Physics and Detectors Summary (WG1)

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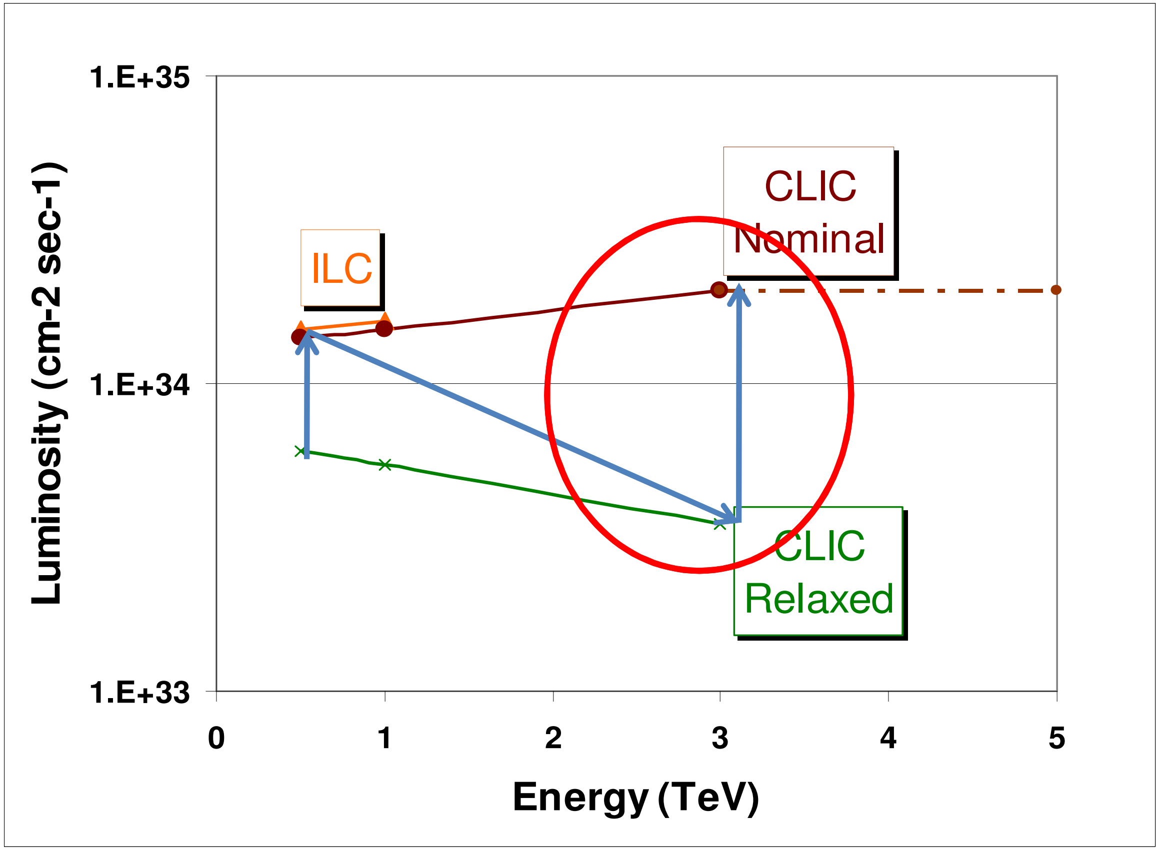
Tohoku University
16-Oct-09, CLIC09, CERN

Apology for not covering all works!

CLIC Parameters

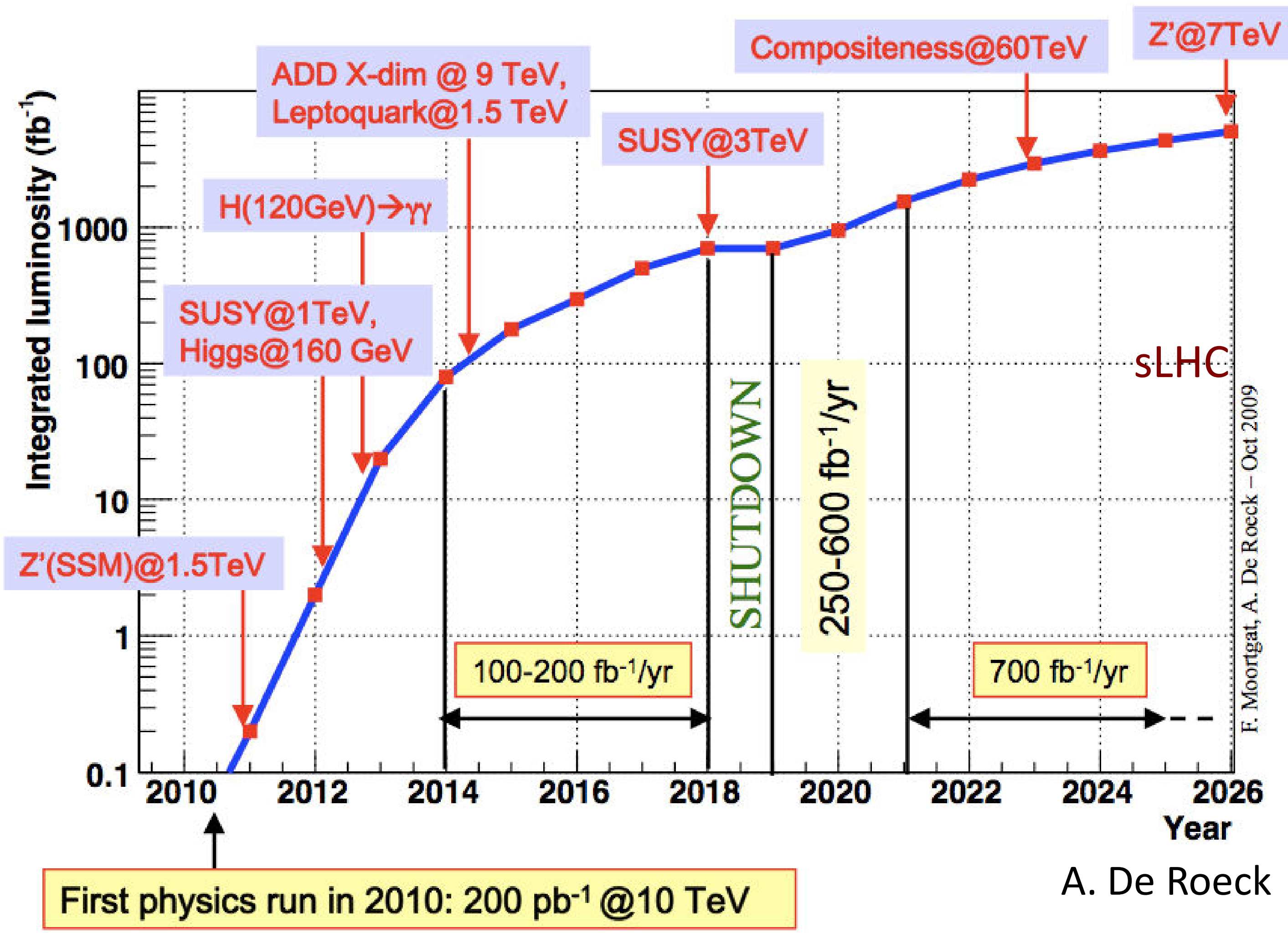
J.P. Delahaye



Focus is at high energy

Immediate goal: CDR end-2010 (120-150 pages)

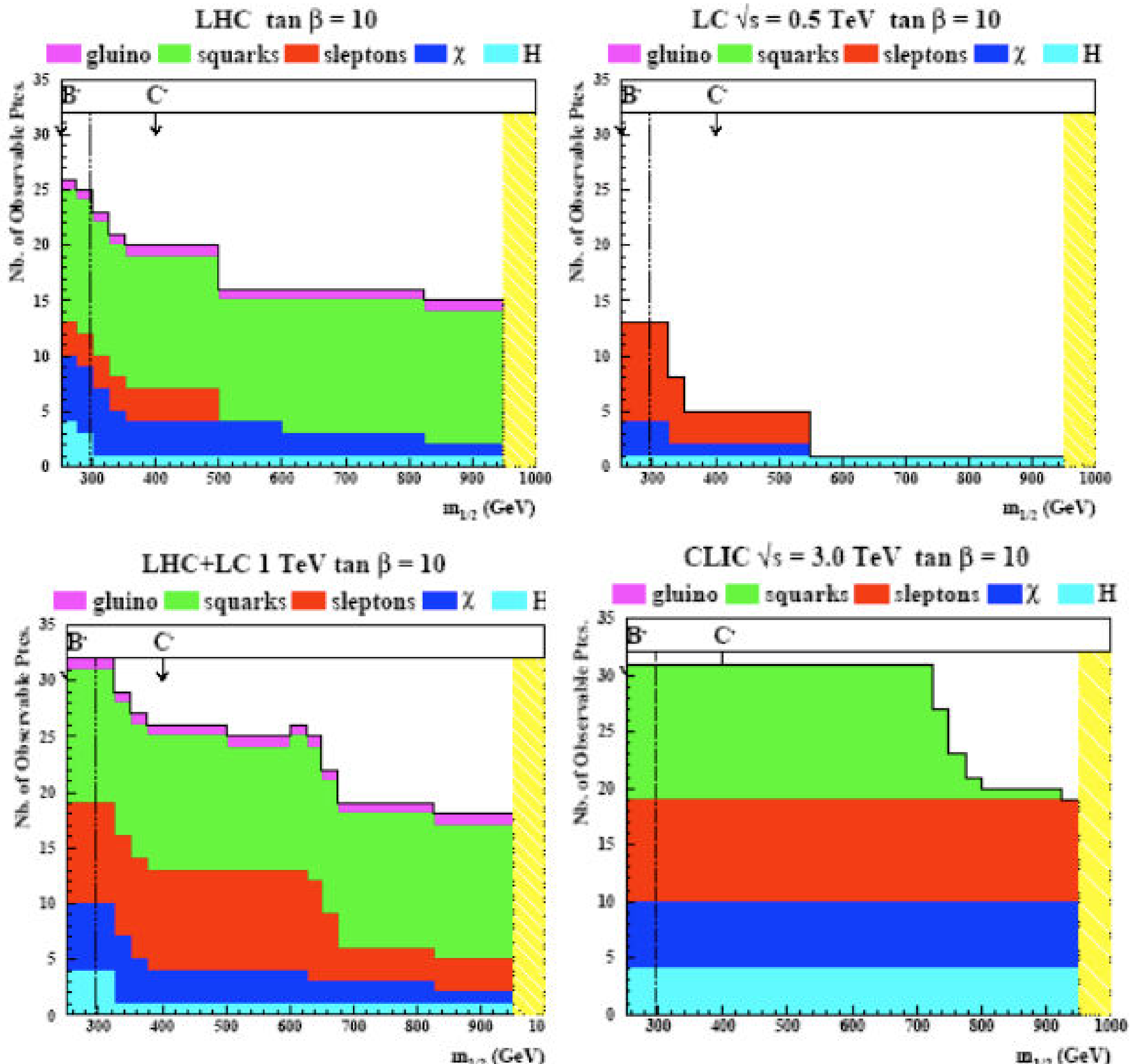
LHC Prospects



A. De Roeck

What LHC discovers will show us the way

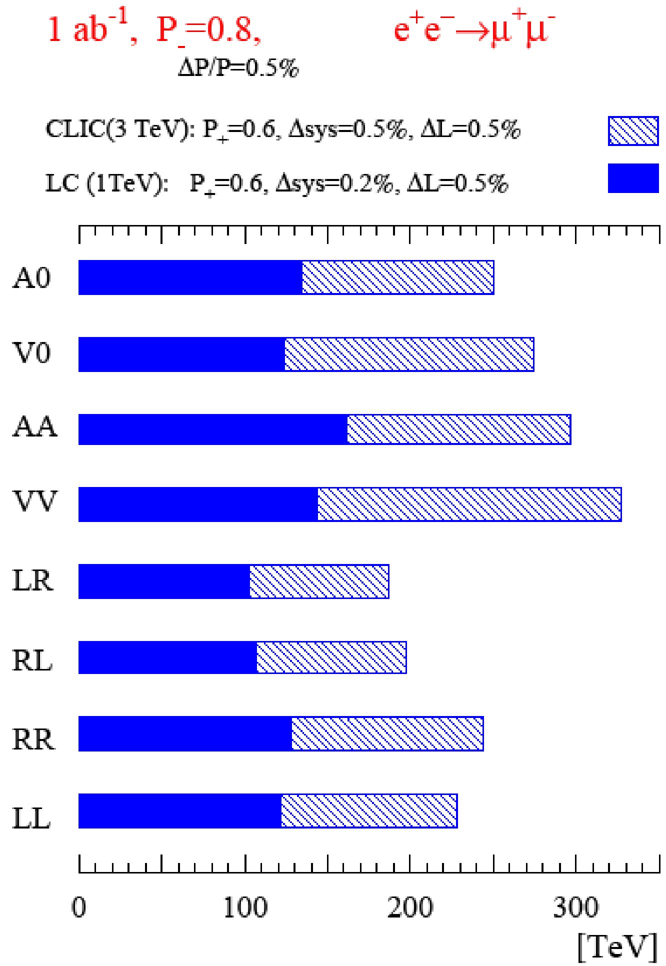
SUSY Particle Discoveries



G.F. Guidice

$e^+e^- \rightarrow ff$ ($\mu\mu$, bb)

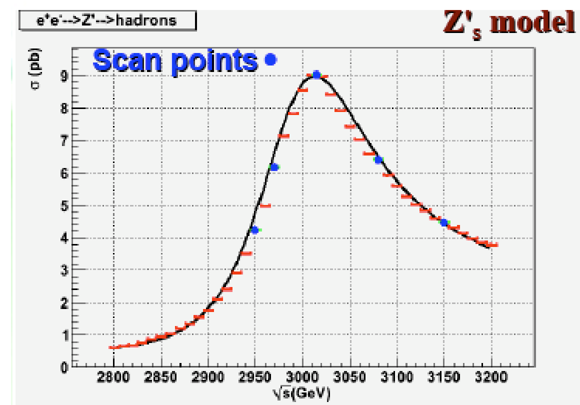
S. Riemann



Parametrization of new physics

$$\frac{\eta_{ij}\, s}{\Lambda^2}$$

Sensitivities to 200~300 GeV
(~twice that of LC(1 TeV))



Direct Z' scan: e+e- → hadrons
(O. Cakir)

Run Plan

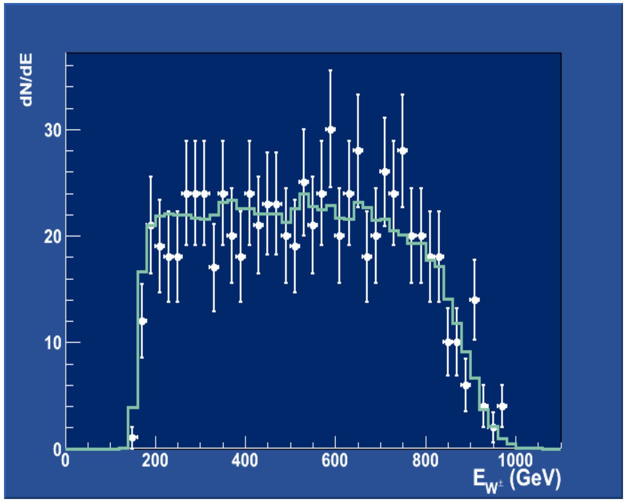
M. Battaglia

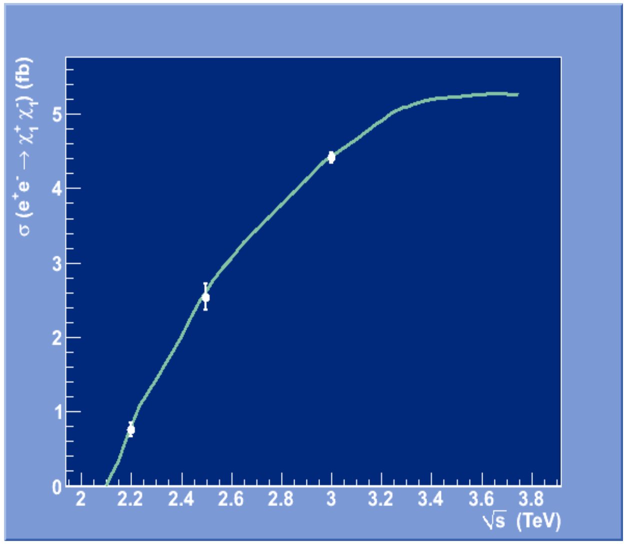
Idealy,

Take a chunk of data (~2 ab^{-1}) at the highest energy (3 TeV) to Identify new particles by energy distribution of W, μ etc.

Then, go to threshold to measure mass, width, spin etc.

$$e^+e^- \rightarrow \chi^+\chi^- \rightarrow W^+W^-\chi^0\chi^0$$





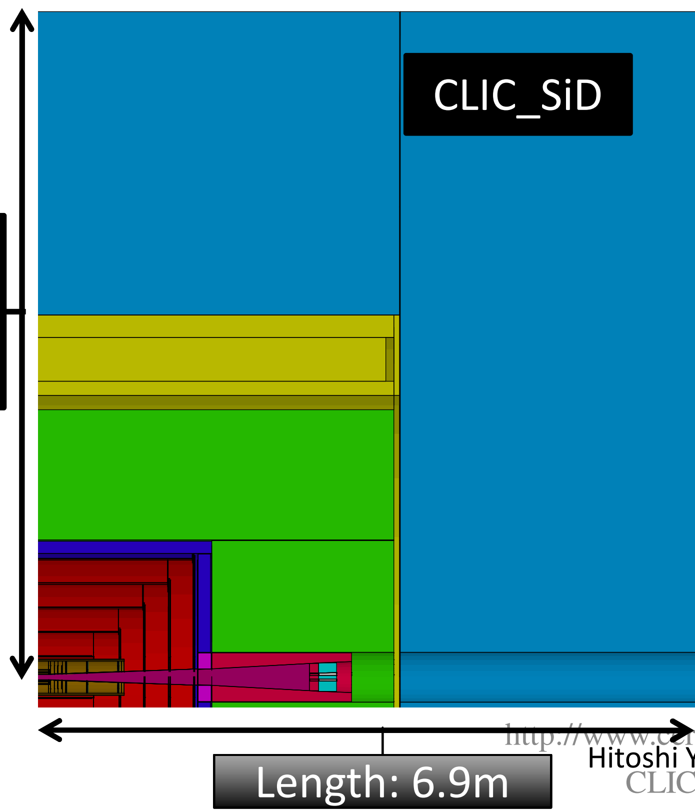
Andre Sailer

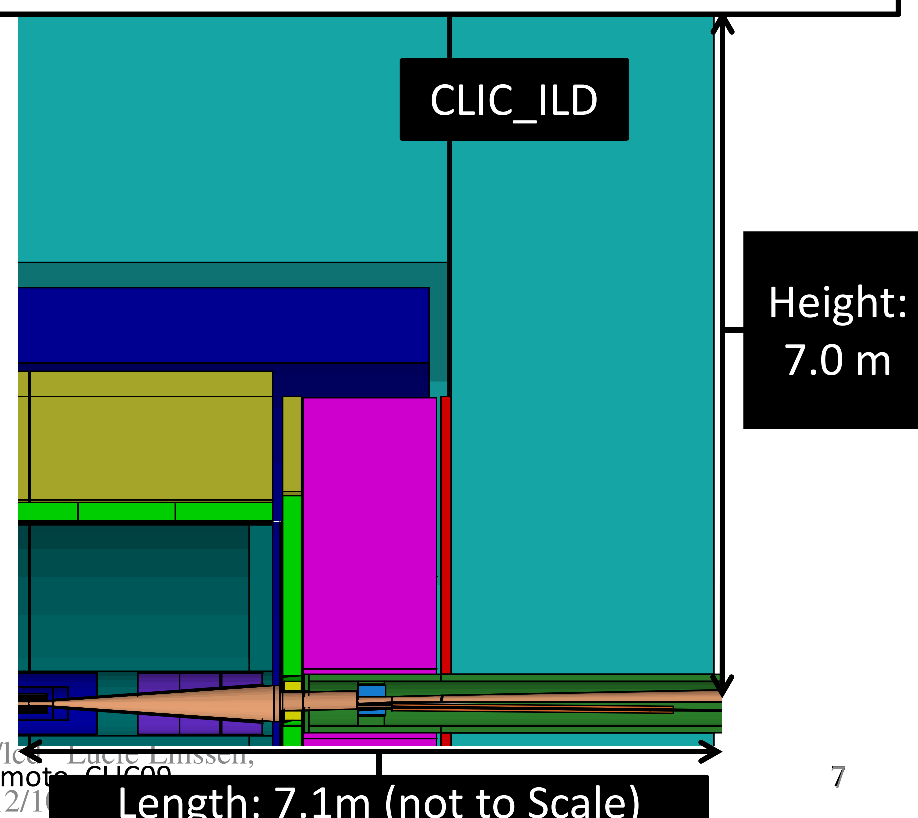
From ILC to CLIC Detectors

■Created CLIC 3 TeV detector models using SiD and ILD geometries and software

Changes:

- 20 mrad crossing angle (instead of 14 mrad)
- Vertex Detector to ~30 mm inner radius, due to Beam-Beam Background
- Hadron Calorimeter, more dense and deeper ($7.5\ \lambda_i$) due to higher energetic Jets
- For CLIC_SiD: Moved Coil to 2.9m (CMS Like)





Pair Backgrounds

Beam parameters

	ILC 0.5 TeV	CLIC 0.5 TeV	CLIC 3 TeV
L [$cm^{-2}s^{-1}$]	2×10^{34}	2×10^{34}	6×10^{34}
BX/train	2670	350	312
BX sep	369 ns	0.5 ns	0.5 ns
Rep. rate	5 Hz	50 Hz	50 Hz
Nbunch [10^9]	20	6.8	3.7
σ_z [μm]	300	40	40
σ_x/σ_y	600 / 6 nm	200 / 2 nm	40 / 1 nm

E (bunch surface) $\propto Qb/\sigma_x\sigma_z$

Pt kick of pairs $\propto E\,\sigma_z \propto Qb/\sigma_x$

Pt(CLIC 3 TeV) ~ 3 x Pt(ILC) : Expect larger pair backbrounds

Pair Backgrounds

CLIC 3 TeV :

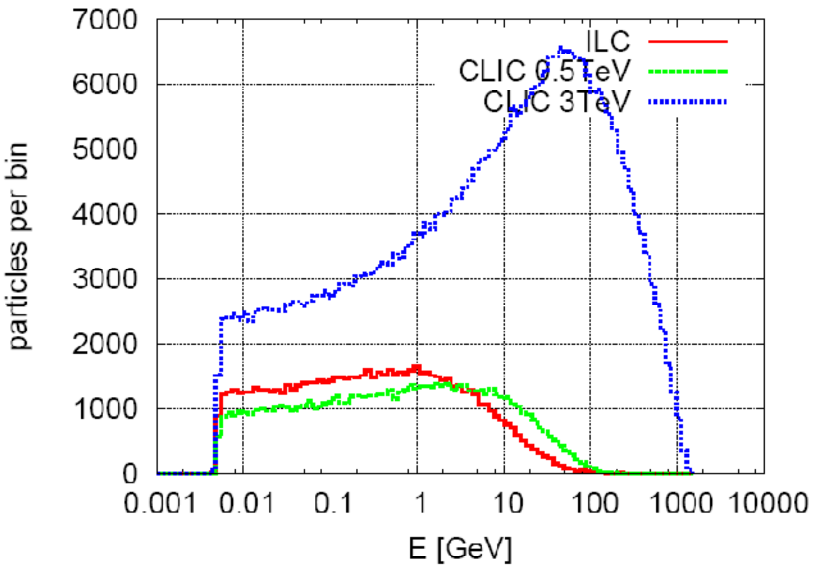
Coherent pairs (3.8×10^8 per bunch crossing)
High energy (~ TeV) → disappear in beam pipe : ignore for now

Incoherent pairs (3.0×10^5 per bunch crossing)
Lower energy → inner vertex layers

B. Dalena, D. Schulte

Incoherent pairs:
ILC 0.5 TeV: n_{incoh} 0.1×10^6 bx
CLIC 0.5 TeV: n_{incoh} 0.08×10^6 bx
CLIC 3 TeV: n_{incoh} 0.3×10^6 bx

Large energy diffrence between 0.5 TeV and 3 TeV.



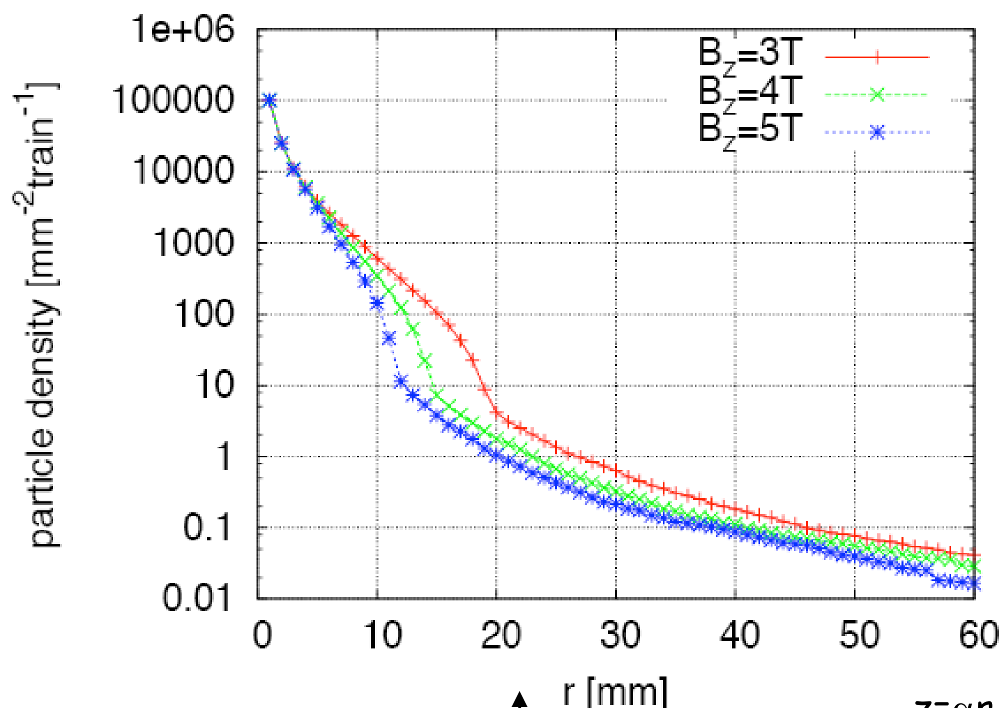
Impact on the vertex detector

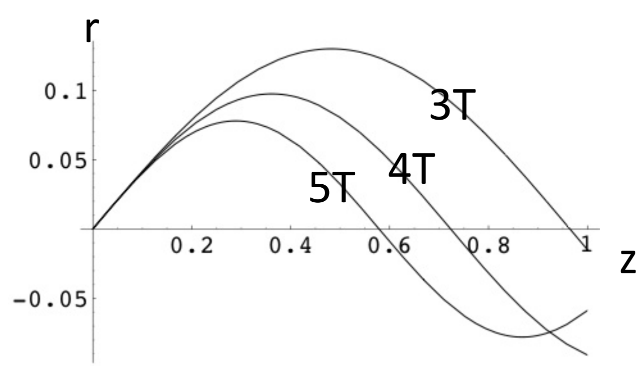
B. Dalena, D. Schulte

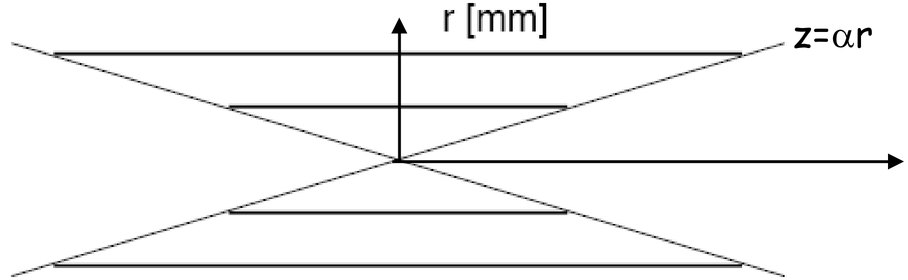
⇒ At $r_1 \approx 30$ mm expected 1 hit per train and mm^2

⇒ vertex radius for constant hit density scale as:

$$r \propto \sqrt{1/Bz}$$

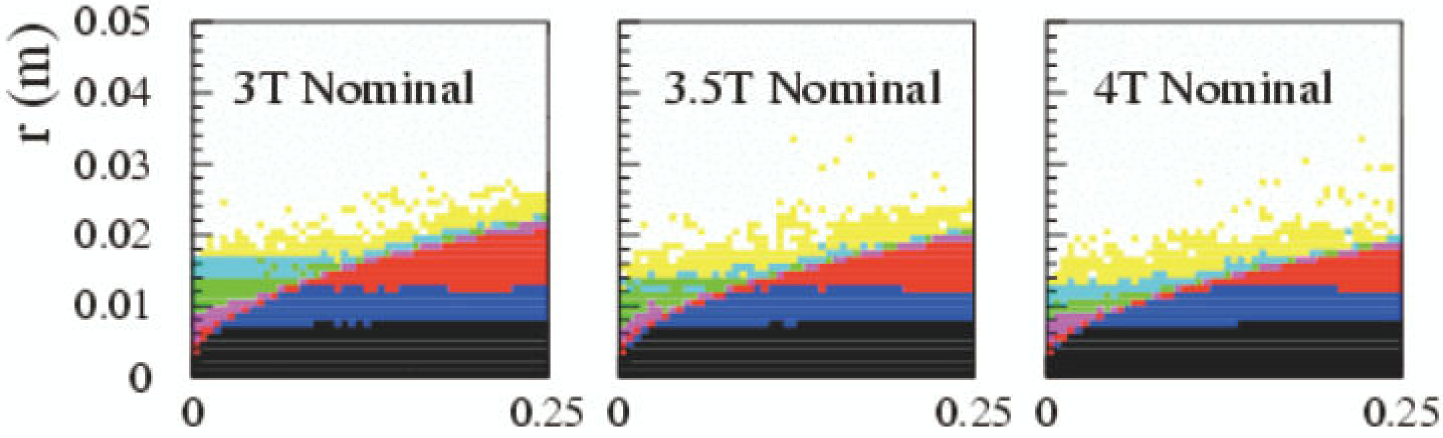


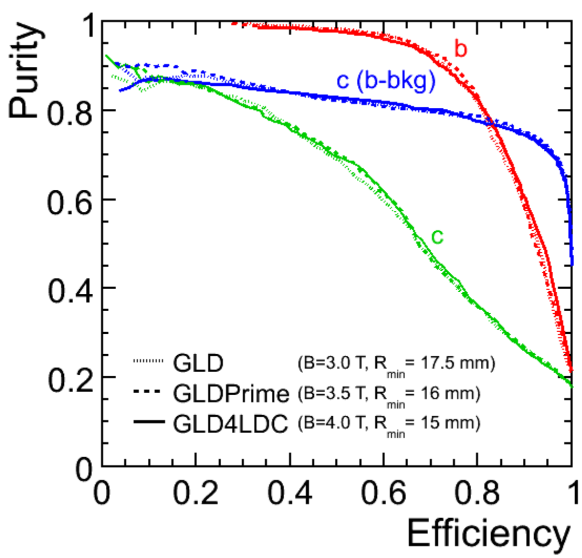




Vertexing and B Field

ILD study : M. Thomson





★ Conclude:

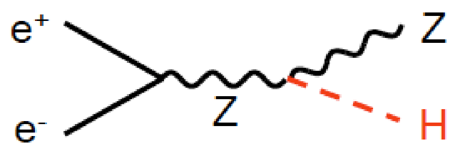
- Differences due to B (and r) are not large
- Smaller inner radius of vertex detector not a strong effect
- Earlier studies showed that going from 15 mm → 25 mm inner radius did not have a large impact on flavour tag

R = 31 mm is probably OK.

Generally Speaking,

S-channel

e.g.

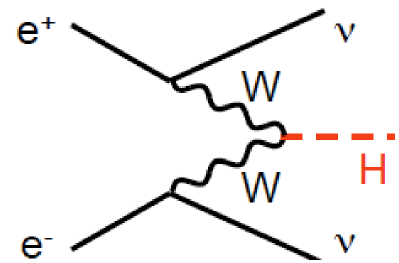


Cross section ∝ 1/S
decreases with S

Particles → barrel region

T-channel

e.g.



Cross section ∝ log S
increases with S

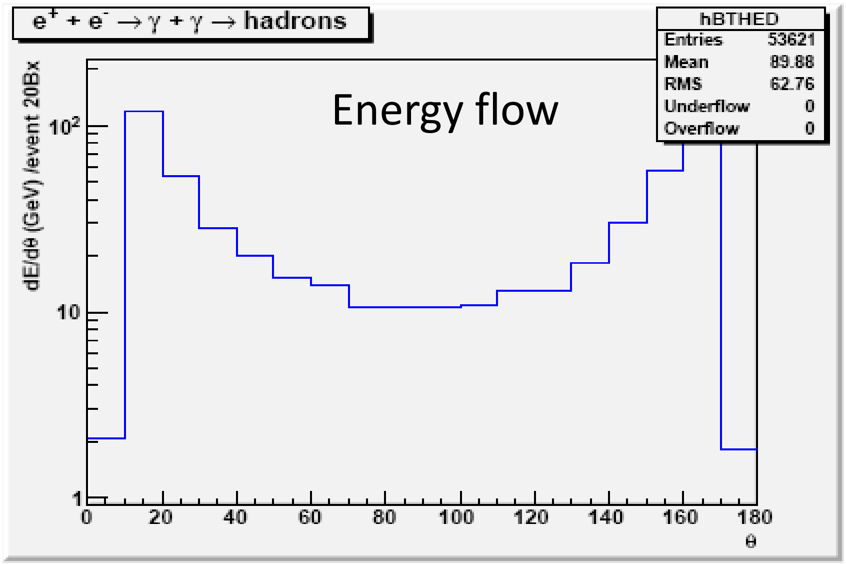
Particles → forward region

At high energy (3 TeV), T-channel processes tend to dominate.

Lots of backgrounds in forward region
- esp. 2γ → hadrons.

$2\gamma \rightarrow$ hadrons

M. Battaglia, J.J. Blaising, J. Quevillon



3TeV

On average, ~3.3 events, ~13 particles per bunch xing and they are highly peaked toward forward region.

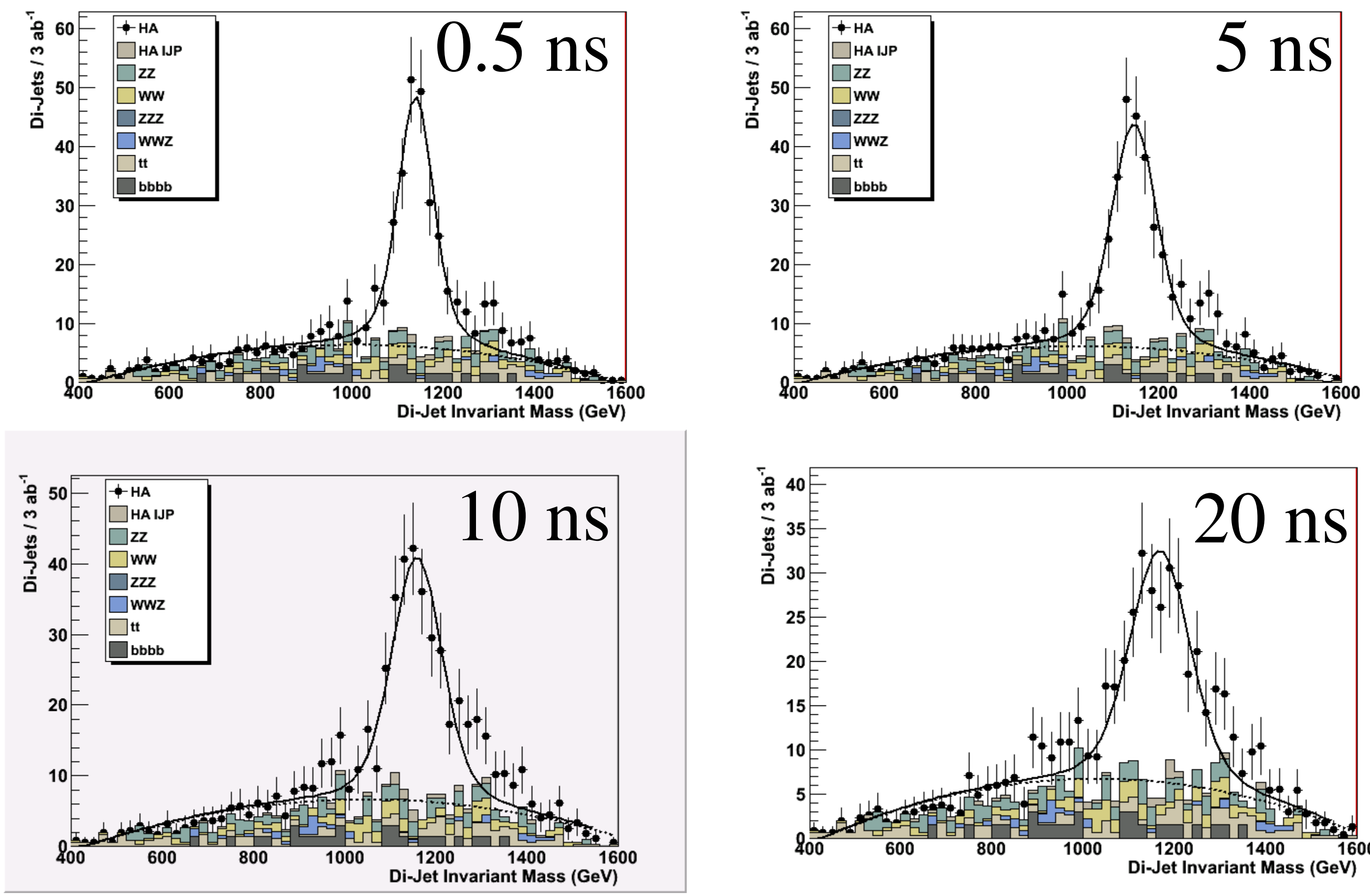
In 10ns: within 10 deg cone
~ 2 GeV in barrel
~ 20 GeV in forward

Time Stamping

Energy in e^+e^- event from $\gamma\gamma \rightarrow$ hadrons background

Degradation of physics signal as function of background integrated in the detector

(MOKKA G4 Simulation + Marlin Reconstruction)



Preliminary results of full G4+reco analyses indicate physics performance impacted for Δt > 10-15 ns

M. Battaglia

Time Stamping in Vertexing

Roundtable: M. Battaglia, Y. Arai, M. Campbell. H.G. Moser, W. Snoeys

At preset: no proven/usable technology to achieve 10ns time stamping with small enough pixel (<25 μm sq.)

H.G. Moser:

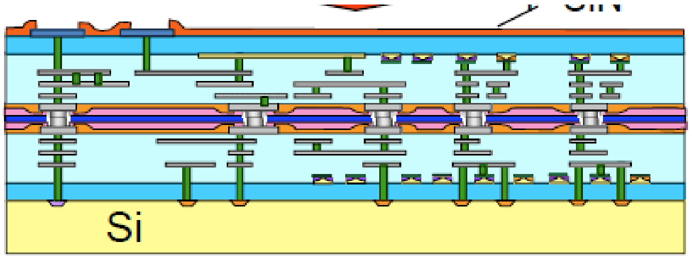
Hybrid Pixels (LHC-like): too much material, large pixels
CMOS Sensors: too slow
DEPFET: too slow (frame readout)

Advanced CMOS: very interesting. Key: PMOS & high resistivity epi

3D integration: solves many problems:
evolution/combination of hybrid pixels, MAPS or DEPFETs
$\Rightarrow$Most promising way to go!

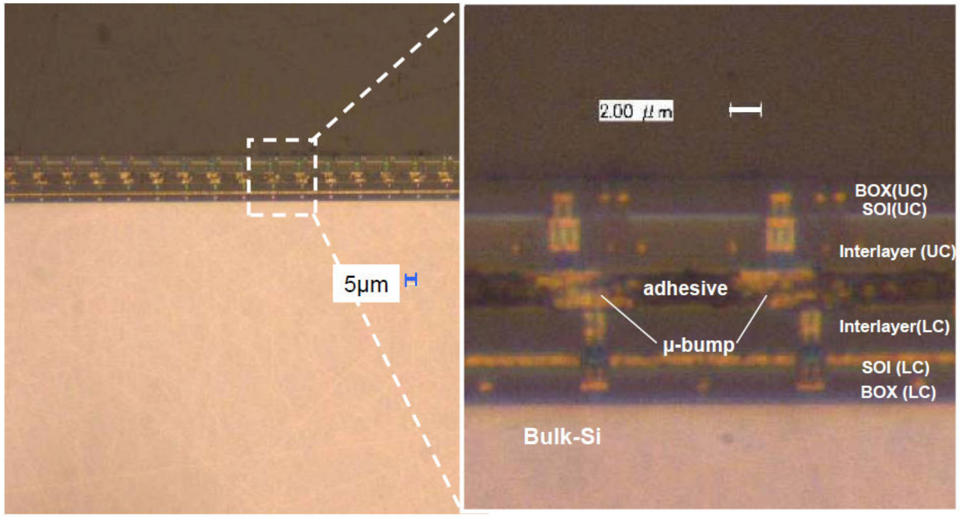
3D Integration (1)

> Higher integration density
> Radiation tolerance
> Lower power cnsumption



Test chip designed by LBNL/KEK.

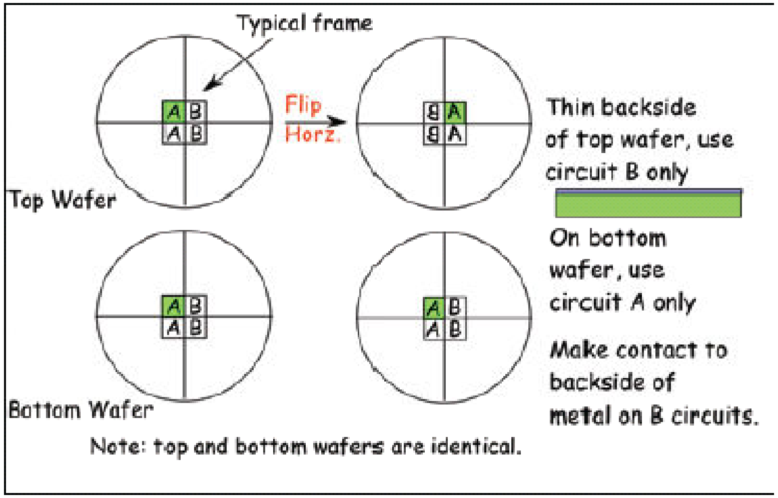
Bonded by Zycube (Co.).
Will be tested soon.



3D integration (2)

First 3D-IC Tezzaron Multiproject Run

Broad range of architectures and applications:

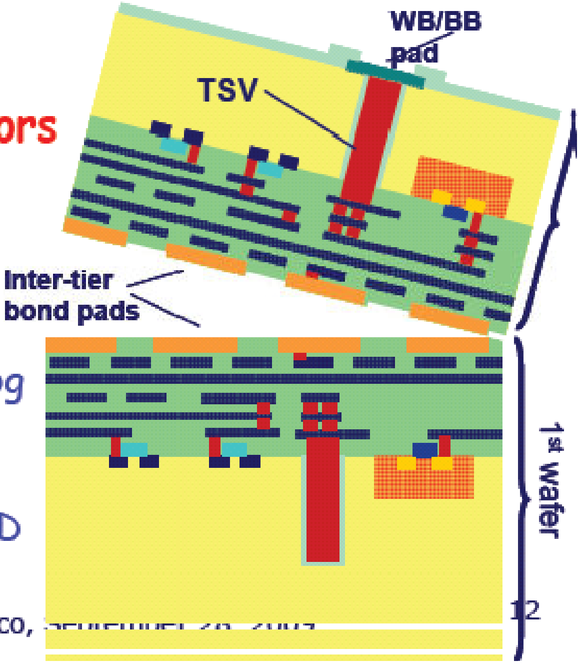


MAPS

- Convert 2D MAPS device to a full CMOS 3D design, with digital readout separated from the sensor and the analog front-end – Italy, France

Readout chips for high resistivity pixel sensors

- Convert MIT LL 3D SOI design to the Tezzaron/Chartered process – Fermilab
- Convert current 0.25 µm readout pixel electronics to a 3D structure with separate analog and digital tiers – France/US
- X-ray imaging/timing chip - Fermilab/BNL/Poland
- 3D chip with structures to test feasibility of a 3D integrated stacked trigger layer. - Fermilab



Forward Tracking

Marcel Vos

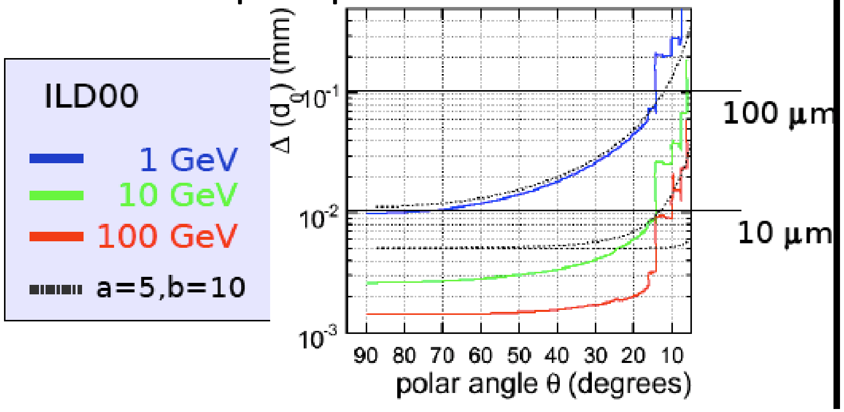
Conslusion:

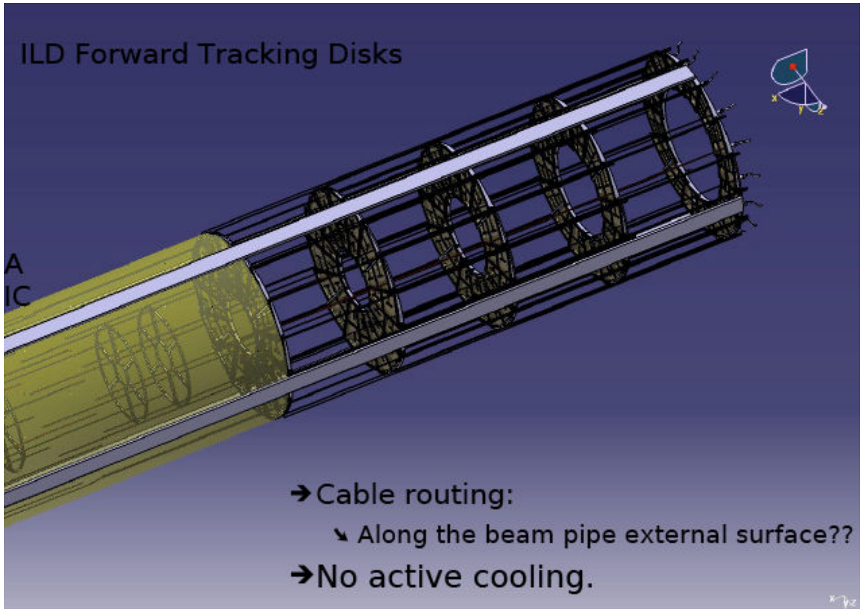
If the central tracking and vertexing is semewhat of a challenge, maintaining good performance at small polar angle is close to impossibility.

- Backgrounds
- Momentum resolution (B field)
- Vertexing (Barrel servicing)
- Pattern recognition

Then what?
Clearly, needs intensive work here.

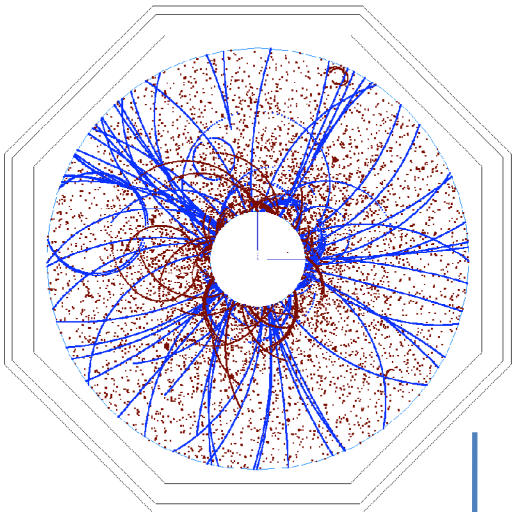
Impact parameter

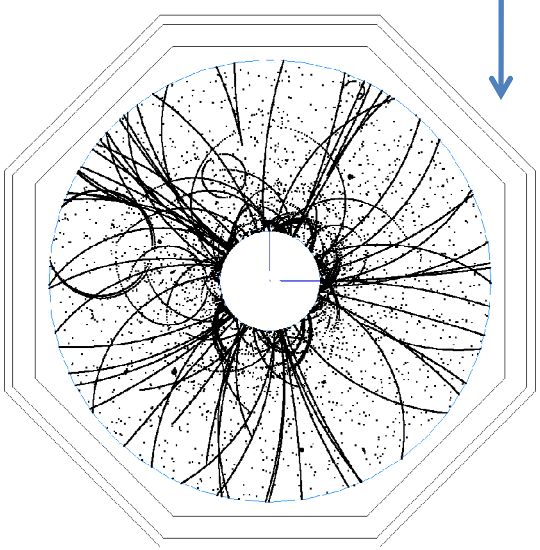


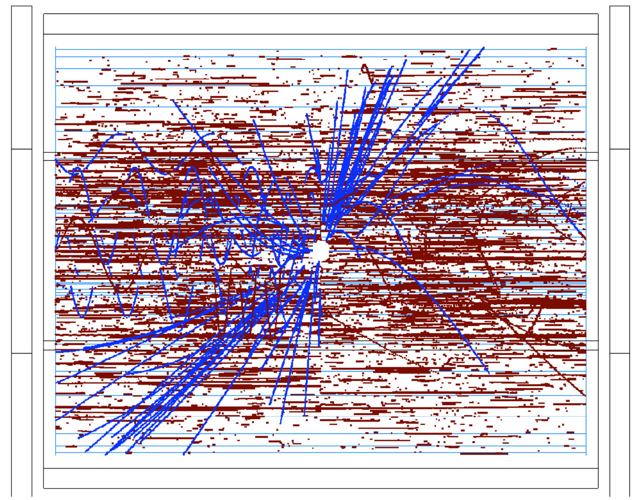


Main Tracker : TPC

ILD study: R. Settles







50 μs full drift = 150 bx
Salt-and pepper backgrounds are mostly removed by rejecting micro-curlers. No significant efficiency loss.

For CLIC, length of micro-curler is =1.5cm.
More backgrounds. 300 bunches for a train.
→ Study is needed.

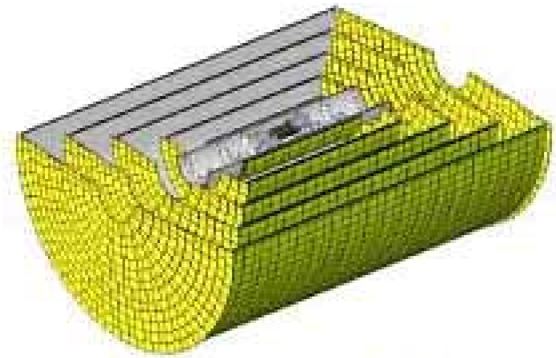
Main Tracker : Silicon

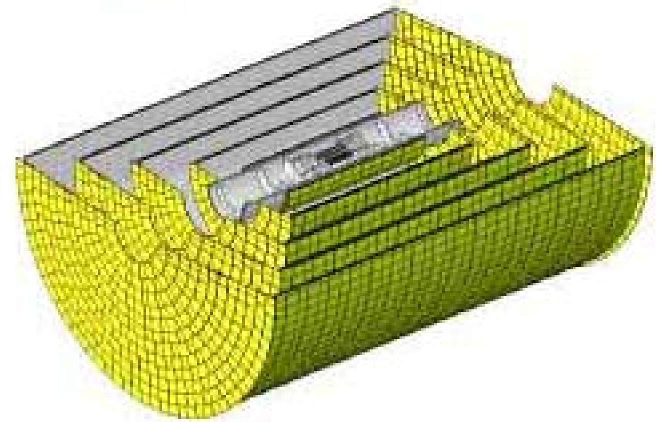
Possibly good for time stamping.

Maybe also better suited for forward region Tracking. (no thick end-plate)

Can pattern recognition work in the high background environment?

Track finding study with realistic geometry Is now on-going. – D. Grefe





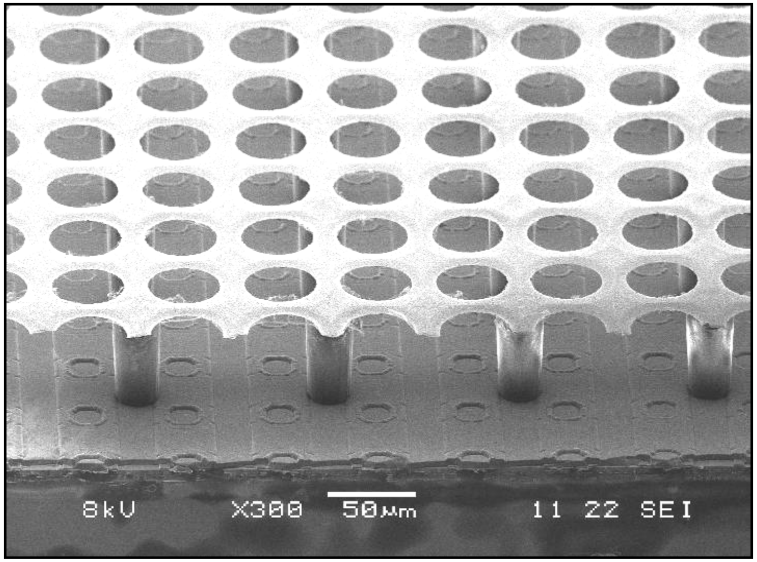
Pixellated TPC

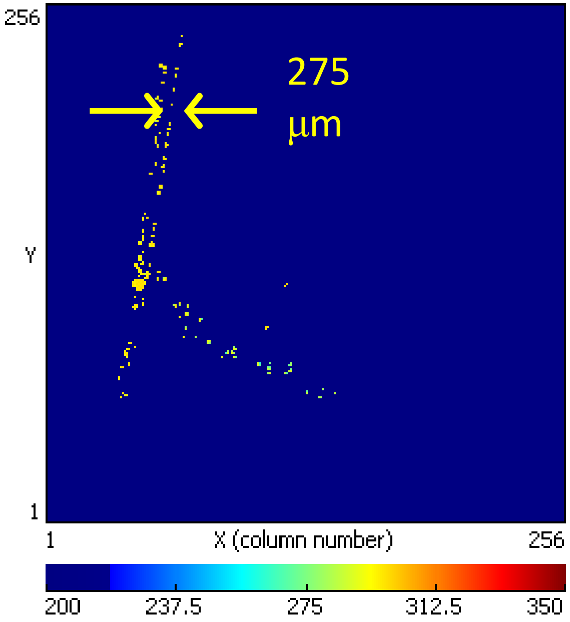
J. Timmermans

Use pixel sensor instead of wire or MPGD
(Micro-Pattern Gas Detector) such as MicroMEGAS or GEM.

Pad size : 1x5 mm^2 to 55x55 μm^2

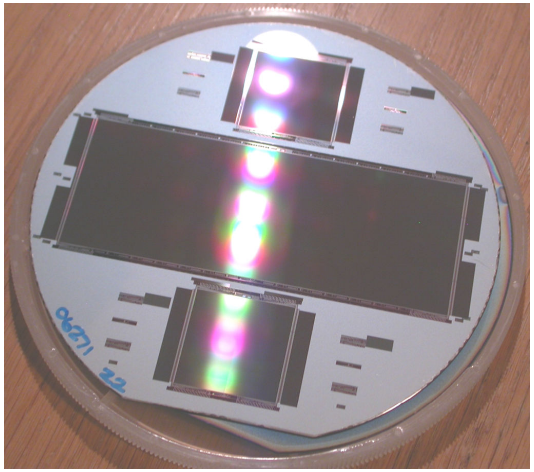
Good spacial resolution
Good 2-track separation (<1mm)
Possibly cluster counting (dE/dx)





Silicon Pixel Tracker

C. Damerell



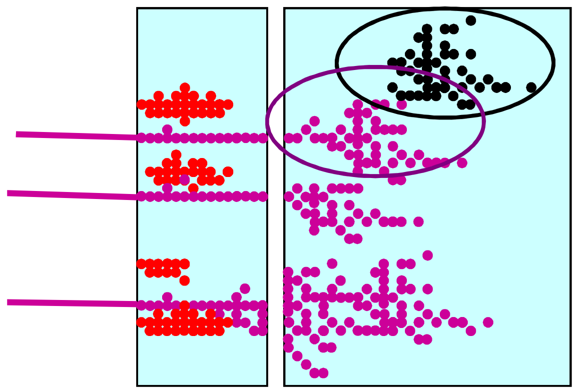
- **Charge-coupled CMOS pixel sensor**
  - **Like a single-cell CCD**
  - **Good noise performance**

- **Suggestion:**
  - **5 tracking layers of 50 μm monolithic pixels, area 81 m^2, 32.6 Gpixels, 0.6% X_0 per layer**
  - **1 double timing layer (outer) of 150 μm hybrid pixels, area 76 m^2, 2.4 Gpixels, 2% X_0 per layer. Timing resolution 1-10 ns, depending on power/cooling considerations (NA 62 an extreme demonstrator)**
  - **1 timing layer (inner) of 150 μm hybrid pixels, area 4.3 m^2, 19 Mpixels, 2% X_0 , if really needed**

Jet reconstruction - PFA (Pandra)

PFA :
Measure charged energy by tracking
Measure neutrals by calorimeters
Remove overcounting by pattern rec.

M. Thomson



B = 4 T (3.5 T for ILD)
HCAL : 8 λ (6 λ for ILD)

Meets the jet energy resolution goal (3~4%) up to 500 GeV jet.

PANDRA PFA is being re-written to be more flexible and use-friendly.
(J. Marshal)

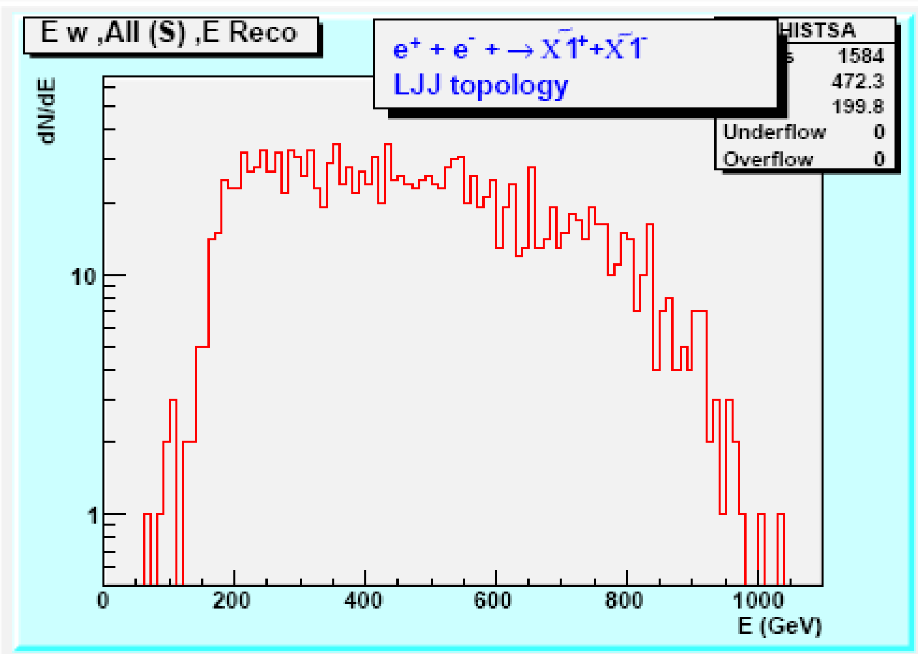
SiD PFA (U. Malik) and Compensating Calorimetry (C. Gatto) give similar jet resolution

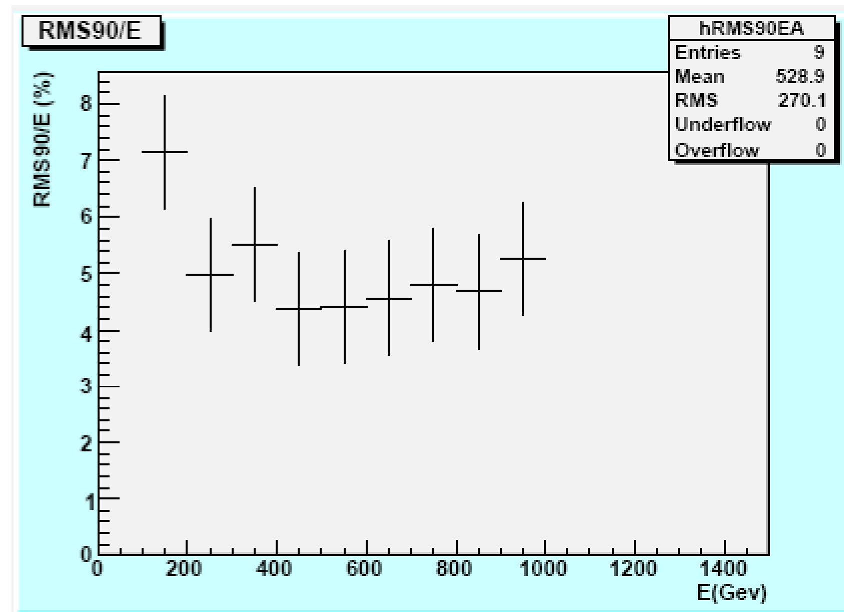
E_{JET}	$\sigma_E/E = \alpha/\sqrt{E_{jj}}$ $\lvert\cos\theta\rvert<0.7$	σ_E/E_j
45 GeV	25.2 %	3.7 %
100 GeV	28.7 %	2.9 %
180 GeV	37.5 %	2.8 %
250 GeV	44.7 %	2.8 %
375 GeV	71.7 %	3.2 %
500 GeV	78.0 %	3.5 %

Jet Reconstruction – Chargino pair

3 TeV

J.J. Blaising





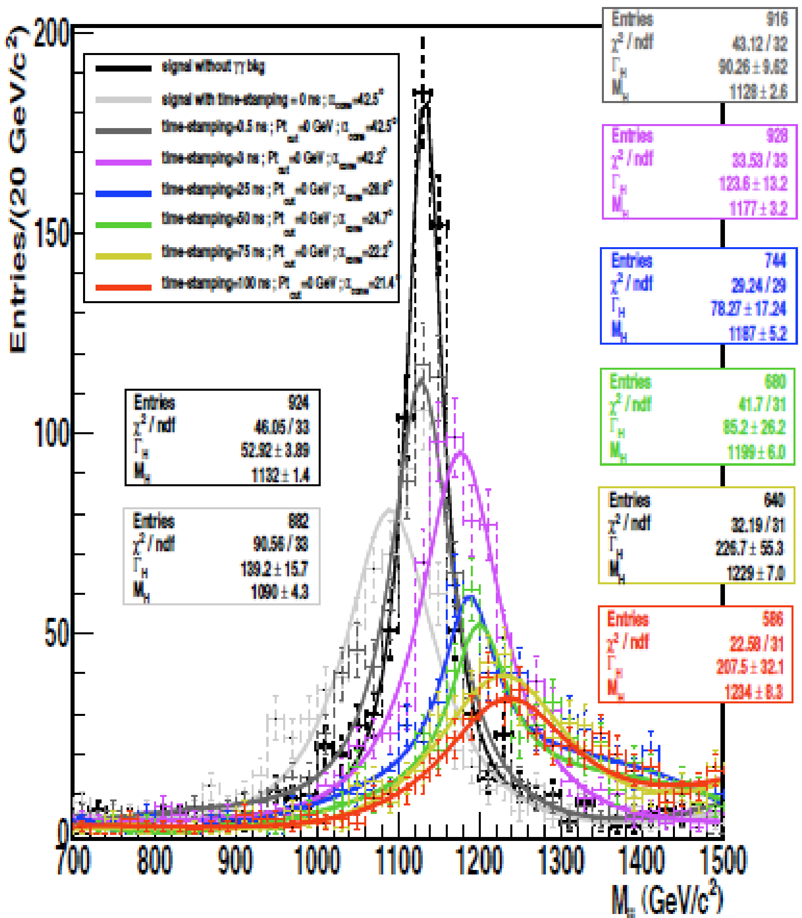
For $\tilde{\chi}_1 \pm$ and $\tilde{\chi}^0$ searches, currently σEw/Ew ~ 5% for the LJJ topology, without γγ background. With γγ background and 10ns time stamping σEw/Ew ~ 7.5% it leads to σM $\tilde{\chi}^0$ /M $\tilde{\chi}^0$ ~ 8%; ok. . The mass resolution is ~ 15%, this resolution is not good enough to have a good W±, Z^0 and h^0 separation

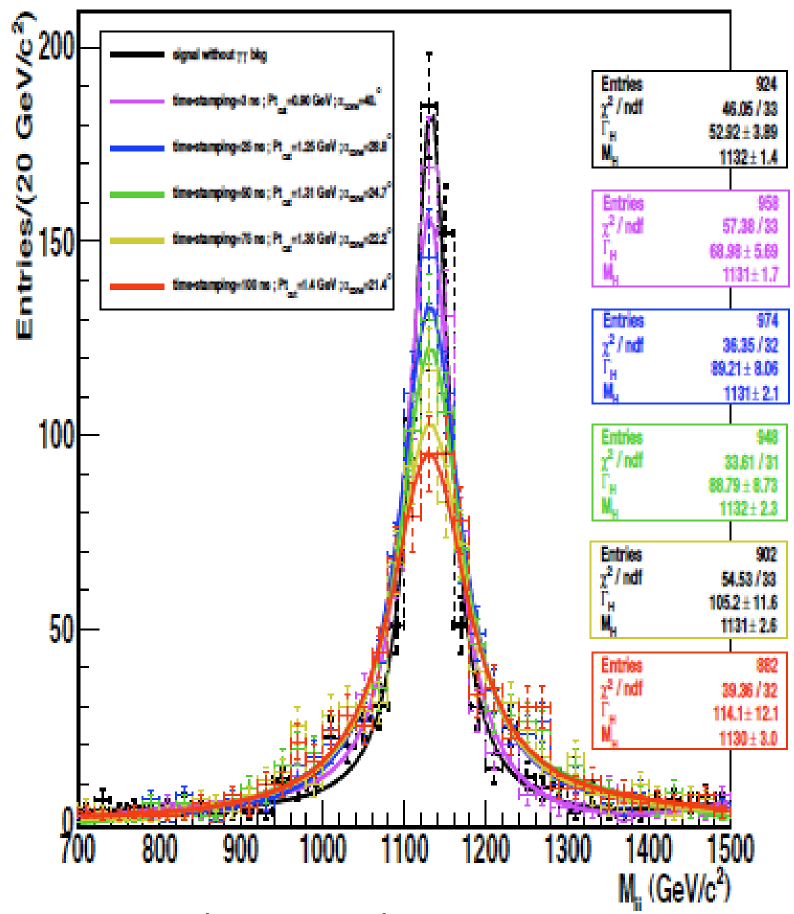
Jet Clustering Tuning

J. Quevillon

Without Pt_{cut} | With optimal Pt_{cut}

$$e^+e^- \to HA \to bbbb$$



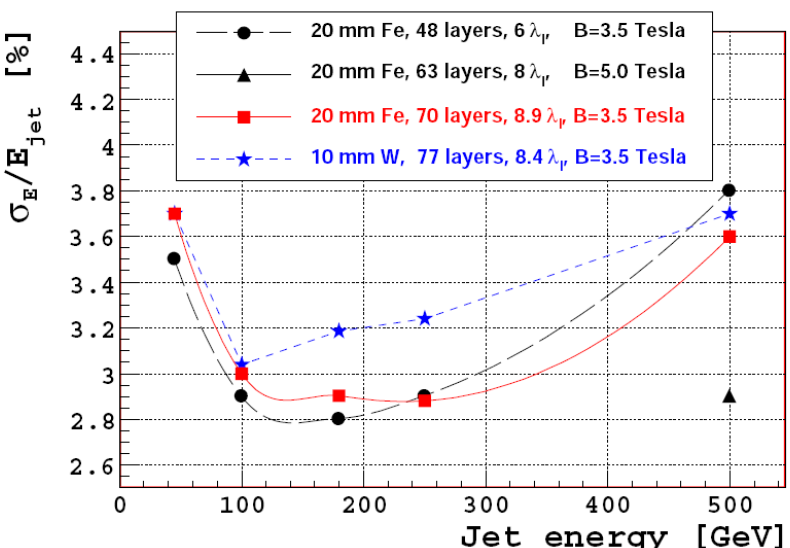


Colors: different time stamping (0-100 ns)

W-HCAL

Simulation :
(P. Speckmayer)

PFA resolution is comparable to Fe
- No tuning done for W



Angela Lucaci-Timoce

Prototype idea:
(W. Klempt)

Start 2010 with a “small” prototype:

*Start with ~20 W plates size 80x80 cm^2, 1 cm thick

*Use as much as possible existing equipment from CALICE (detector planes, readout electronics, DAQ, mechanical infrastructure…..)

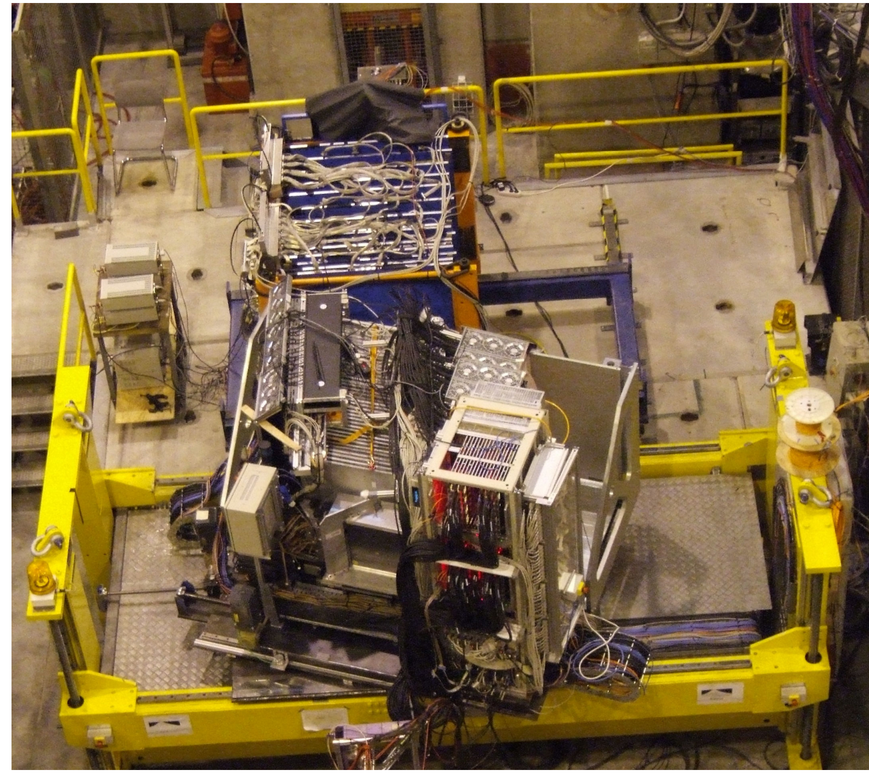
*First test beam at PS/SPS in autumn 2010

*Later increase depth to 40 or more layers

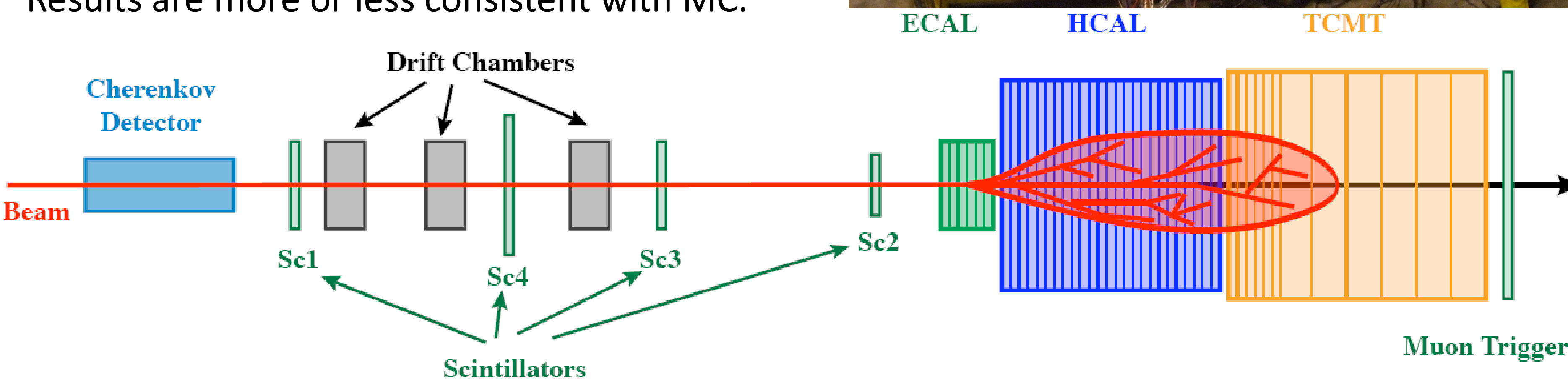
CALICE Beam Tests

D. Ward

- Main beam tests, using π, μ, e beams:
- 2006-7
  - SiW ECAL + AHCAL + TCMT @ CERN
- 2007
  - Small DHCAL test @ Fermilab
- 2008
  - SiW ECAL + AHCAL + TCMT @ Fermilab
- 2009
  - Scint-W ECAL + AHCAL + TCMT @ Fermilab
  - Standalone RPC and Micromegas tests @ CERN
- 2010 planned
  - SiW ECAL + DHCAL + TCMT @ Fermilab



There is no perfect Hadron shower MC.
Results are more or less consistent with MC.

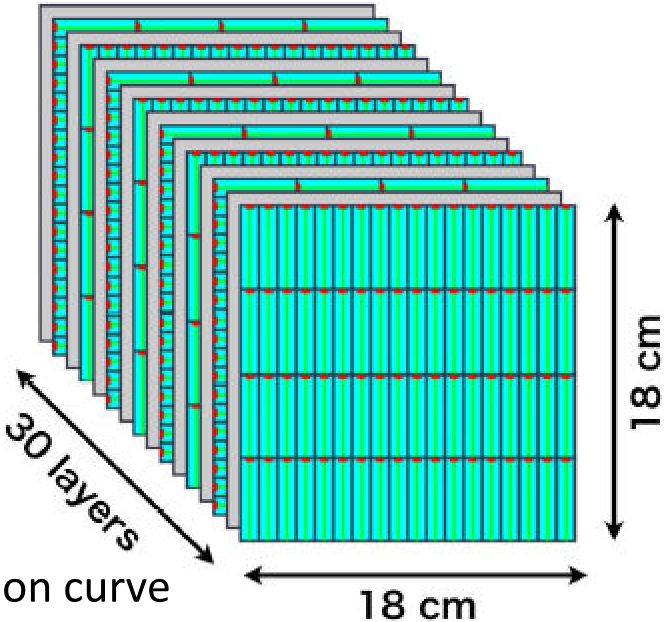


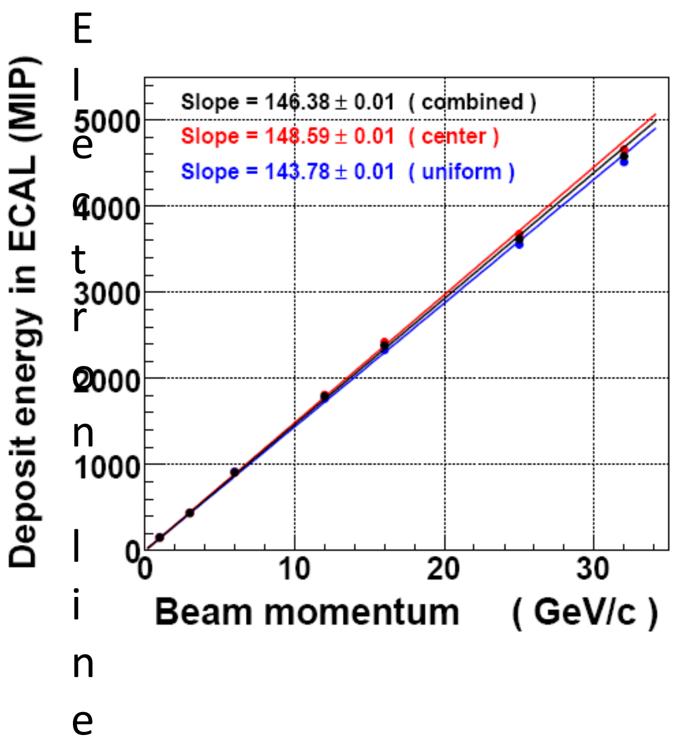
Scintillator ECAL

T. Takeshita

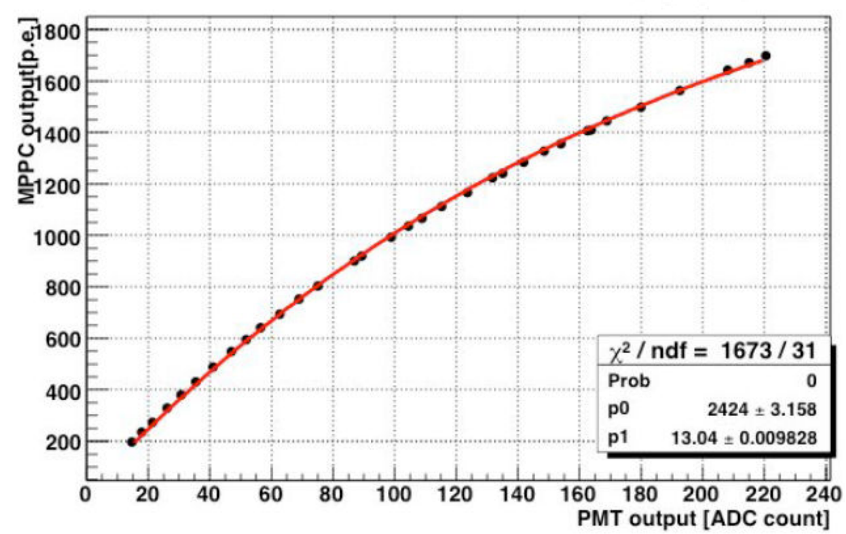
- Scintillator strips 1x4.5x0.3 cm^3
- Read out via WLS fibres by MPPCs (SiPMs)
- Tested at Fermilab

e⁻ energy resolution
$1.4\% \oplus 15.1\%/\sqrt{E}$



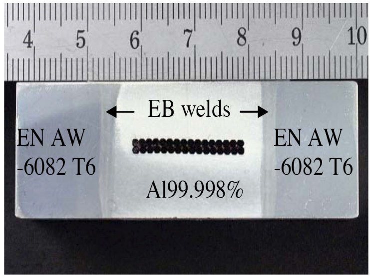


MPPC saturation curve



Solenoid

W. Craddock

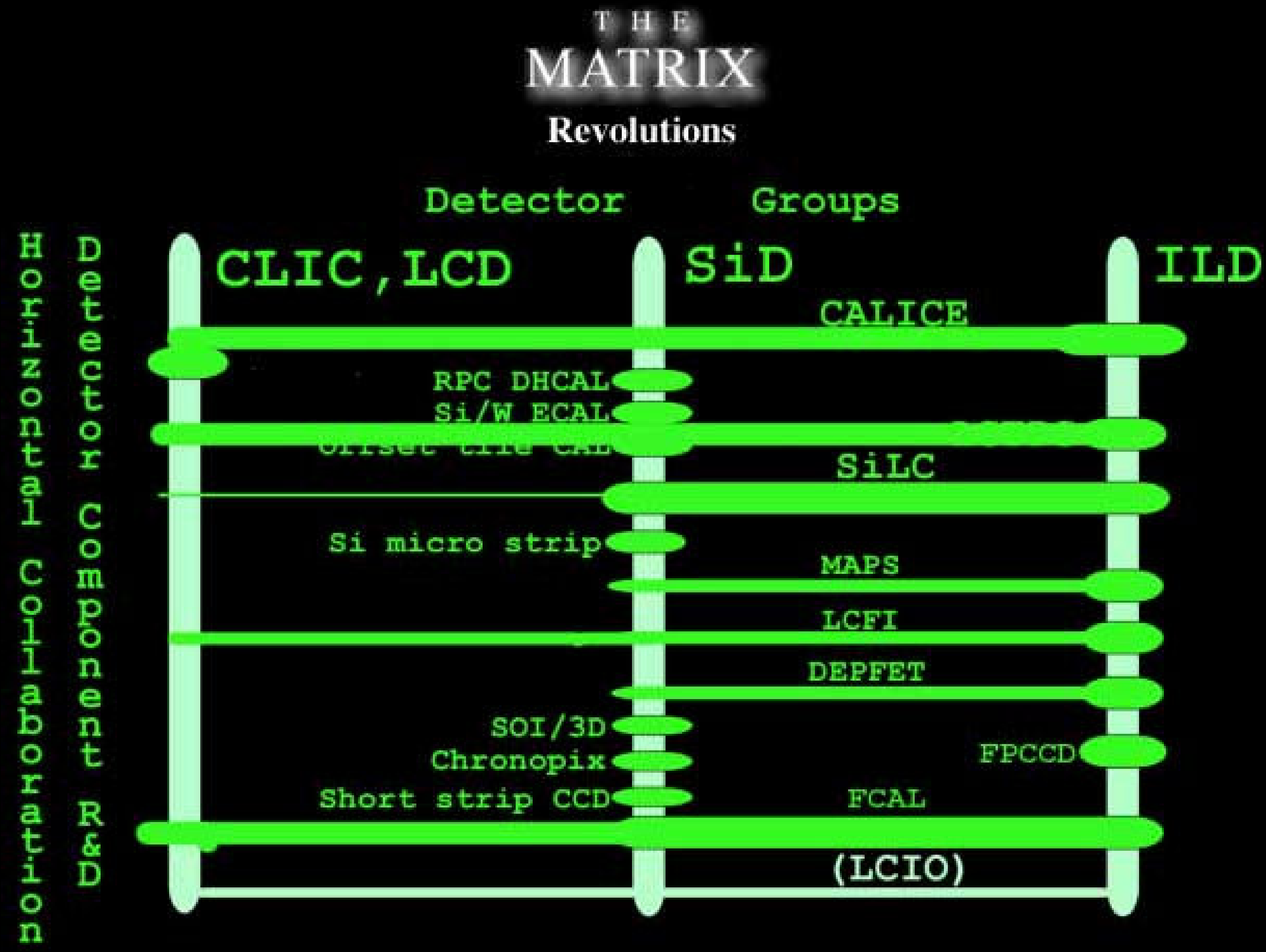


CONCLUSIONS of the Solenoid Workshop

- **CLIC Solenoid Design is just beginning using validated ILC solenoid designs as a starting point for CLIC**
- **The CMS and ATLAS solenoid engineering, construction techniques and conductor metallurgy provide the starting point and basis for all ILC superconducting magnet designs. This saves an enormous amount of engineering time and cost.**
- **Magnet design ideas were shared**
- **CERN, KEK, SLAC and other institutions will work together on advanced conductor metallurgy**
- **A central web site will collect all available resources that can be shared among Linear Collider design groups (e.g. high purity aluminum, superconducting cable, R&D tools and facilities)**
- **An informal workshop for conductor metallurgy at MT21, next week.**
- **THIS WAS A VERY GOOD START IN COORDINATING THE INTERNATIONAL LINEAR COLLIDER MAGNET DESIGN EFFORT.**

Summary

- The physics potential of CLIC is impressive.
  - The detail will, however, depends strongly on LHC outputs.
- Pair and hadronic 2γ backgrounds are large, and detailed full simulation studies are needed for
  - Vertexing detector configuration
  - Choice of TPC vs Silicon (or others)
  - Time stamping needs for each subdetector
- Dominant t-channels (signal and backgrounds) pose severe challenge for the forward region
- Much work has been done, but much more to be done.
- Collaboration between CLIC and ILC is critical .


THE
MATRIX
Revolutions
Detector Groups
Horizontal Collaboration
Detector Component R&D
CLIC,LCD
SiD
ILD
CALICE
RPC DHCAL
Si/W ECAL
SiLC
Si micro strip
MAPS
LCFI
DEPFET
SOI/3D
Chronopix
FPCCD
Short strip CCD
FCAL
(LCIO)