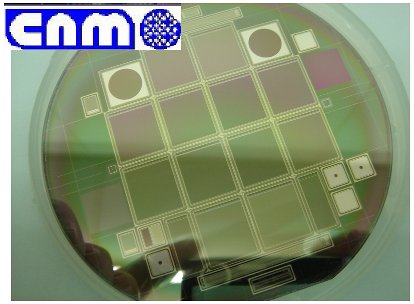
Silicon μ-strip detector R&D

- Interconnection: integrate pitch adapter on second metal layer
- *New ways to bring in power: serial or DC/DC (in common with LHC)*
- *New ways to remove power: gas-cooled systems (in common with ILC)*
- *Interesting development on use of charge sharing to measure coordinate along the strip*
- New planar single sided strips technology, large sensors (6''), edgeless and high transmittance (IR laser alignment) options
- CLIC specific R&D (faster FE electronics!)

New edgeless sensors







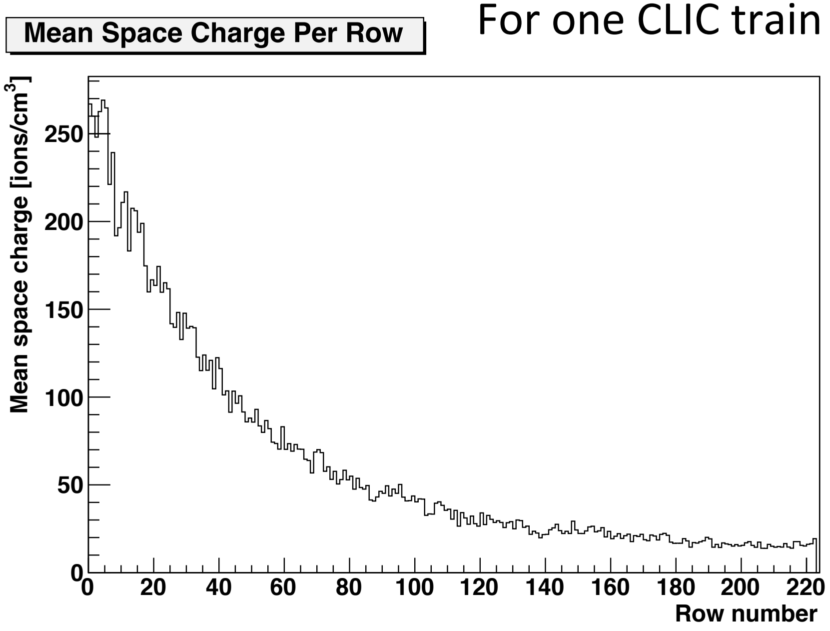
High transmittance sensors
Goal: T~70%; Already now: 50%

Ion space charge effects in TPC

- Distortion studies due to ions:
  - Ion discs supressed with gating device
  - Distortions from ions between gate and anode negligible
  - Prel. calculations distortions due to volume charge density: 'small' at ILC (< 12 μm)

  - No estimate yet for CLIC, but mean space charge (near cathode) is about 10x larger for CLIC

For one CLIC train

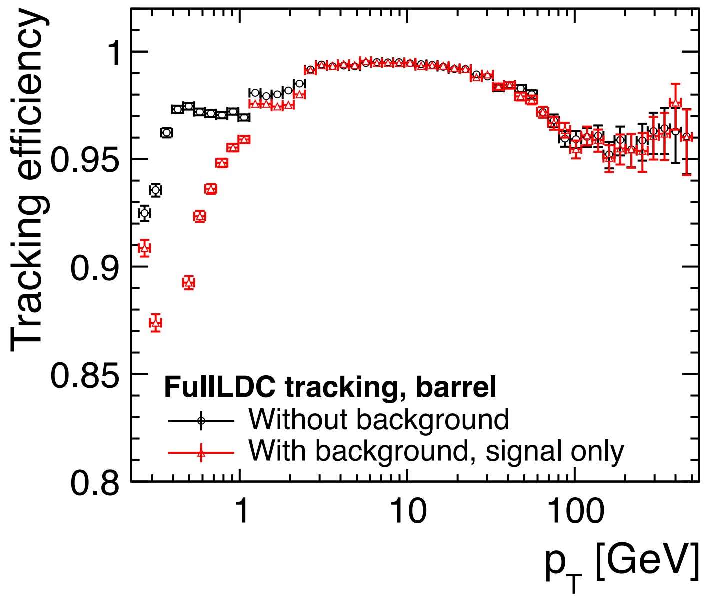


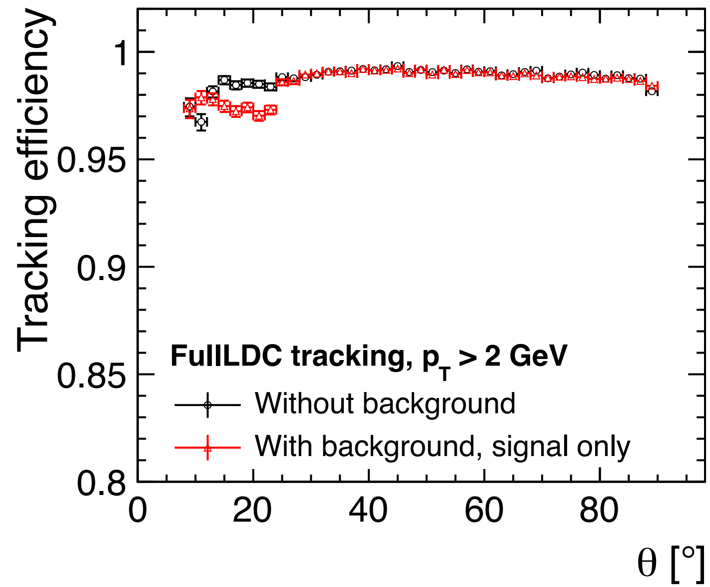
Tracking performance CLIC_ILD (1)

- TPC allows robust pattern recognition even with large background
- Tracking done in 3 steps:
  - Pattern recognition + fitting in TPC alone (time of track few ns; see LCD-Note-2011-30)
  - Same in silicon detectors
  - "FullLDC tracking": matching between the two and re-fit
- Tracking efficiency studied without and with 60 BX of γγ -> hadrons background (full bunch train of 312 BX background for TPC was not possible in ('old') software)
  - With background, efficiency is given for "signal only" tracks

- Remember: for occupancy and timing studies (MarlinTPC) full bunchtrain background included

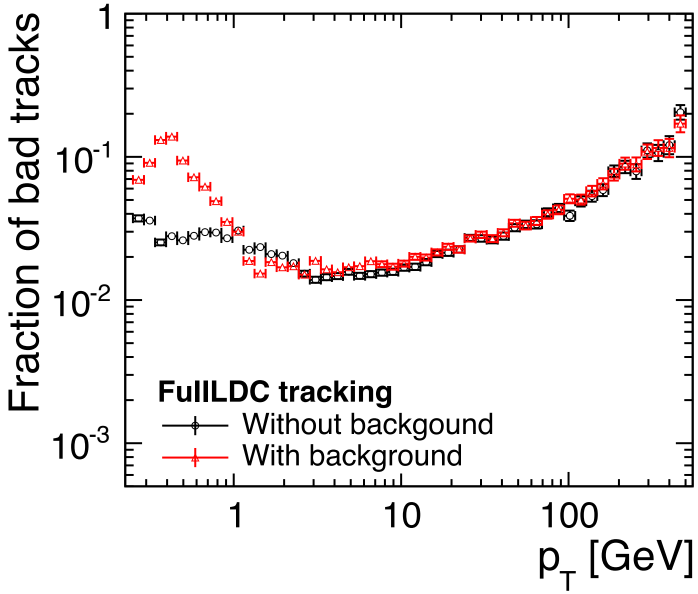
Tracking performance CLIC_ILD (2): efficiencies

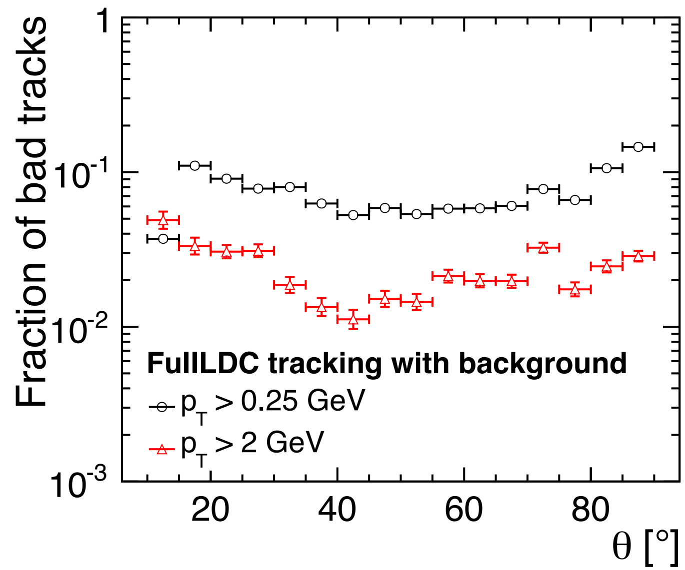




- ttbar events:
- Efficiency (no BG) >99% for p_T>2 GeV and >97% for p_T > 0.4 GeV
- With background, efficiency is defined for "signal only" tracks
- With BG eff. drops down to 87% mainly below 1 GeV
- Dependence on polar angle is weak for p_T > 2 GeV
- Efficiency stays above 97% down to $\theta = 8^{o}$ even with BG

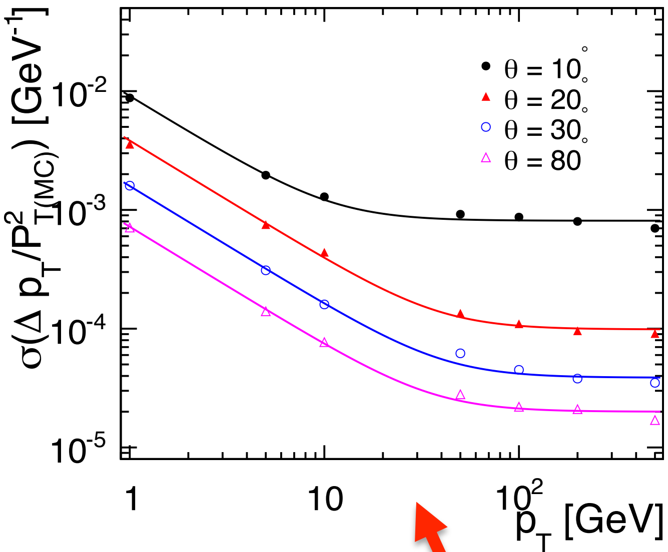
Tracking performance CLIC_ILD (3): "bad" rates

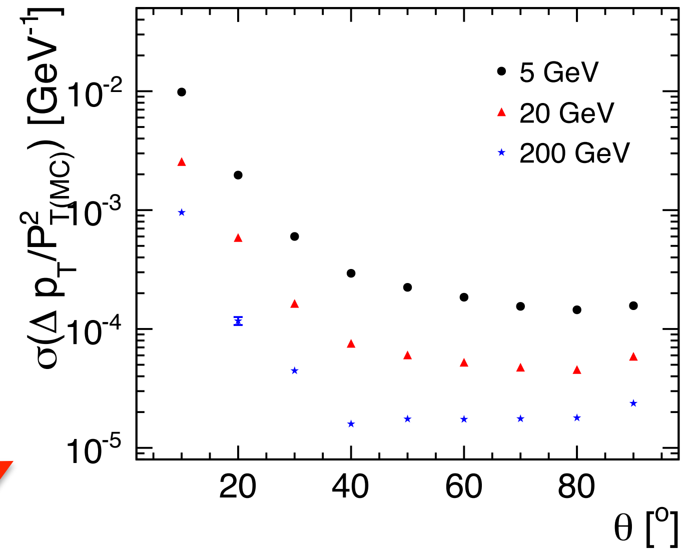




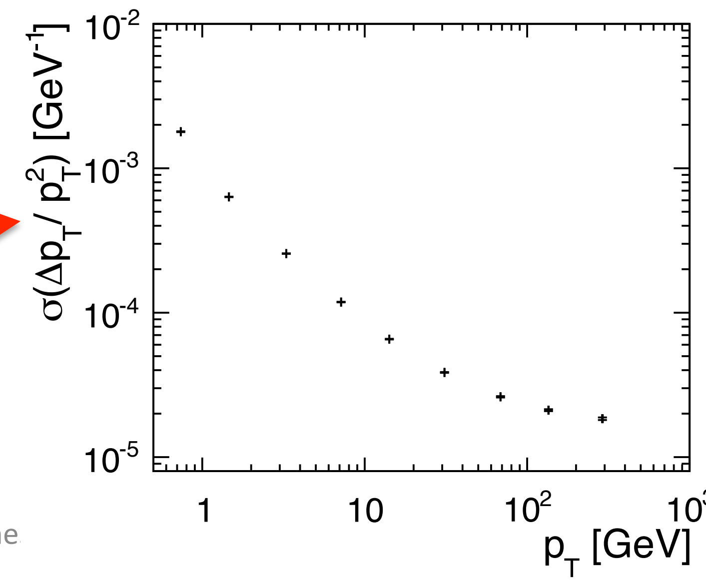
- ttbar events: "bad" track fails quality cut of > 96% correctly assigned hits
- For p_T > 1 GeV "bad" track fraction not affected by background

Tracking performance CLIC_ILD (4): p_T resolution





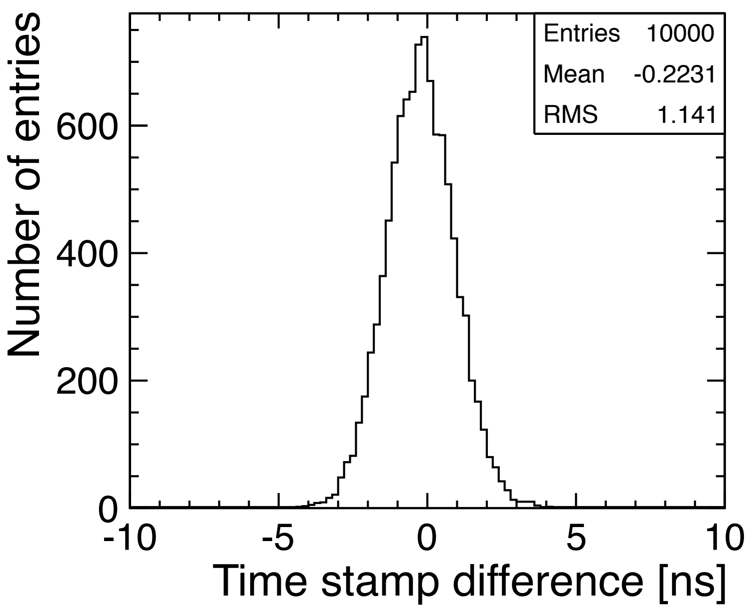
- Single muons:
  - p_T resolution reaches expected asymptotic values
- ttbar events:
  - p_T resolution reaches same asymptotic values for p_T > 100 GeV

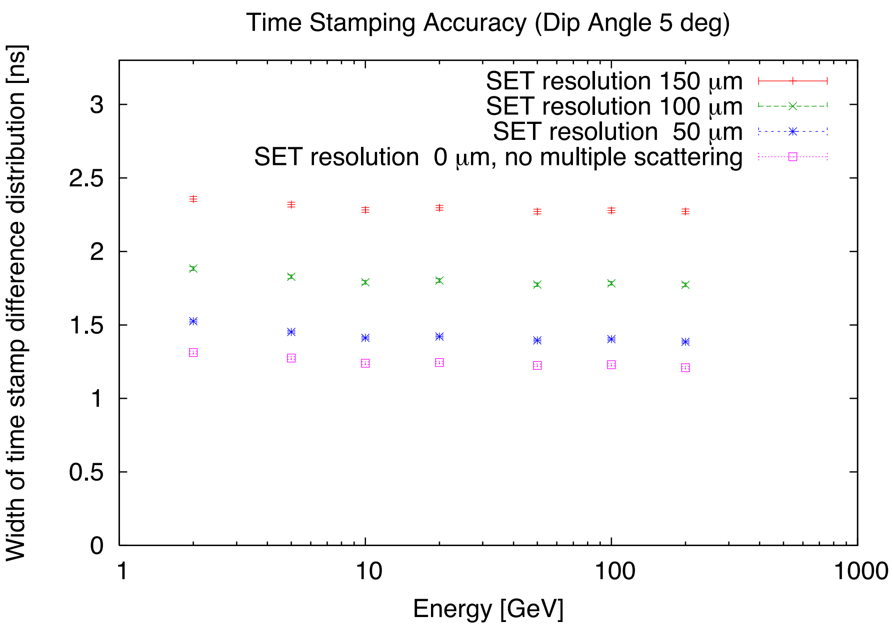


Conclusions

- CLIC_ILD tracking
  - Highly redundant, continuous tracking and dE/dx
  - Allows easy and precise reconstruction of non-pointing tracks
  - Time stamping ~ 2ns + TPC-Si tracking
- But: (too?) high occupancy at small radius
- Space charge effects under study
- Very active R&D program

Time stamping for TPC + comparison with SET



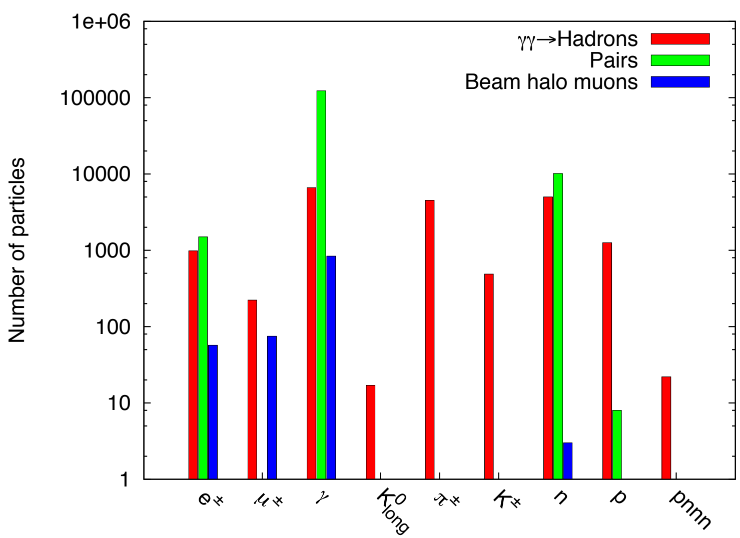


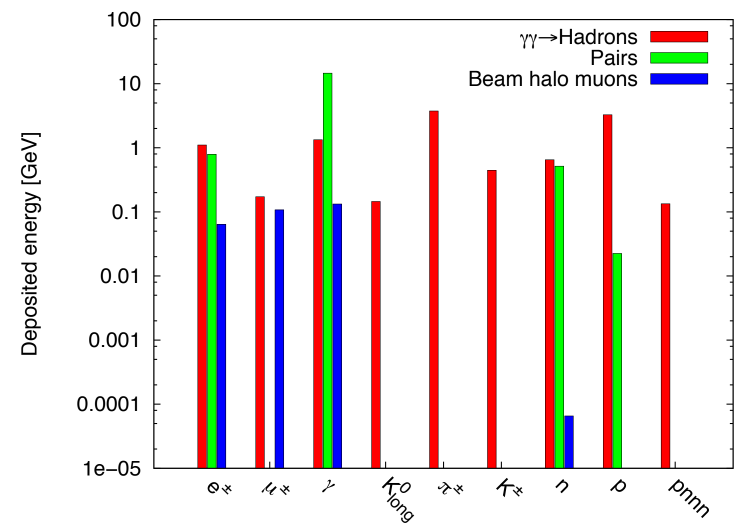
Θ = 40 degrees

θ = 85 degrees

Backgrounds in TPC

Particle	$\gamma\gamma \to$ hadrons Count	$\gamma\gamma \to$ hadrons E_{dep} [GeV]	Pairs Count	Pairs E_{dep} [GeV]	Beam halo muons Count	Beam halo muons E_{dep} [GeV]	Total E_{dep} (GeV)
$e^{\pm}$	984	1.11	1502	0.790	57	0.0640	2
$\mu^{\pm}$	223	0.172	-	-	75	0.107	
γ	6628	1.34	123222	14.6	838	0.133	16
K^0_{long}	17	0.145	-	-	-	-	
$\pi^{\pm}$	4523	3.75	-	-	-	-	4
$K^{\pm}$	489	0.444	-	-	-	-	
n	5008	0.650	10176	0.516	3	$6.57 \cdot 10^{-5}$	1.1
p	1260	3.28	8	0.0225	-	-	3.3
pnnn	22	0.134	-	-	-	-	





FTD occupancies
(safety factor included)