JORNADAS SOBRE EL FUTURO COLISIONADOR LINEAL

WORKSHOP ON THE FUTURE LINEAR COLLIDER

Palacio Ducal GANDÍA, 1 al 3 de Diciembre 2005

Celebrating Antonio Ferrer's 60th anniversary

e^+ → ← e^-

http://ific.uv.es/~mas/gandia
http://ific.uv.es/~forward/Gandia_2005

CSIC

IFIC - Instituto de Física Corpuscular

UNIVERSITAT INTERNACIONAL DE GANDIA uig

Worldwide Study of the Physics and Detectors for Future Linear e+ e- Colliders

ANNOUNCEMENT of the WORKSHOP ON THE FUTURE LINEAR COLLIDER

(Gandía, December 1-3, 2005)

The Instituto de Física Corpuscular (CSIC-University of Valencia), in coordination with the Universitat Internacional de Gandía, is organizing a Workshop on the Future Linear Collider, from 1st to 3rd of December, 2005 to be held at the Palacio Ducal in the city of Gandía, province of Valencia (Spain).

This Workshop is **mainly addressed to Spanish experimental and theoretical groups** and individuals interested in the physics, design and technology spanned by the project, with the contribution of invited speakers, highly expert in the field.

The Linear Collider is a proposed new electron-positron collider. Together with the Large Hadron Collider at CERN, it would permit physicists to explore energy regions beyond the reach of present accelerators. Expectedly, new discoveries will be made possible, eventually leading to new understanding of what the universe is made of and how it works. The nature of electron-positron collisions would allow to answering compelling questions that the LHC will likely raise, from the existence of particles beyond the Standard Model (like non-standard Higgs bosons) to the identity of dark matter and the possibility of extra dimensions.

Therefore, this announcement can be seen as a **call for interest to those Spanish Groups** and individuals already or potentially i**nterested in the participation in the Linear Collider Project, starting a fruitful exchange of ideas including a round-table discussion, and preparing possible collaborations for the future**.

Programa

1st December		
10:30	Welcome and Motivations	D. Espriu (UB)
11:30	Physics at ILC – theoretical overview	W. Hollik (MPI-Munich)
12:15	Lepton Number Violation at ILC	M. Hirsch (IFIC)
16:00	ILC Perspectives: Theory and Experiments	F. Richard (LAL)
16:50	ILC Communication and Outreach	P. Royole-Degieux (LAL)
17:50	The Detectors Concepts	K. Monig (DESY)
18:30	The Machine Detector Interface Challenges	Ph. Bambade (LAL)
2nd December		
09:00	R&D for the ILC Detectors – an Overview	W. Lohman (DESY)
09:30	Calorimeter for the ILC Experiment	J.C. Brient (LLR)
10:40	Forward Calorimetry	W. Lohman (DESY)
11:15	DEPFET Technology for Vertex detector	H.G. Moser (MPI-Munich)
12:15	The SiLC project	A. Savoy-Navarro (Paris VI)
17:00	Antonio Ferrer 60th birthday	
20:30	Cocktel and Dinner	
3rd December		
10:00	News from GDE	B. Foster (Oxford Univ)
10:40	The CLIC study if a Multi-Tev e+e- Linear Collider	J. P. Delahaye (CERN)
11:40	Spanish activities and Interest for LC. General Discussion	
	IFIC (A. Faus-Golfe, C. Lacasta)	
	CIEMAT (F. Toral)	
	UPC (Y. Kubyshin)	
	UGR (J.A, Saavedra & F. Cornet)	
	ICFA (C. Martínez)	
14:30	Fideuá	

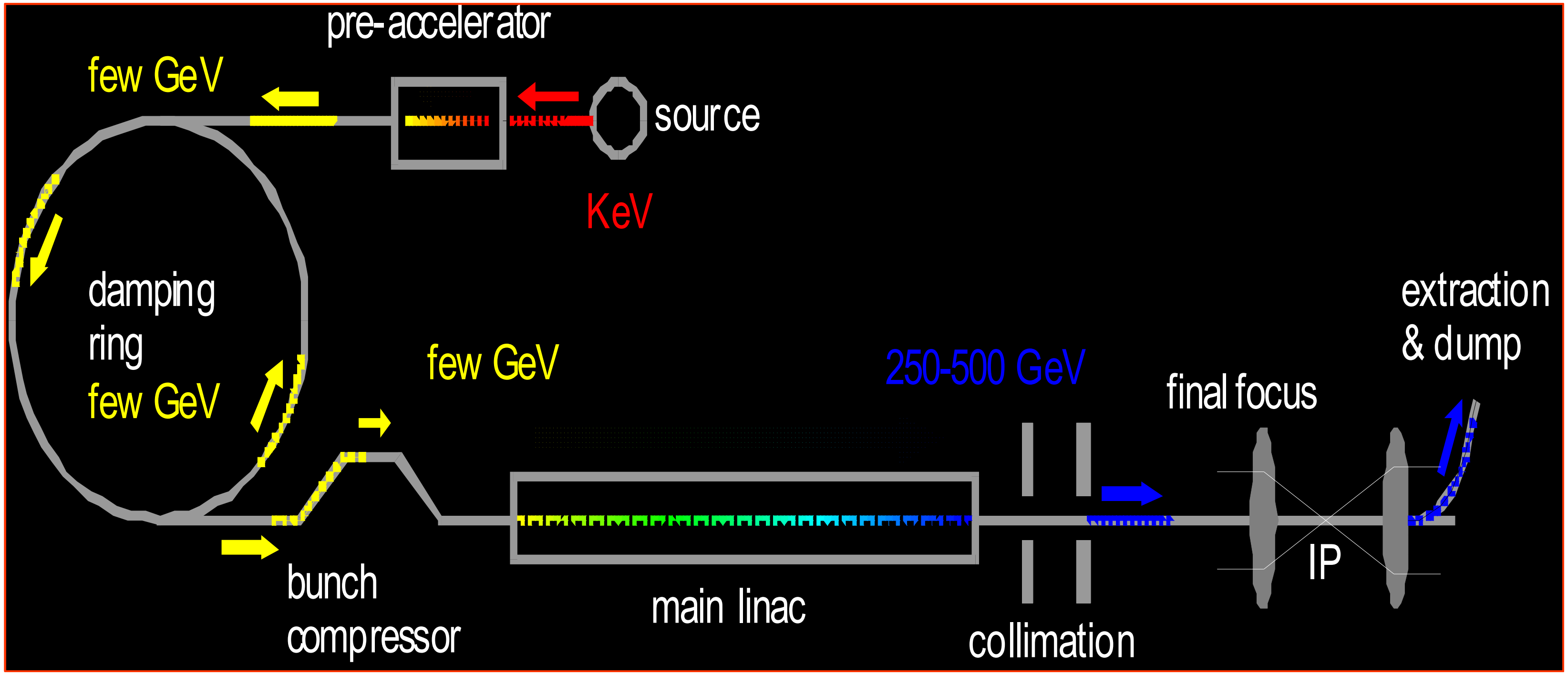
http://www.linearcollider.org

AVISO

- Esta charla está completamente sesgada
  - Mis filias y fobias con los temas/speakers
  - Mis propios intereses
  - Mi comprensión de los diferentes tópicos
- Me he tomado la libertad de utilizar, mezclar y modificar las transparencias disponibles
- Muchísima más información en las transparencias originales que en esta presentación
  - http://ific.uv.es/~forward/Gandia_2005
- Mi objetivo:
  - Encuadrar la discusión sobre una posible participación del CIEMAT en el I+D para los detectores del Linear Collider

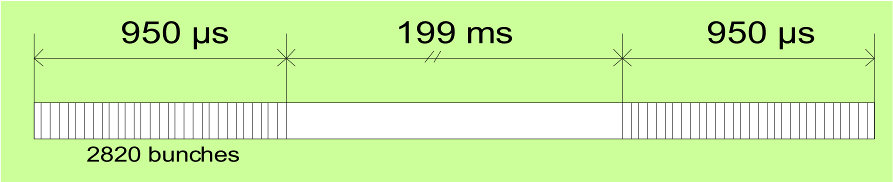
El acelerador

- E_{cm} ajustable entre 200-500 GeV y ampliable hasta 1 TeV
- Luminosidad
  - Integrada de ~500 fb^{-1} en 4 años
  - Instantanea de 2 x 10^{34} cm^{-2} s^{-1}
- Estabilidad y precisón en la energía mejor que el 0.1%
- Polarización >80%



Estructura del haz

- 2820 (4500) bunches spaced by 337 (189) ns
- 199 ms between trains (5 Hz Bunch Trains)



- Background (Beamstrahlung)
  - 140.000 e+e- pairs/BX
    - 0.03(0.05) hits/mm^2/BX @ E=500(800) GeV, R=15mm, B=4T
    - Bunch train = 85 hits/mm^2/BT
    - 10% occupancy for 25 μm^2 pixel
  - ~20 readout cycles/BT (47.5 μs) to keep occupancy low
  - 50 MHz (20 ns) readout @ detector level
- <u>NO ELECTRONIC TRIGGER</u> → All physics on tape is unbiased

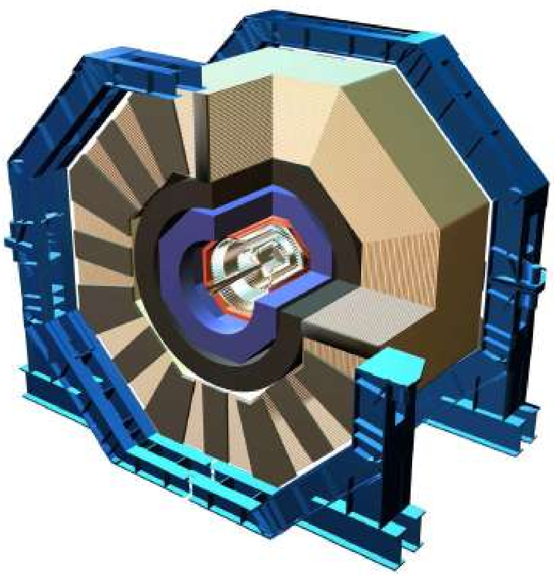
Comparación con otros aceleradores

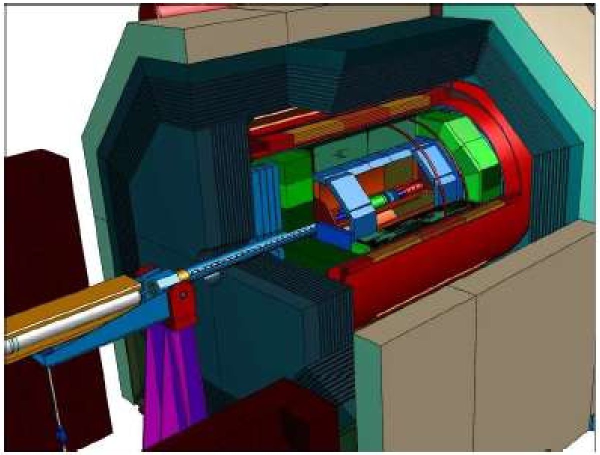
$$L \sim \frac{n_b N_e^2 f}{4\pi\sigma_x\sigma_y} H_D$$

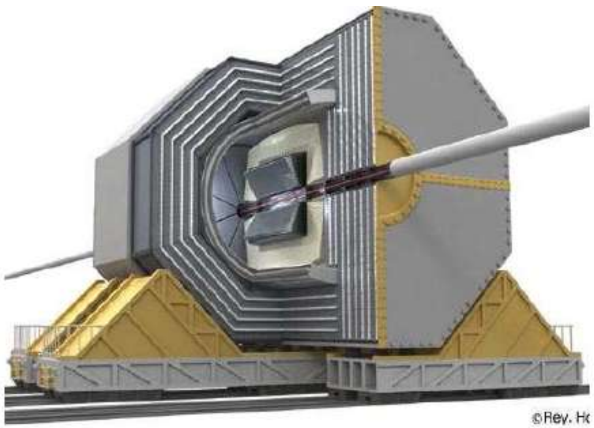
	LEP	LHC	SLC	ILC
Energy (GeV)	45-100	7000	45	200-500
Time between collisions (μs)	22	0.025	8300	0.2-0.337
Beam dimensions	X: 200 μm	X: 16.7 μm	X: 1.4 μm	X: 543 nm
	Y: 2.5 μm	Y: 16.7 μm	Y: 0.7 μm	Y: 5.7 nm
	Z: 1.0 cm	Z: 7.7 cm		Z: 300 μm
Particles per bunch ($x10^{10}$)	45	12	4	2
Bunches per ring	4 in trains <4	2808		2820-4000
Luminosity (10^{30} cm^{-2} s^{-1})	24-100	10000	3	20000
Radiation	-	~1 Grad/year	-	~20 krad/year

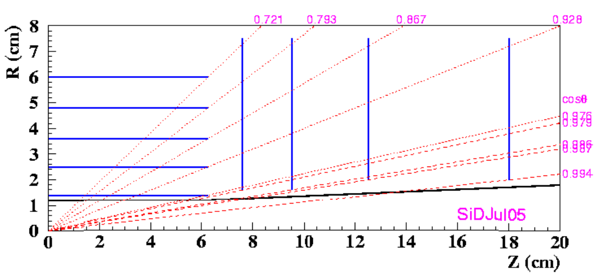
Detectores

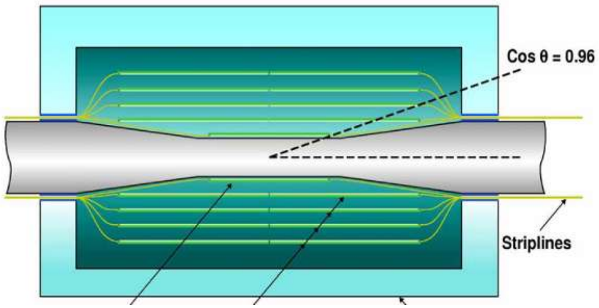
SiD	LDC	GLD
- small radius (1.3m)	- med. Radius (1.7m)	- large radius (2.1m)
- high B field (5T)	- med. B field (4T)	- low B field (3T)
- few track meas. points with high res. (Si)	- many track meas. points with med. res. (TPC)	- many track meas. points with med. res. (TPC)
- Si-W Calorimetry	- Si-W Calorimetry	- Sci.-W Calorimetry
- VTX: r_{min}=1.4 cm	- VTX: r_{min}=1.5 cm	- VTX: r_{min}=1.7 cm

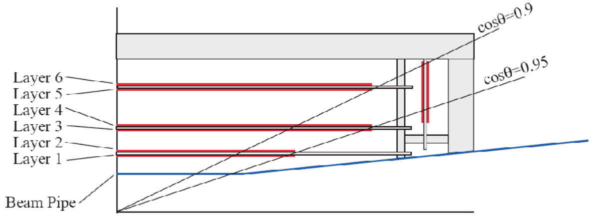












Requirements for the detector

The task of ILC is precision measurements

This means

- Reconstruct all available channels
- with the highest possible efficiency
- the lowest possible systematics
- insensitive to machine-related background

Because of the environment an ILC detector is often considered "easy"

However the extreme precision requirements make the detector pretty challenging

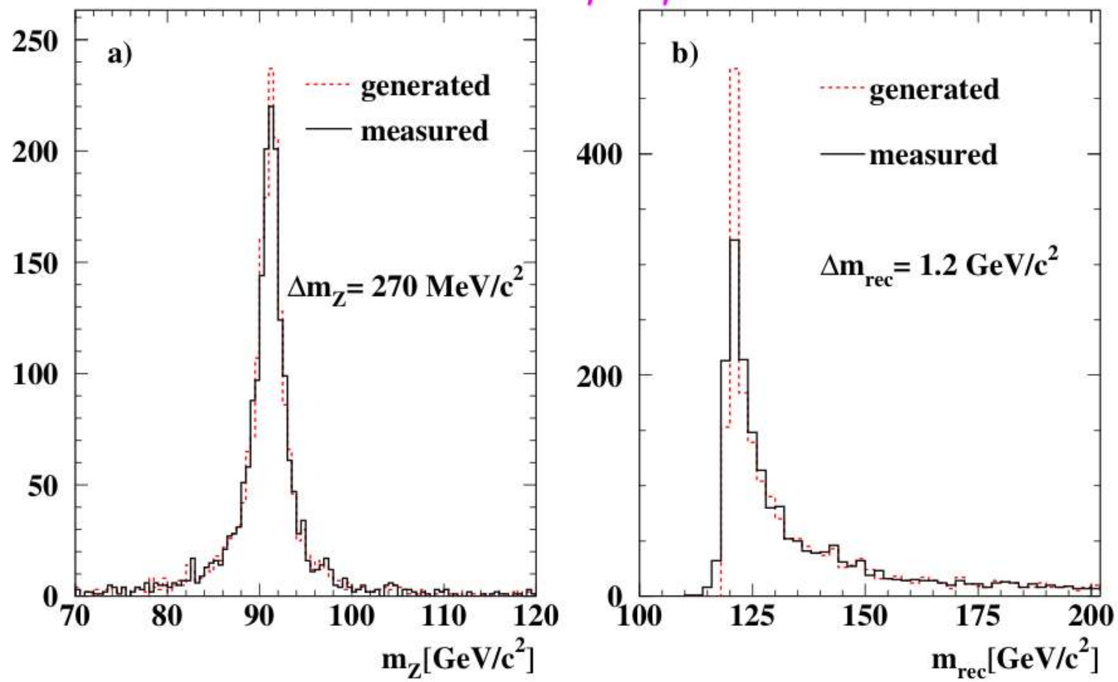
Benchmarks for the detector design

Momentum resolution

Want to reconstruct ZZH coupling from $e^+e^- \rightarrow ZH \rightarrow \mu^+\mu^- X$ using the $\mu^+\mu^-$ recoil mass

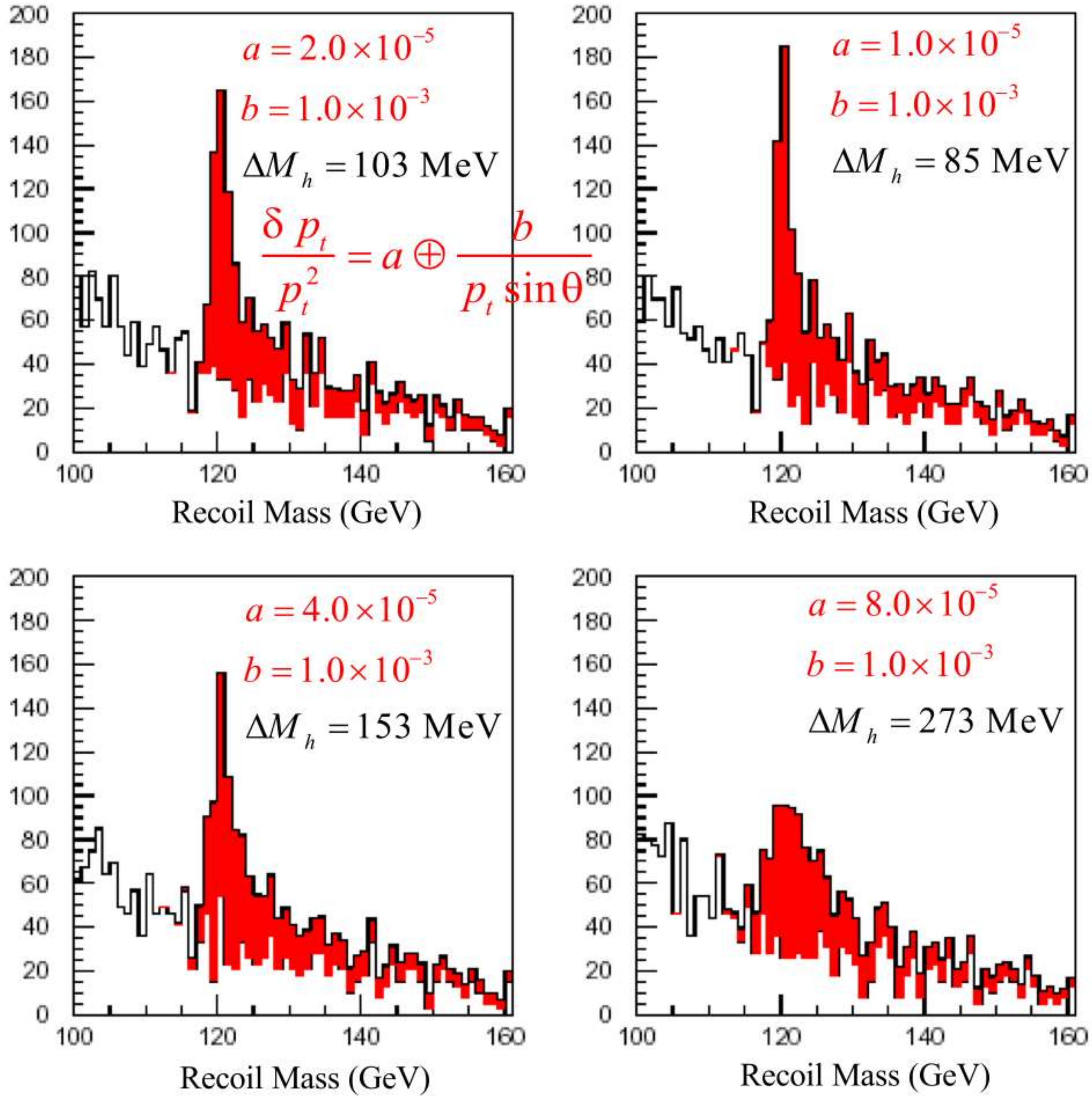
Need $\Delta\frac{1}{p} \approx 4 \cdot 10^{-5}/\,\mathrm{GeV}$ for large momenta

Generated and reconstructed $\mu^+\mu^-$ mass and recoil mass



Is a better momentum resolution useful?

- Even better momentum resolution can give sharper signals
- However effect on physics quantities (H mass after constrained fit, H branching ratios, SUSY masses) seems modest



Tracking - Comparación

a = stochastic term
b = multiple scattering term

Momentum resolution

$$\frac{\Delta p}{p} = a \times p \oplus b$$

$$\Delta \frac{1}{p} = a \oplus \frac{b}{p}$$

$$\Delta \frac{1}{p} \propto \frac{\delta}{R^2 B \sqrt{n}}$$

	DELPHI	CMS	ILC
a $(\mathrm{GeV}/c)^{-1}$	$0.6 \cdot x \cdot 10^{-3}$	0.15×10^{-3}	5×10^{-5}
b	-	0.005	-

Impact parameter

$$\sigma^{IP}_{R\phi} = \frac{\alpha_{MS}}{p \sin^{3/2}\theta} \oplus \sigma^{0}_{R\phi}$$

$$\sigma^{IP}_{z} = \frac{\alpha'_{MS}}{p \sin^{5/2}\theta} \oplus \sigma^{0}_{z}$$

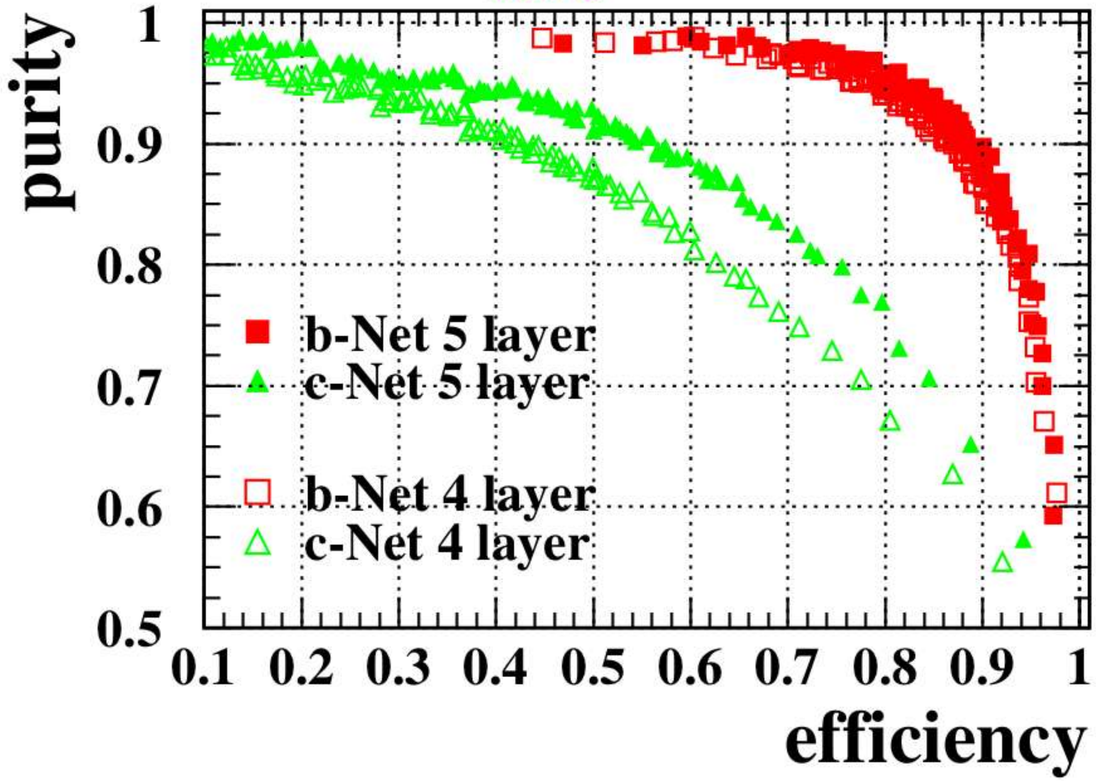
$$\sigma^{IP} \propto \sqrt{X}\, r$$

	DELPHI	CMS	ILC
α_{MS} (μm GeV/c)	65	80	10
$\sigma_{R\Phi}$ (μm)	20	9	5
α'_{MS} (μm GeV/c)	71-151	200	
σ_z (μm)	39-96	10	

B-tagging

- Want to measure $BR(H \to \mathrm{c\bar{c}})$ which is $< 10\%$ of $BR(H \to \mathrm{b\bar{b}})$
- Have to tag 4-b final states ($\mathrm{e^+e^-} \to ZHH$, $\mathrm{e^+e^-} \to \mathrm{t\bar{t}}H$ under huge non-b and 2-b background

Efficiency/purity for the b-tagging in the LDC



- b-tagging quite robust, but remember

$$\epsilon_{\mathrm{tot}} \propto \epsilon_b^4$$

- c-tagging very sensitive to detector quality

B-tagging

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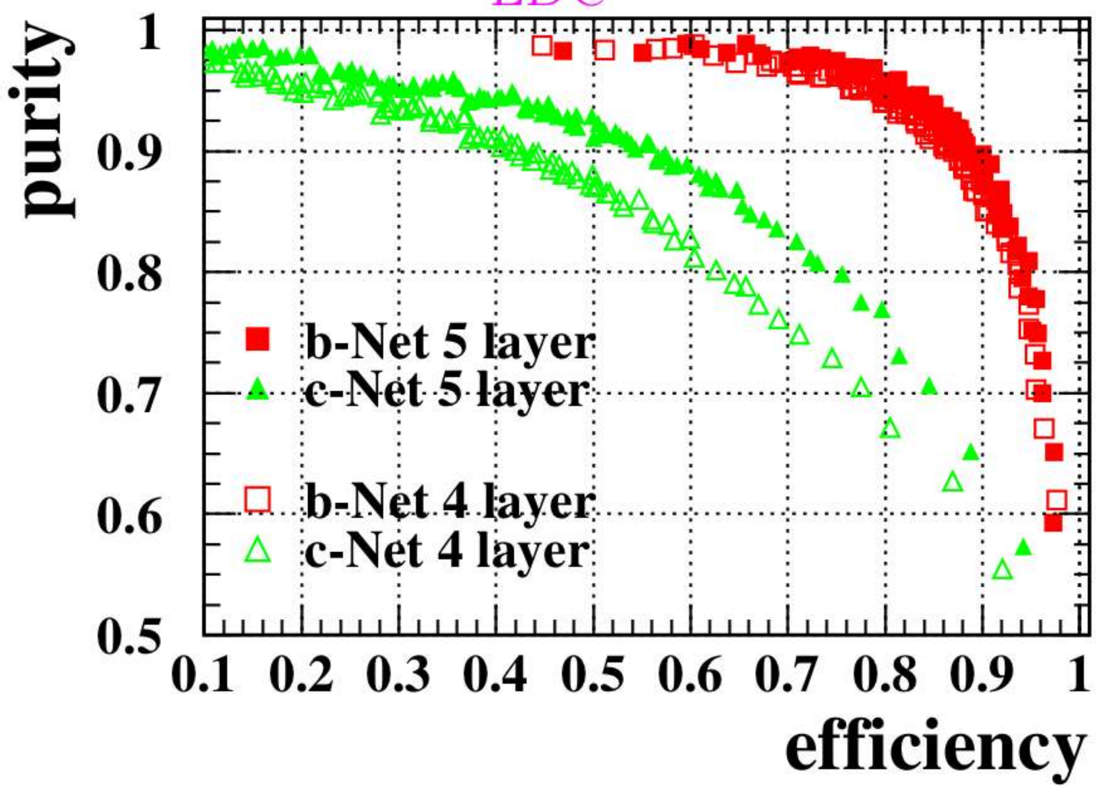
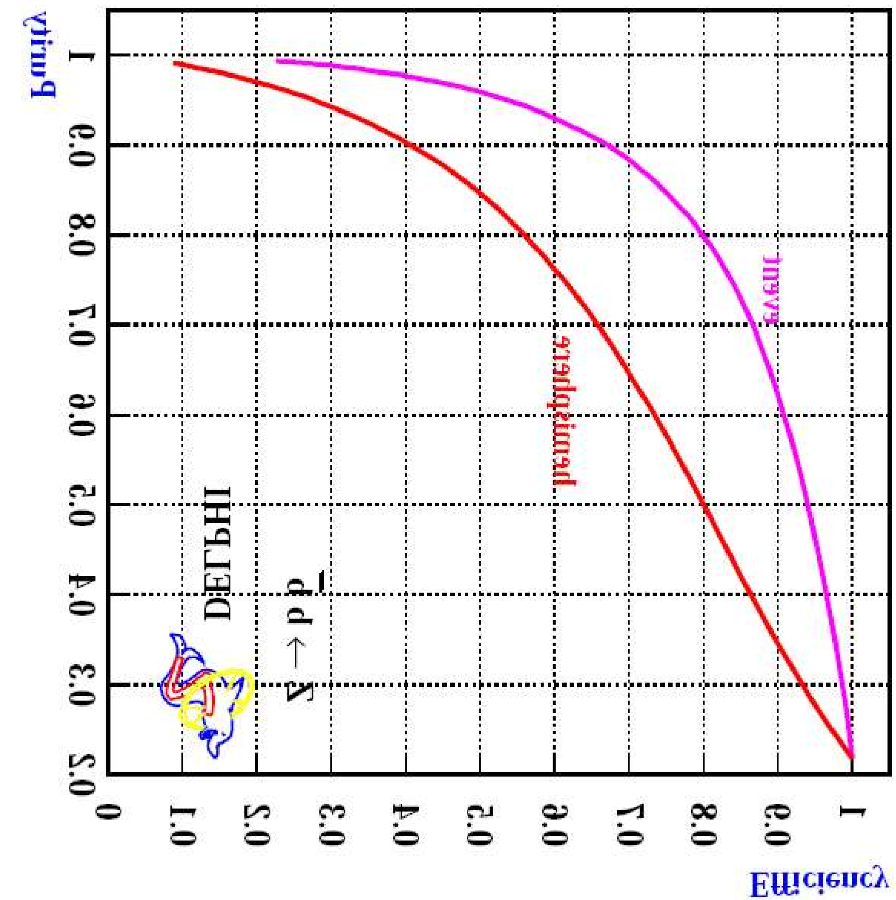




The golden mode is very interesting , in particular because It is independant from the Higgs decays,
(mode invisible en LSP par exemple)

But statistically, there more interest in ...

The jets

Start from physics ,
Not from a technology

processes at ILC

Multi bosons	Multifermions + Boson(s)
ZH	e^+e^- H , e+e− Z
WW	$\nu\nu$ H , $\nu\nu$ Z
ZZ	ttH
ZHH	e ν W
ZZZ	$\nu\nu$ WW, $\nu\nu$ ZZ
ZWW	ttbar

Etc … but also the taus decays reconstruction for SUSY, CP… etc

Bosons Tagging

Z to	BR
$\ell^+ \ell^-$	10%
qq (jets)	70%

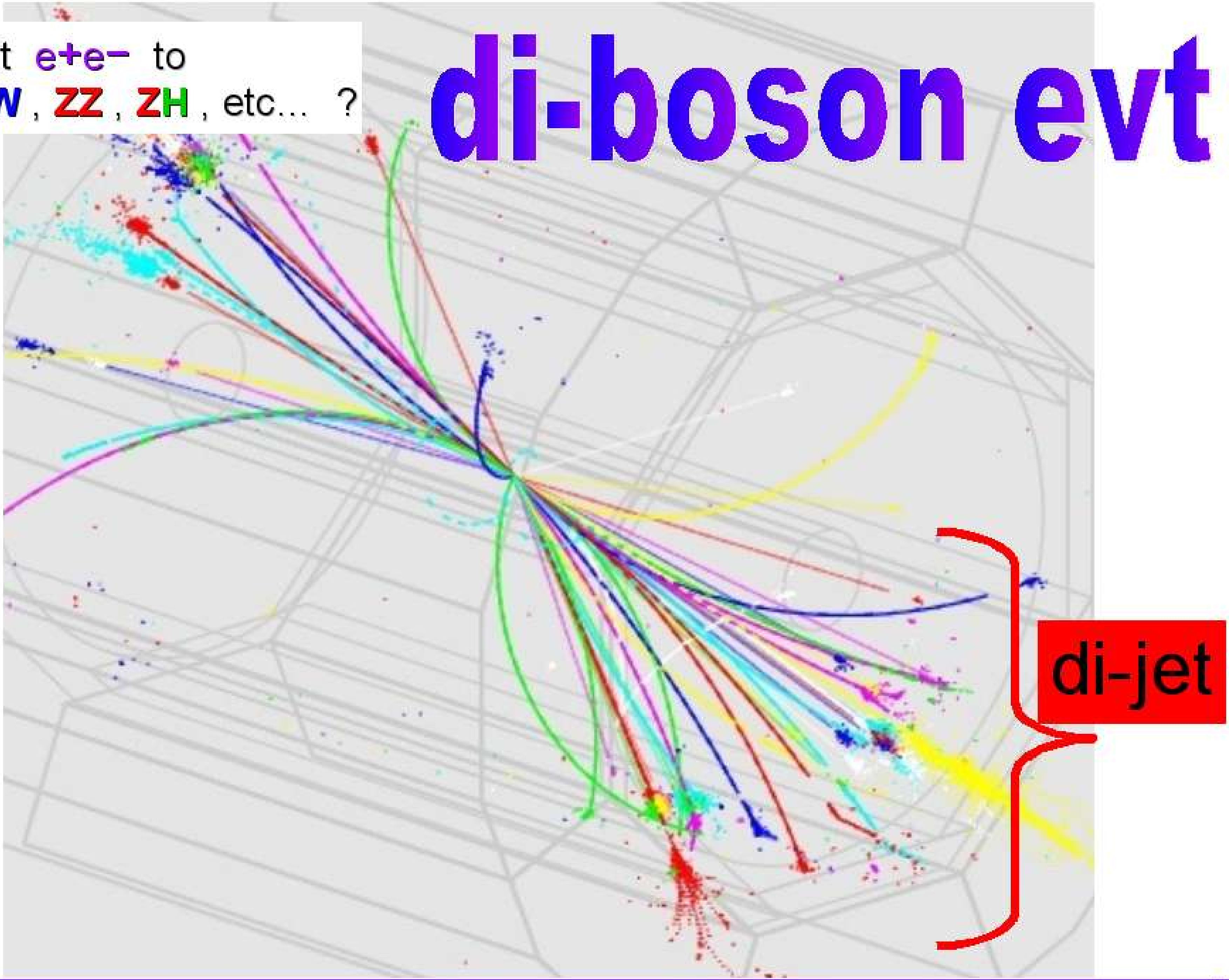
W to	BR
$\ell^\pm \nu$	32%
qq' (jets)	68%

H(120,SM) to	BR
$\ell^+ \ell^-$	<15%
qq(jets) ,WW,ZZ	>85%

In order to **use** all the produced events (the luminosity of the machine)
It is needed to tag the bosons **W,Z,H in their decays to jets**

Is it e+e− to
WW , ZZ , ZH , etc… ?

di-boson evt



Is it

ww

evt

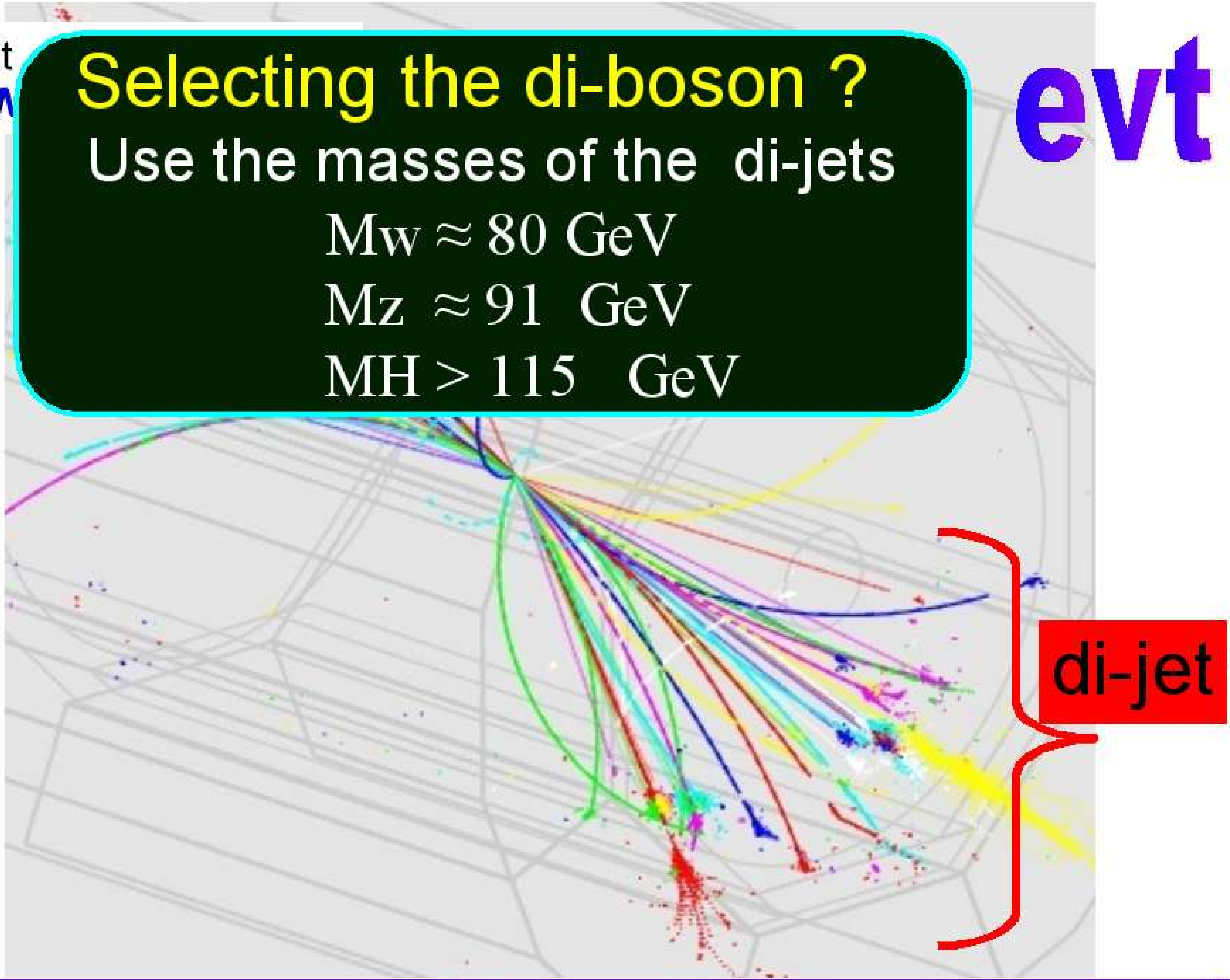
Selecting the di-boson ?

Use the masses of the di-jets

$M_W \approx 80$ GeV

$M_Z \approx 91$ GeV

$M_H > 115$ GeV



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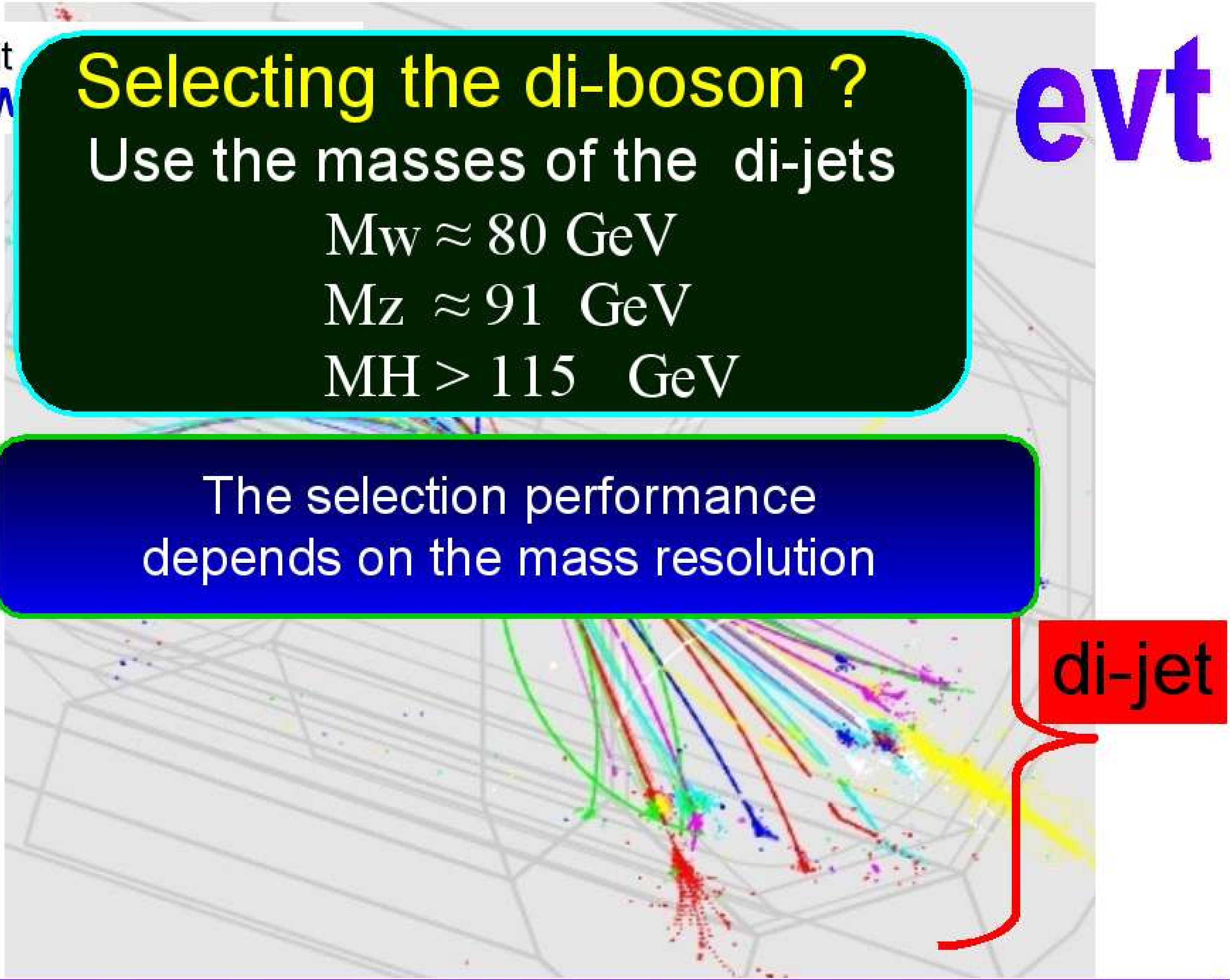

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jet

<u>The only known method</u>

Reconstruct individually

ALL the final state particles

Sort of modern bubble chamber

Particle Flow

Particle flow is the common paradigm of the 1st three concepts

How to measure the energy of a jet?

- Classical method: Calorimetry
  - typical event: 30% electromagnetic and 70% hadronic energy
  - typical resolution: $10\%/\sqrt{E}$ for Ecal and $50\%/\sqrt{E}$ for Hcal

  ➠ $\Delta E/E > 45\%/\sqrt{E}$ for jets
- The particle flow method
  - typical event: 60% charged tracks 30% electromagnetic and 10% neutral hadronic energy
  - tracking resolution negligible on this scale

  ➠ $\Delta E/E = 20\%/\sqrt{E}$ for jets possible in principle

WHY

The « Particle Flow » method

In our detectors, the charged tracks are better measured than photon(s) which are themselves better measured than neutral hadron(s)

Resolution on the charged track(s)	$\Delta p/p$	~ qq 10^{-5}
Resolution on the photon(s)	$\Delta E/E$	~ 12%
Resolution on the h°	$\Delta E/E$	~ 45%

$E_{jet} = E_{charged\ tracks} + E_{\gamma} + E_{h^0}$

	$E_{charged\ tracks}$	E_{γ}	E_{h^0}
fraction	65%	26%	9%

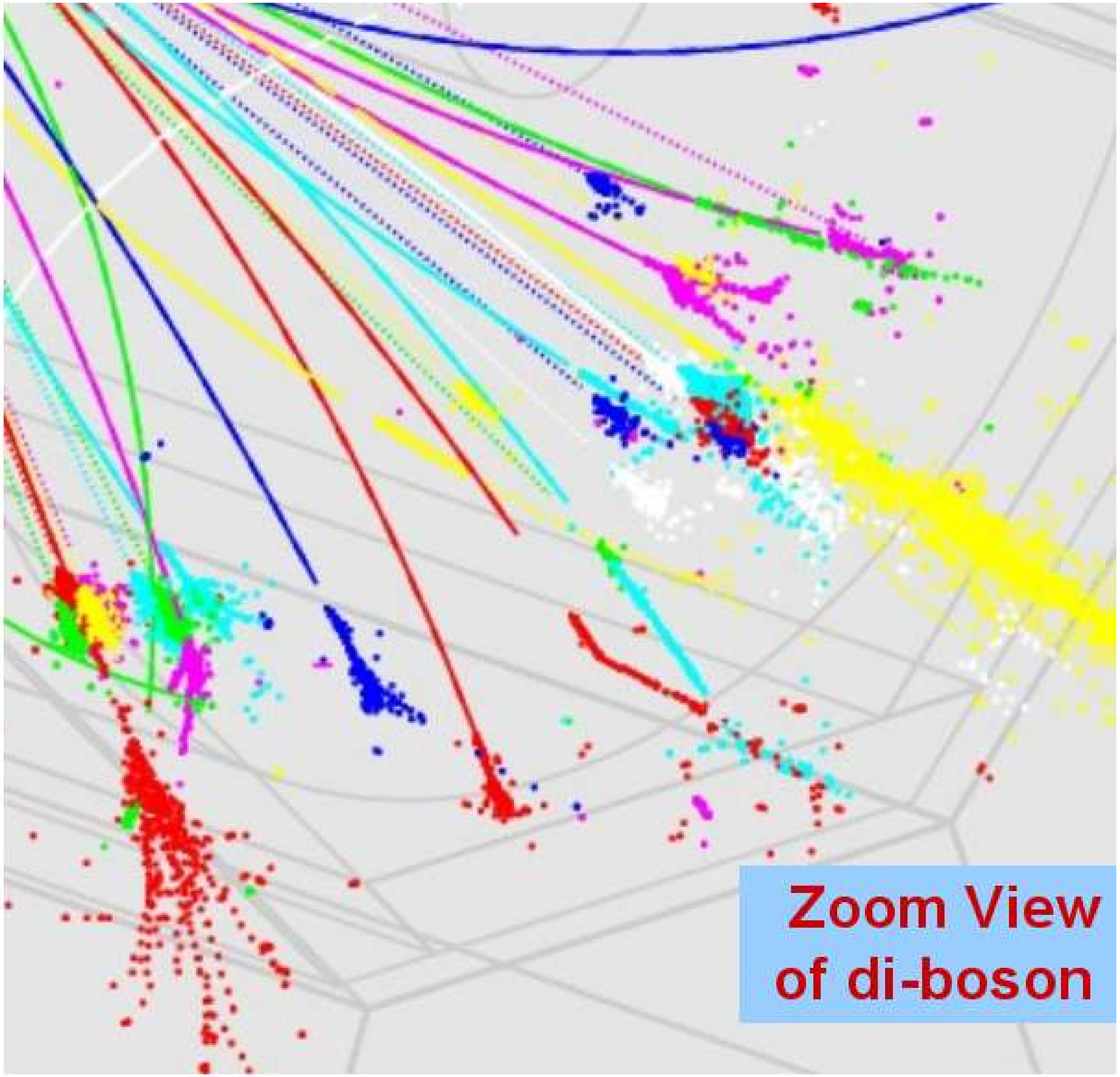
With a perfect detector, no confusion between species and individual reconstruction

$\sigma^2\,\mathrm{jet} = \sigma^2\mathrm{ch.} + \sigma^2\,\gamma + \sigma^2\,h^0$ gives about $(0.14)^2\,E_{jet}$

Real life and real detector →

- σ^2threshold → Energy threshold to be rec. (depend on species)
- σ^2efficiency → loss of particles (not reconstructed)
- σ^2confusion → Mixing between particles in the calorimeter

HOW



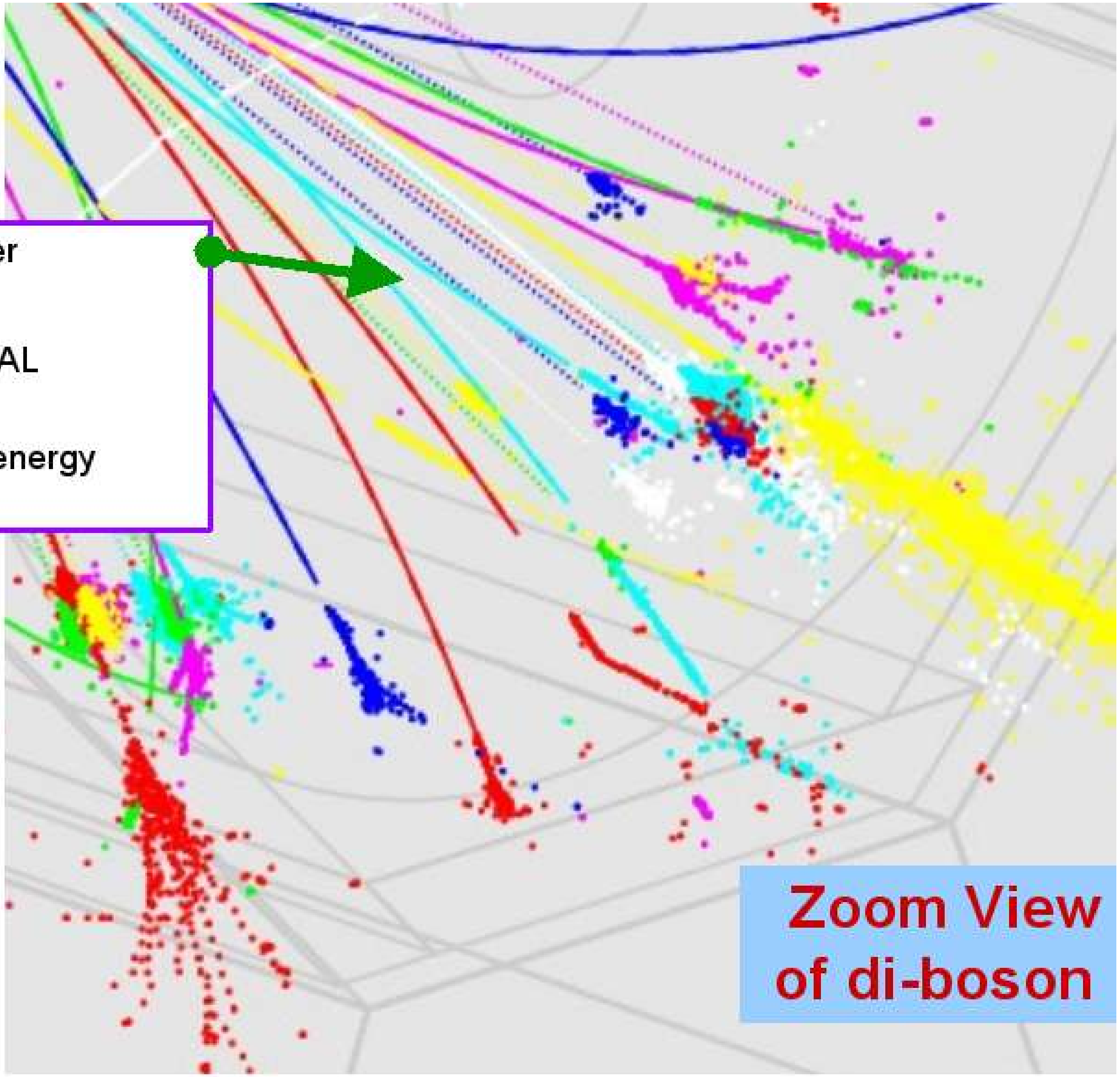
HOW

❶ find the charged particles in the tracker

❷ the photon(s) in the ECAL

❸ the neutral hadron(s) in the ECAL, HCAL

Process ❷ and ❸ are possible only
if there is no mixing between deposited energy
from different particles



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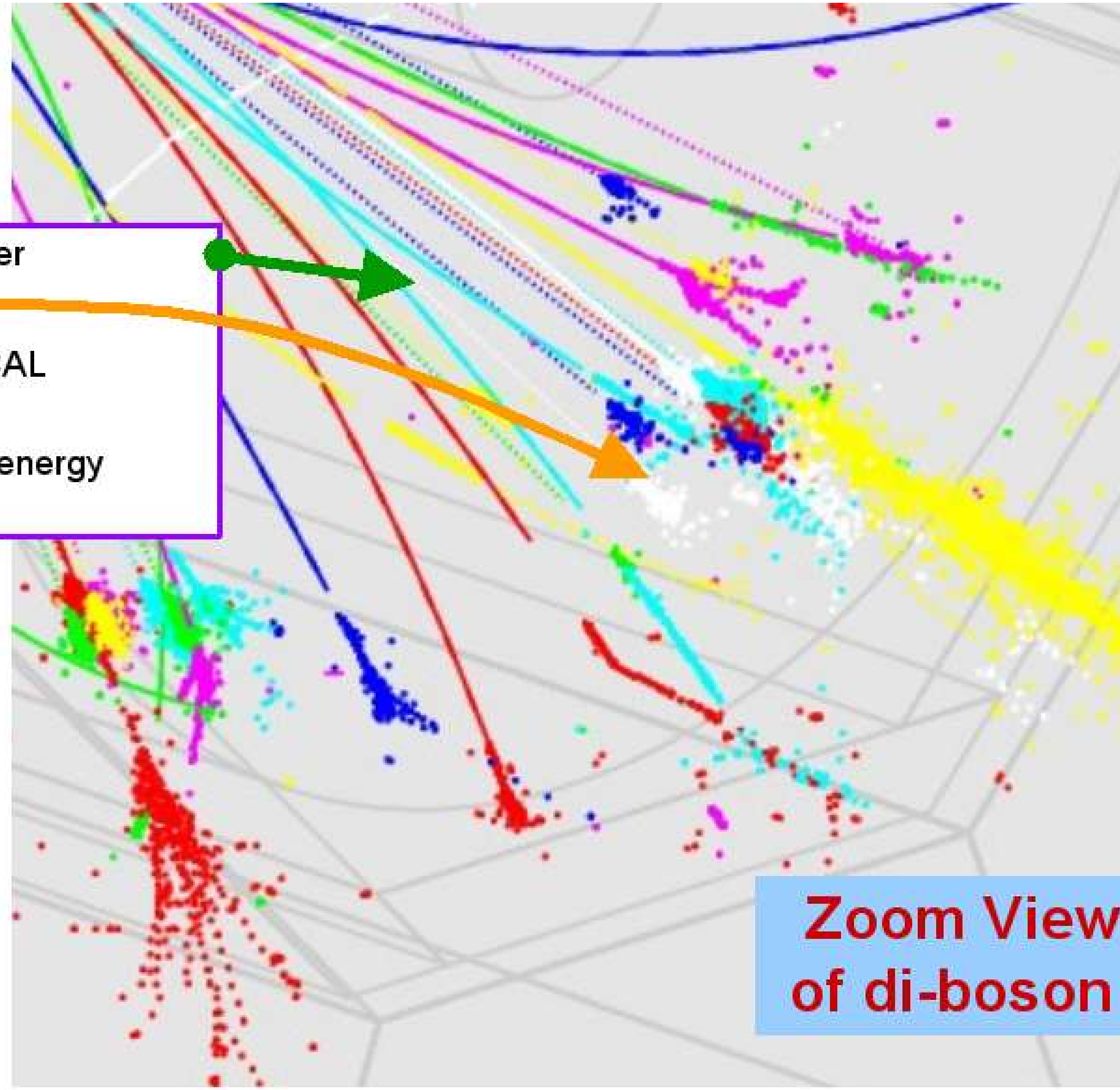

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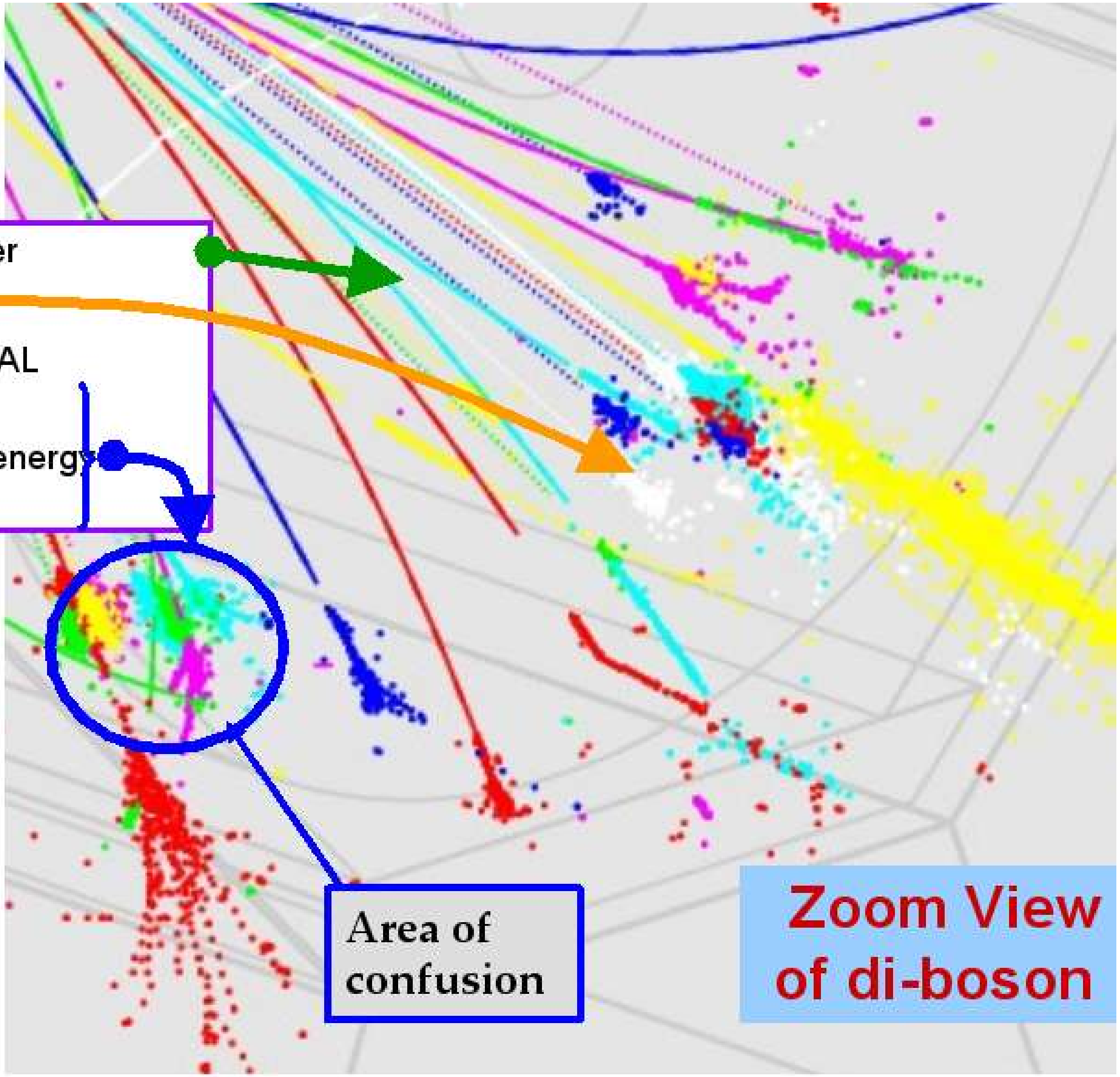

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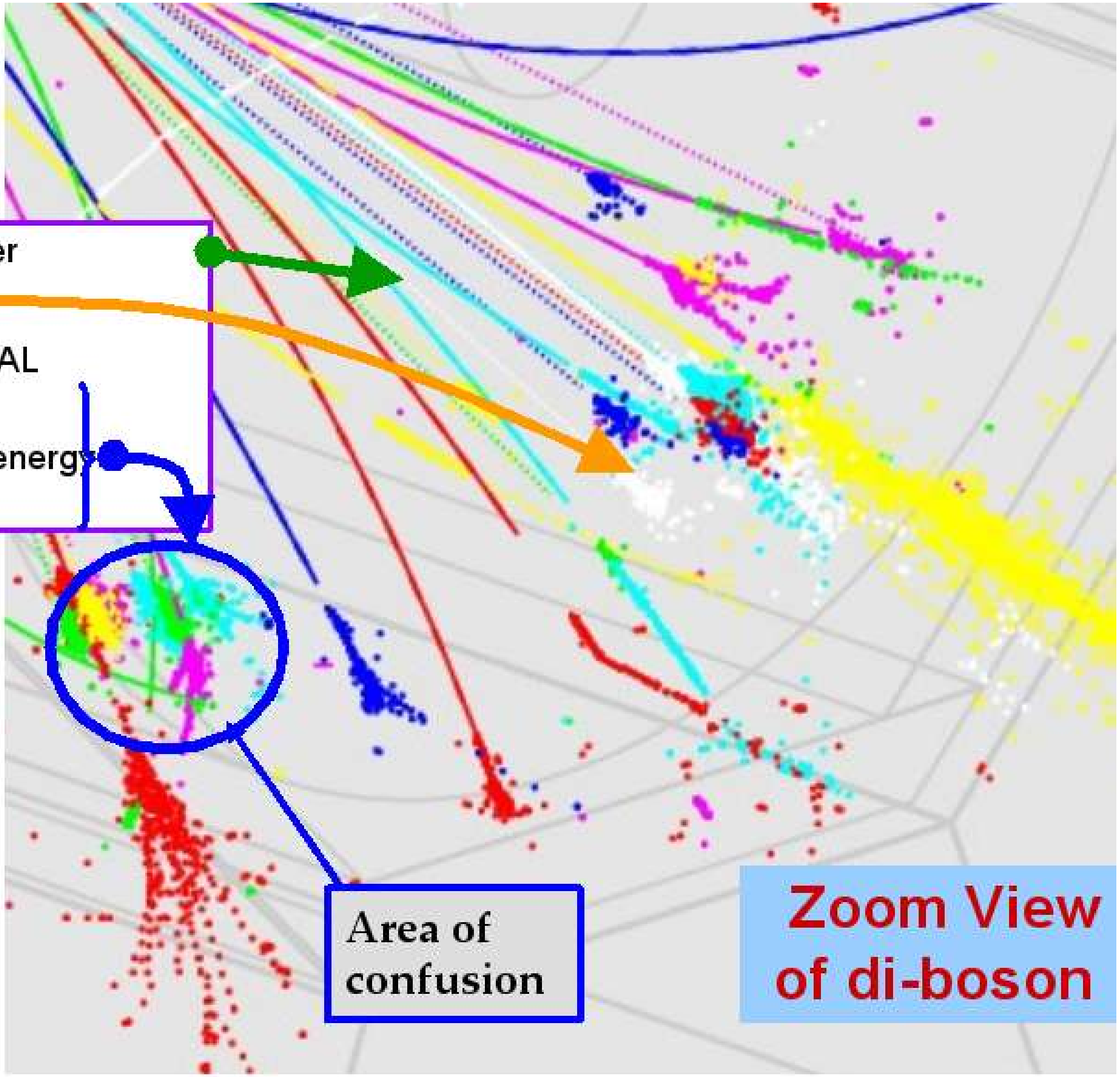
Associate the deposited energy With the depositing particle



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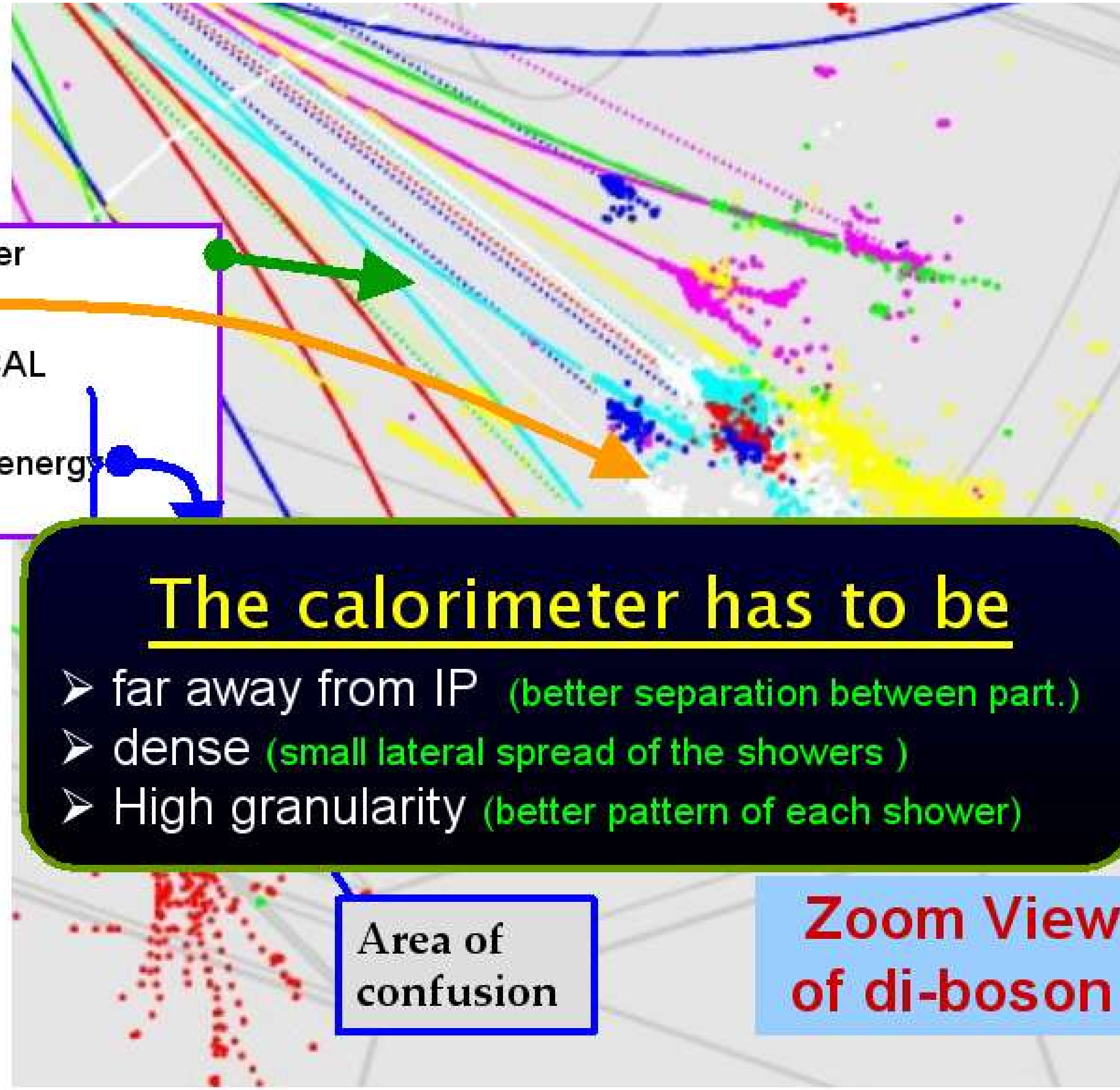

The calorimeter has to be

- far away from IP (better separation between part.)
- dense (small lateral spread of the showers)
- High granularity (better pattern of each shower)

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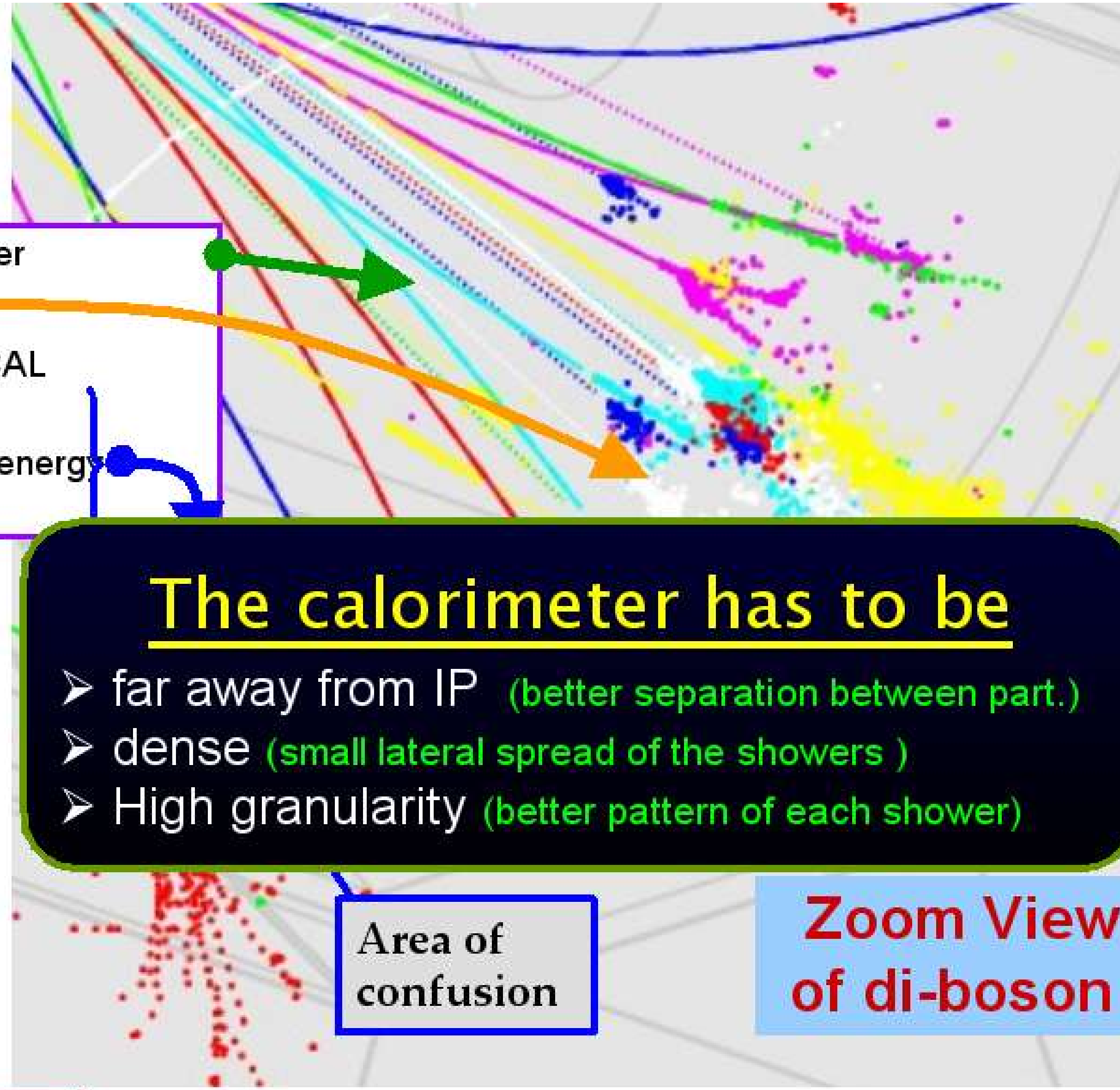

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Quality of the «photo»

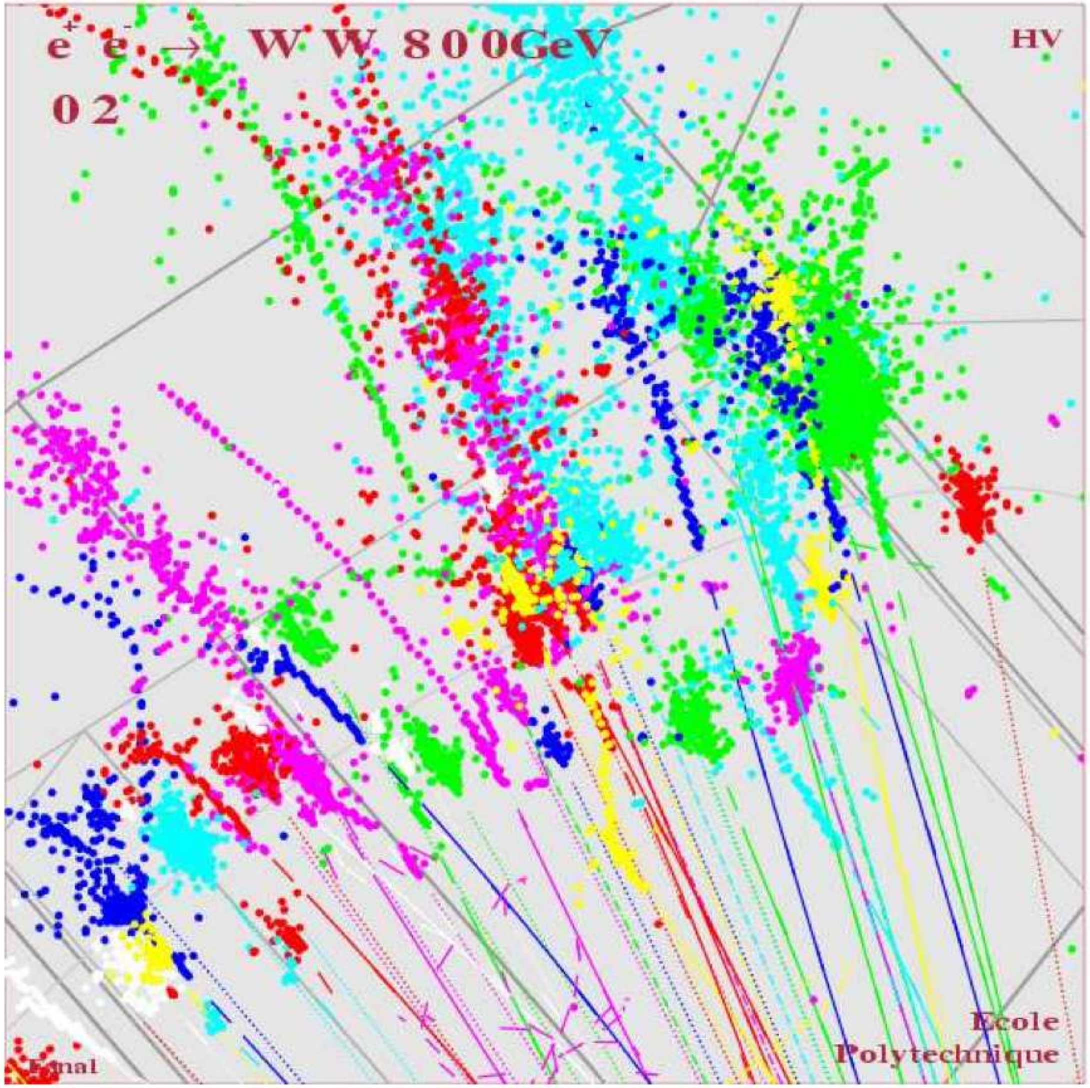
- **Détector readout in 3D**
- **Small pixel size**
- **ECAL AND HCAL inside the coil**

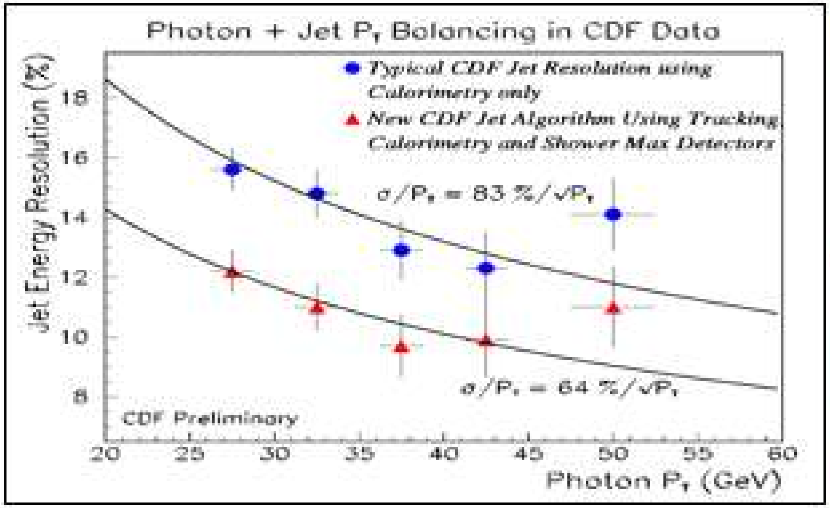
Main problem: Confusion

- At high energy jets are very narrow

➠ Tracks are very close at the calorimeter

- Need very fine granularity of calorimeter and sophisticated software to separate showers
- Energy resolution still dominated by confusion term



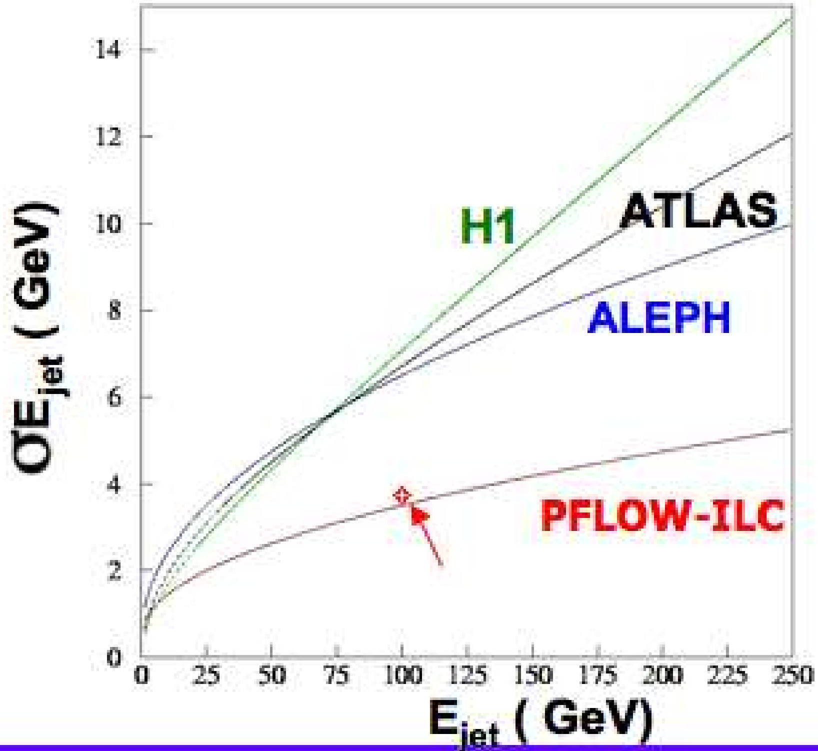


Recent improvement using PFLOW in CDF

WARNING
The stochastic term is not the only parameter

complete law

$$\Delta E_J = a \times \sqrt{E_J} \oplus b \times E_J + c$$



	a	b	c (GeV)
ALEPH method QPFLOW	0.59	0	0.6
ATLAS	0.6	0.03	0
H1	0.5	0.05	0
PFLOW-ILC	0.3	0	0.5

Needed to fulfill the ILC physics program

AND the Angular Dependence !!

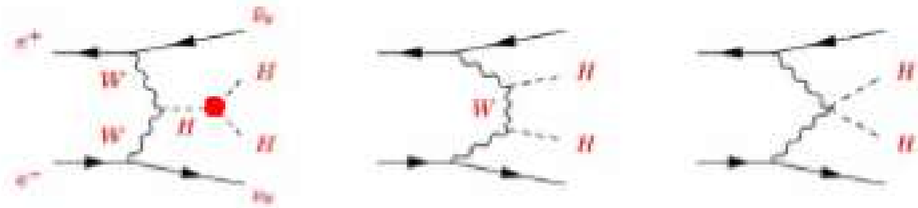
* NIM A360 (1994),480

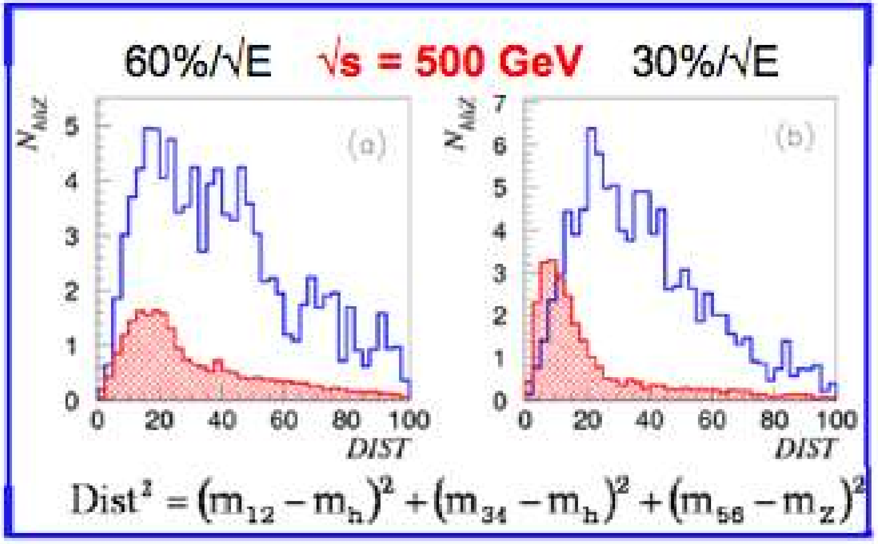
Physics versus performance on the jets

Example 1 **ZHH (Higgs Selfcoupling)**
Observation possible (signal at **5σ**) **only for** **a=0.3**

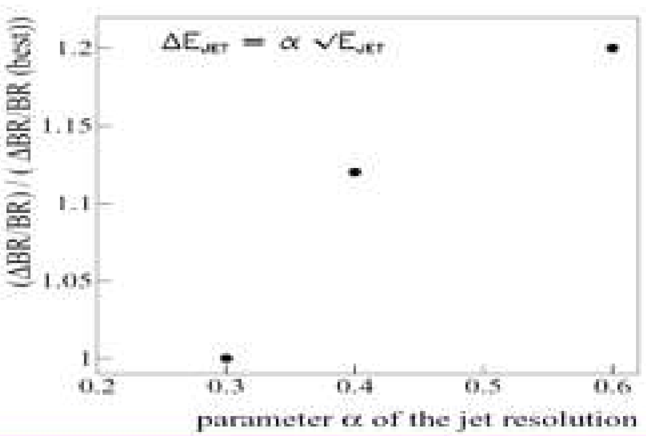
double Higgs-strahlung: $e^+e^- \rightarrow Zhh$

WW **double-Higgs fusion:** $e^+e^- \rightarrow \bar{\nu}_e \nu_e hh$



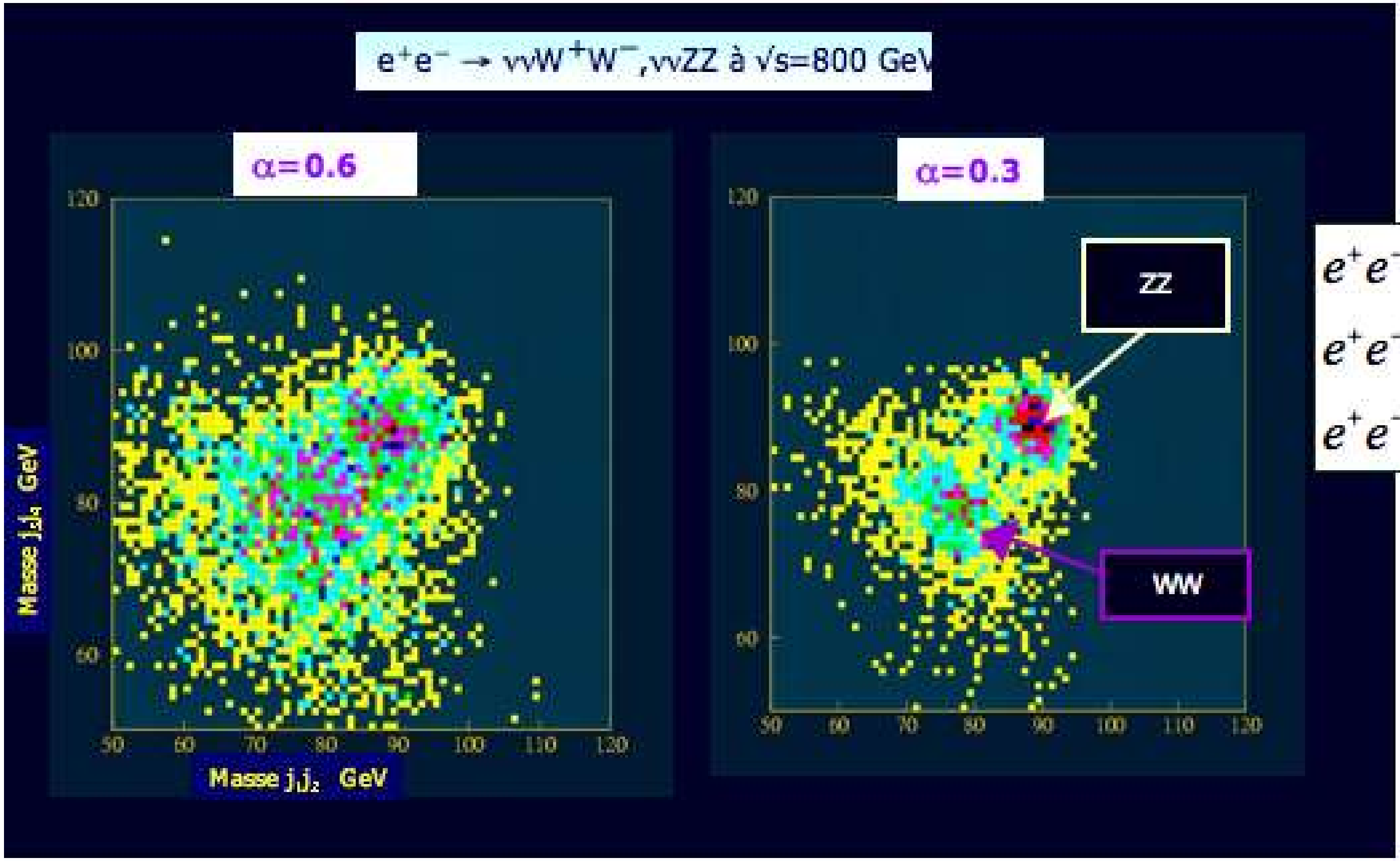


Example 2 **Higgs branching fraction (H →WW)**
Going from **a=0.3** to **a=0.6** is equivalent to
a loss of 45% of the luminosity (running time)



Physics versus performance on the jets

Example 3 **Longitudinal W_L coupling, Coupling in SuSy, etc…**
($e^+e^- \to \nu\nu WW$, $\nu\nu ZZ$, *séparation WW/ZZ*)
Going from **a=0.3** to **a=0.6** is equivalent to a loss of 45% of the luminosity (running time)



$$e^+e^- \to \nu\nu W^+W^-\ ,\ \nu\nu ZZ$$
$$e^+e^- \to \chi_1^+\chi_1^- \to \chi_1^0\chi_1^0 W^+W^-$$
$$e^+e^- \to \chi_2^0\chi_2^0 \to \chi_1^0\chi_1^0 ZZ$$

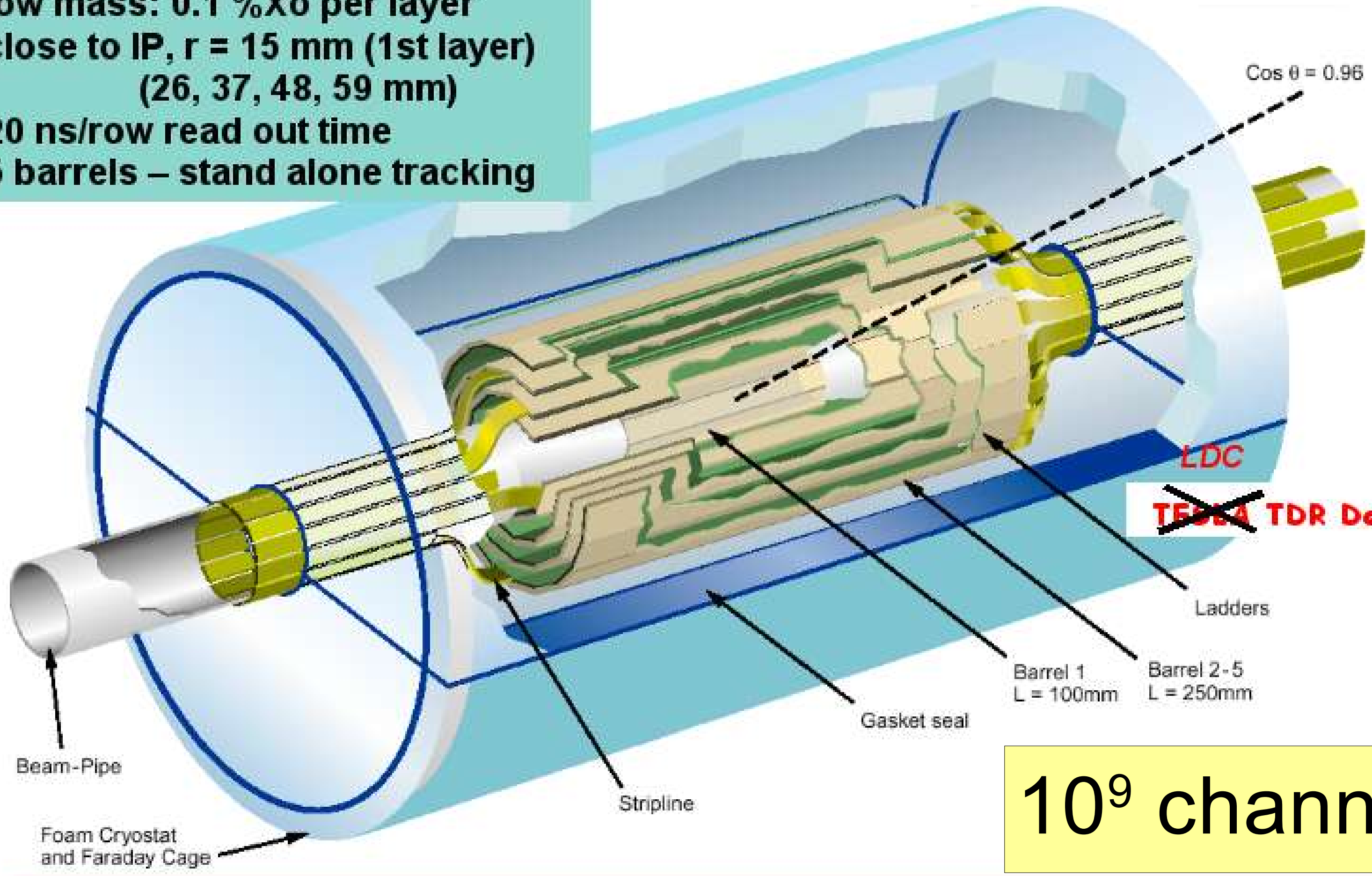
Los detectores

- Detector de vértices (Pixel y/o CCD)
  - DEPFET (MPI)
  - MAPS (Strasbourg)
  - CCD (Liverpool,Manchester)
  - Microstrips (Paris VI)
- TPC – Ninguna presentación en el meeting (Orsay)
- Calorimetría (Calice, LLR)
- Electrónica
  - Desarrollo de preamplificadores

H.-G. Moser
Max-Planck-Institut for Physics, Munich

Pixel Vertex Detector at the ILC

- pixel size: 20-30 µm
- low mass: 0.1 %Xo per layer
- close to IP, r = 15 mm (1st layer)
  (26, 37, 48, 59 mm)
- 20 ns/row read out time
- 5 barrels – stand alone tracking



10^9 channels

1st layer module: 100x13 mm², 2nd-5th layer : 125x22 mm² → Σ120 modules

Several Sensor Concepts: CCDs, MAPs, SOI, DEPFETs

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GANDÍA,
1 al 3 de Diciembre 2005

The DEPFET active pixel sensor

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Max-Planck-Institut for Physics, Munich

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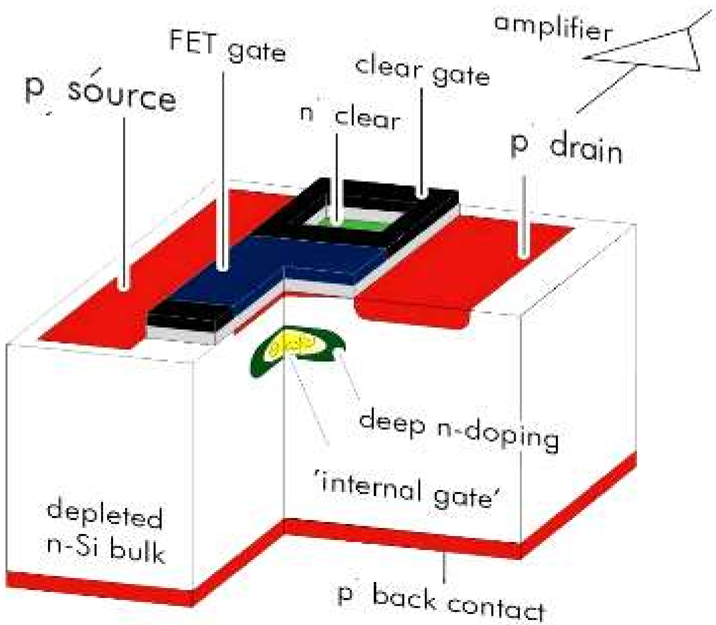
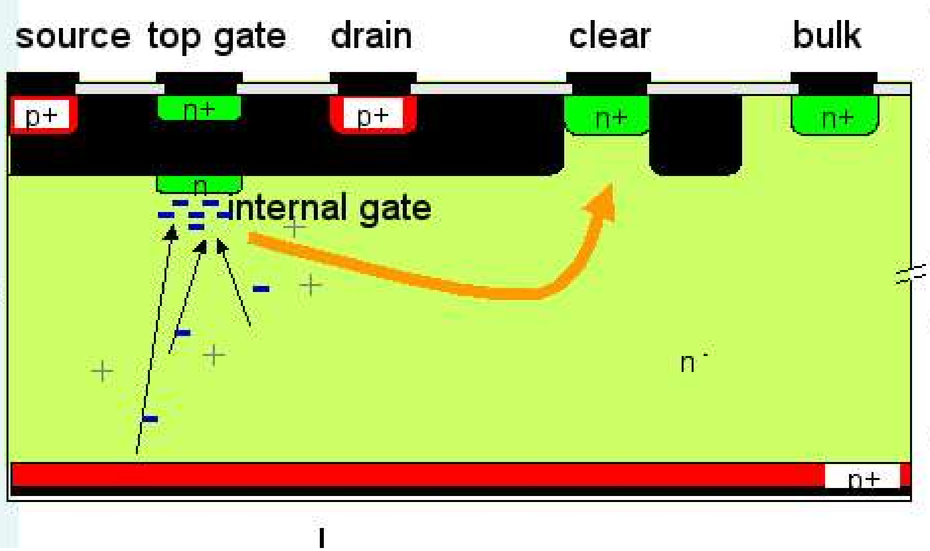
GANDÍA,
1 al 3 de Diciembre 2005





Depleted Field EffectTransistor

- Charge generated in fully depleted bulk
- Fast charge collection by drift underneath the transistor channel
- Modulates the transistor current (400 pA/e for ILC layout)
- Combined function of sensor and amplifier
- Low capacitance and low noise (10-20 fC)
- Signal charge remains undisturbed by readout
- Internal storage
- Complete clearing of signal charge
- No reset noise

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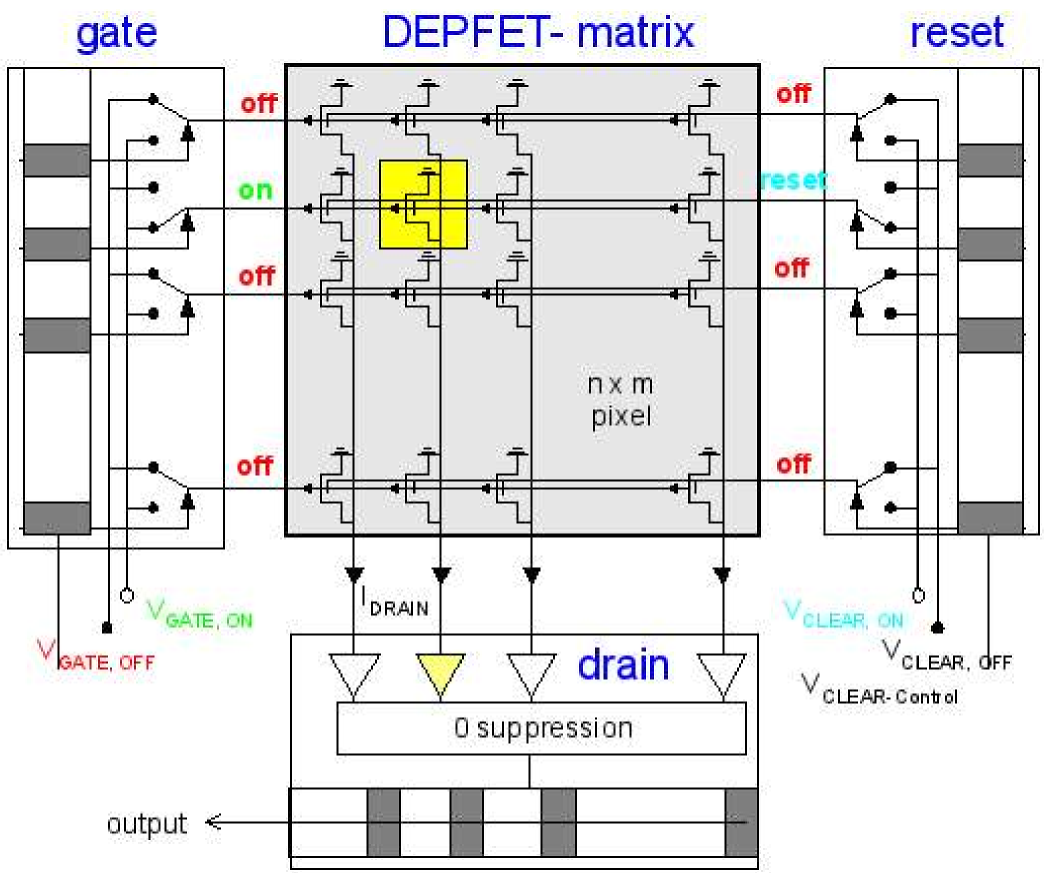
Munich

Matrix operation



- Charge collection in "OFF" state of the transistor
- Select one row via external gates and measure pedestal + signal current
- Reset that row and measure pedestal currents …..

Only one single row active at a time and dissipating power
However, sensor is sensitive even if DEPFET is OFF!

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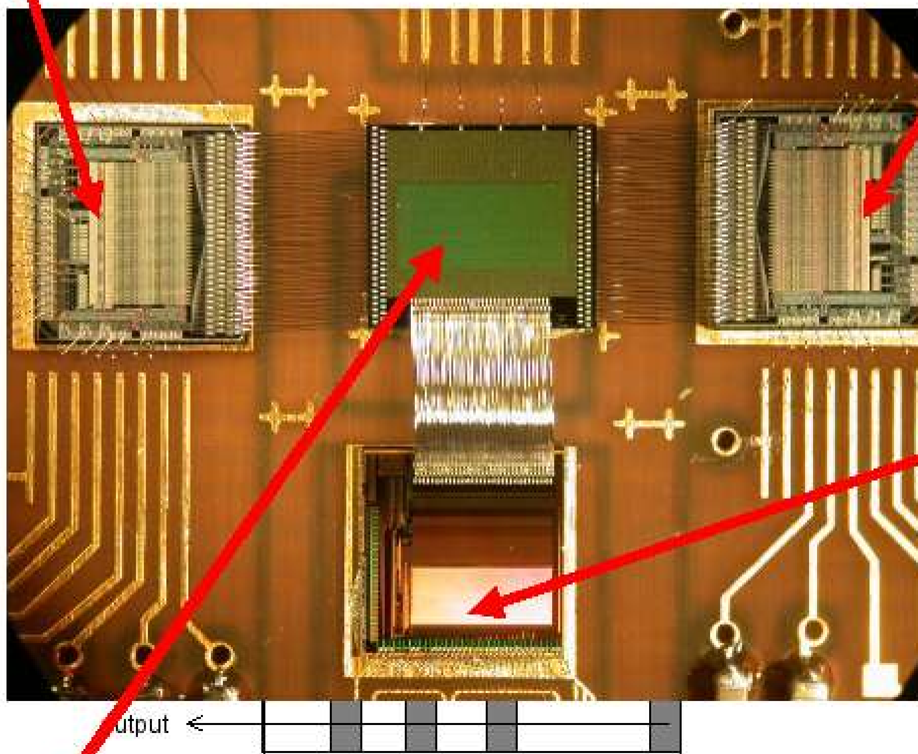
DEPFET Matrix Test System

Switcher I: selects rows for readout (switch external gate)

Switcher II: clears rows



Curo II readout chip
128 channel current amplifier for column readout
Internal pipeline & 0-suppression

DEPFET matrix
64x128 pixels
28.5x36 μm^2

PXD4 - DEPFET: Two projects on one wafer

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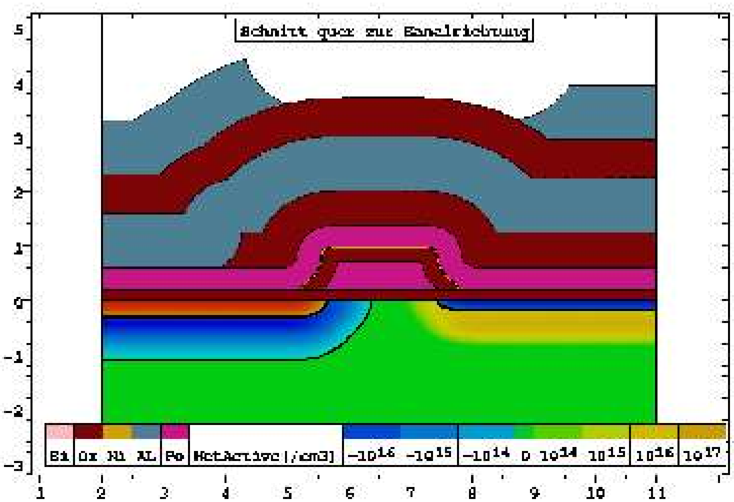
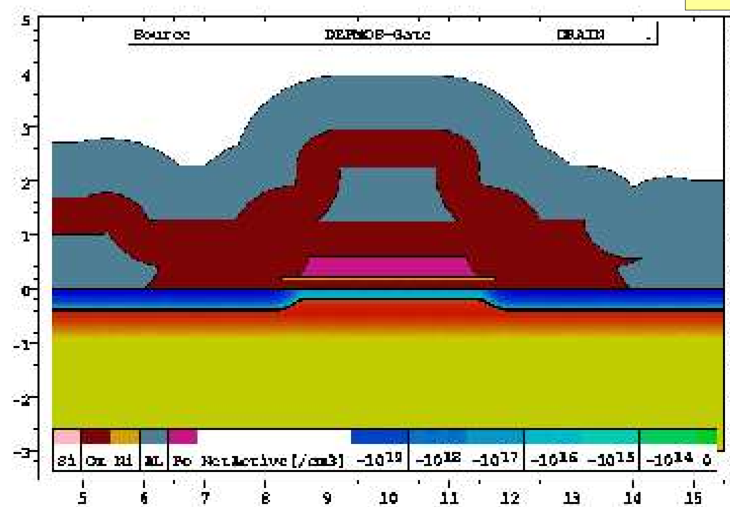
Max-Planck-Institut for Physics, Munich

	ILC	XEUS	DES Infrared photometry
purpose	particle tracking	imaging X-ray spectroscopy	
sensor size	1.3 x 10 cm², 2.2 x 12.5 cm²	7.68 x 7.68 cm²	~3.0x6.0 cm²
pixel size	25 µm	75 µm	15 µm
sensor thickness	50 µm	300 ... 500 µm	250 µm
noise	~ 100 el. ENC	4 el. ENC	7 el ENC
Readout time per row	20 ns	2.5 µs	17 s





Double metal, double poly process

Clustering

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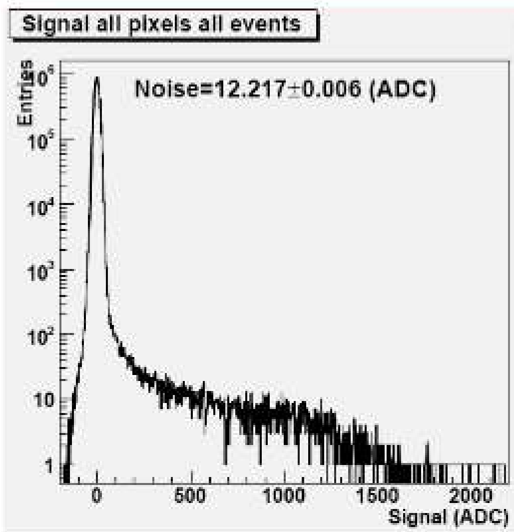
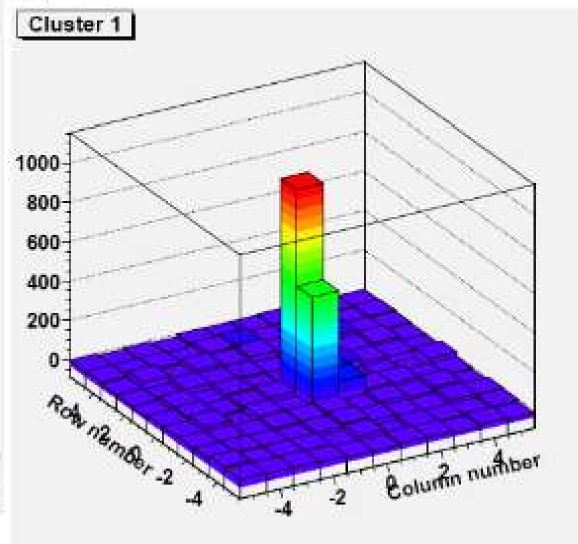
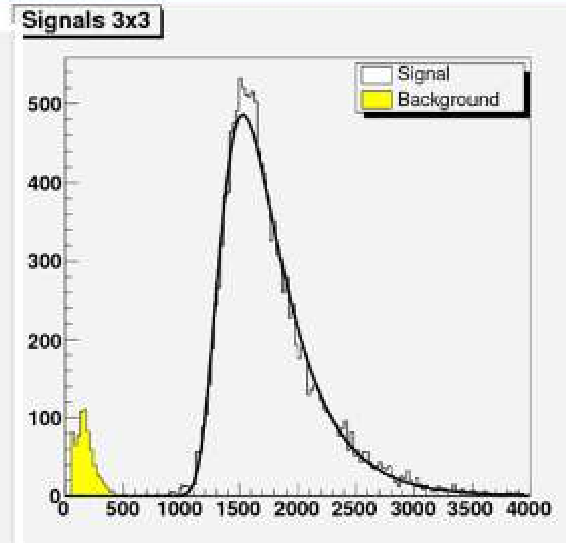
for Physic
Munich







Full 128 x 64 matrix
Noise: 258 e
Noise dominated by pickup:
Front end: 160 e

Look for clusters:
- Seed cut >5σ
- Neighbour cut >2σ
- Typical cluster size: 5-6 pixels

Combine signals seed & neighbours
Signal: 32500 e

→ S/N (3x3) = 126 (scaled to 50 μm detector: 14)

Module Concept & Material Budget

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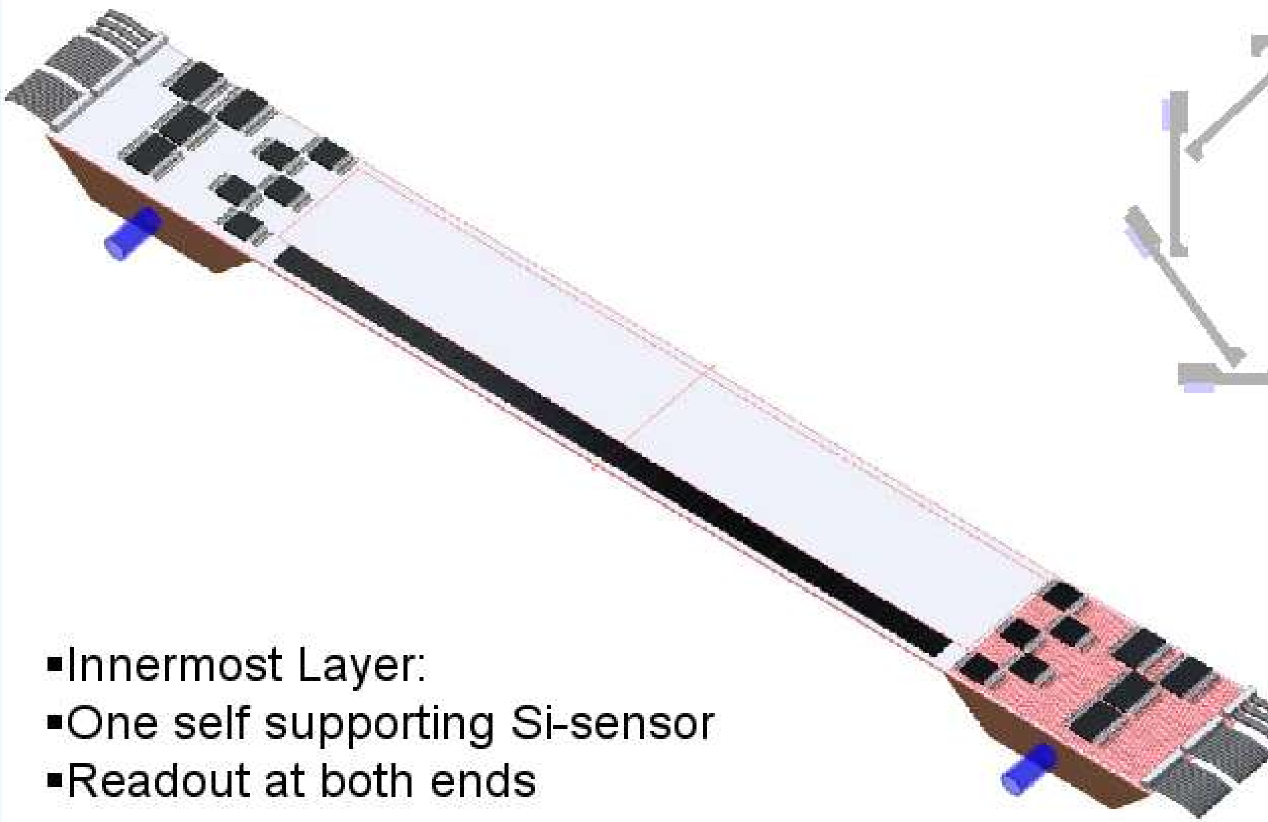

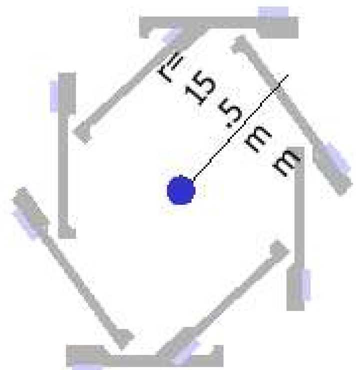

- Innermost Layer:
- One self supporting Si-sensor
- Readout at both ends
- Sensitive area thinned to 50 μm
- Support frame not thinned (300 μm)
- Thinned (50 μm) ASIC bump bonded

Material Budget

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Munich

Estimated Material Budget (1st layer):

Pixel area:	100x13 mm², 50 µm:	0.05% X_0
steer. chips:	100x2 mm², 50 µm:	0.008% X_0
(perforated) frame :	100x4 mm², 300 µm:	0.05% X_0
		0.11%X_0

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Alternatives/Competitors: MAPS

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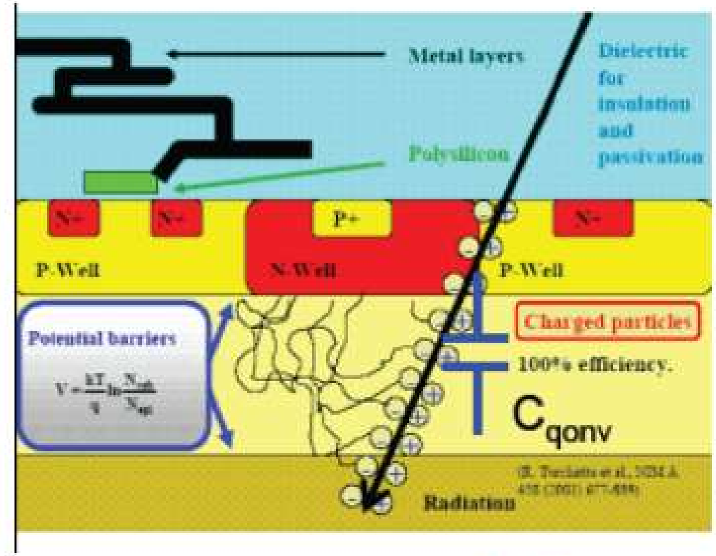
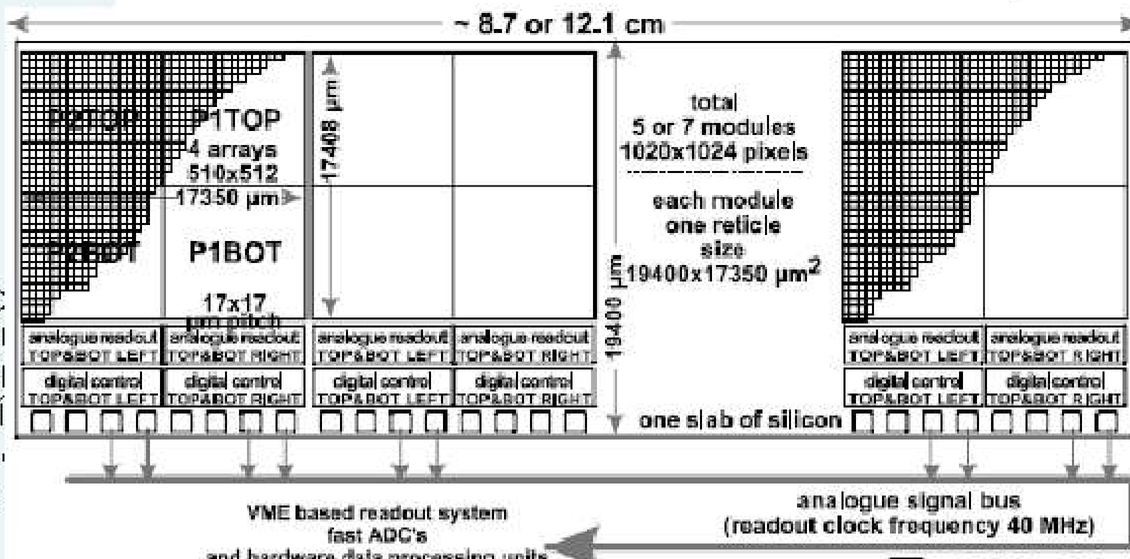
N-well used for signal collection
Only p-well possible for processing

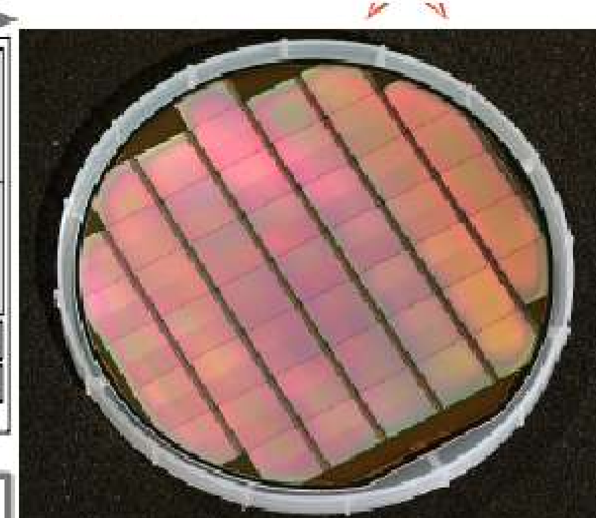
N- & p-well only in periphery

Successful prototypes
S/N: 20/1
Resolution < 2 μm
However: signal distributed over many pixels

Speed: not yet to LHC specs (inner layer)
Power: ?????







TRANSVERSE LADDER READOUT

Alternatives/Competitors: CCD

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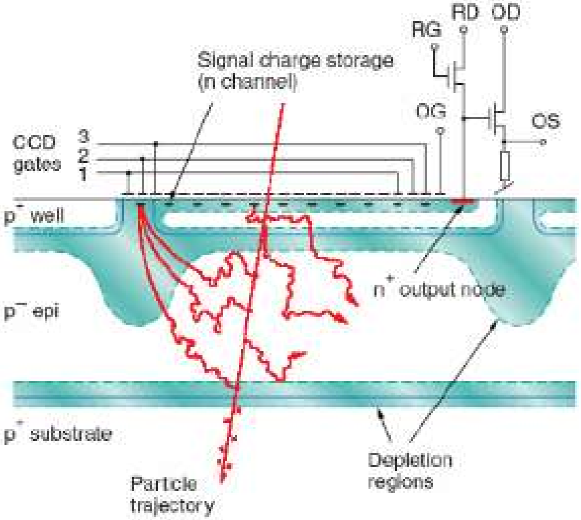
CCDs with double column parallel reaout
25 MHz with 1.9 V !!!
Noise: 60 e-

Radiation damage?
Wafer scale devices?

New concept: ISIS CCDs

In situ storage of ~ 20 “events”
Exists for high speed optical cameras

Immune to noise pickup from beam (SLD lession)



Why *whisper* just when an express train roars through the station?
(Chris Demerell)

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GANDÍA,
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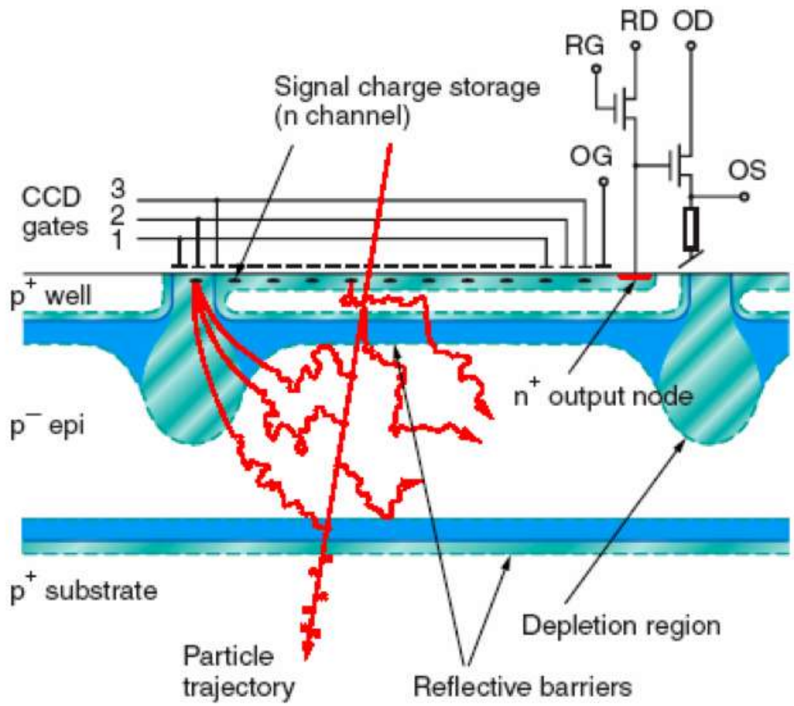
Sensors – ISIS

- In-situ Storage Image Sensor.



- Signal collected on photogate then transferred to CCD register in pixel 20 times during bunch train.
- Beam-related RF pickup is concern for all sensors converting charge to voltage during bunch train.
- ISIS eliminates this source of EMI:
- Readout in 200 ms quiet period between bunch trains.
- Column parallel readout at ~ 1 MHz sufficient to read out before arrival of next bunch train.
- Signal charge always buried in silicon until bunch train has passed.
- Approx. 100 times more radiation tolerant than CCDs.
- Easier to drive than CPCCD because of low clock frequency.

An (un)biased comparison

	Resolution 5μm	Material budget $\leq 0.1\%\ X_0$	r/o speed 50μs/frame	Power consumpt.	Rad. tolerance γ, n	Remarks
CP-CCD	4.2μm + + (expectation)	+ R&D, comp. Ladder	25MHz done + R&D	$V_{clk}\approx 2V$ + R&D	- (n) low T op.	rad. tolerance may be the limiting factor
CMOS MAPS	2μm +++ But at high speed?	+ R&D, comp. Ladder	R&D !	+	+ γ,n but with non std. techno.	large devices? d_{epi}?
SOI Sensors						
DEPFET	Like CCD + + (expectation)	+ R&D, all-silicon module	+ all comp. Ok, system test? R&D!	+ +	γ: + n: ?, but expect Ok!	no show stoppers so far.... ☺
HAPS (ATLAS&CMS)	7μm (-)	- -	+ +	- -	+ +	Backup solution

Workshop

A Vertex Detector for the ILC

- Physics and Technologies -

May 28, 2006 - May 31, 2006

http://www.hll.mpg.de/~lca/ringberg

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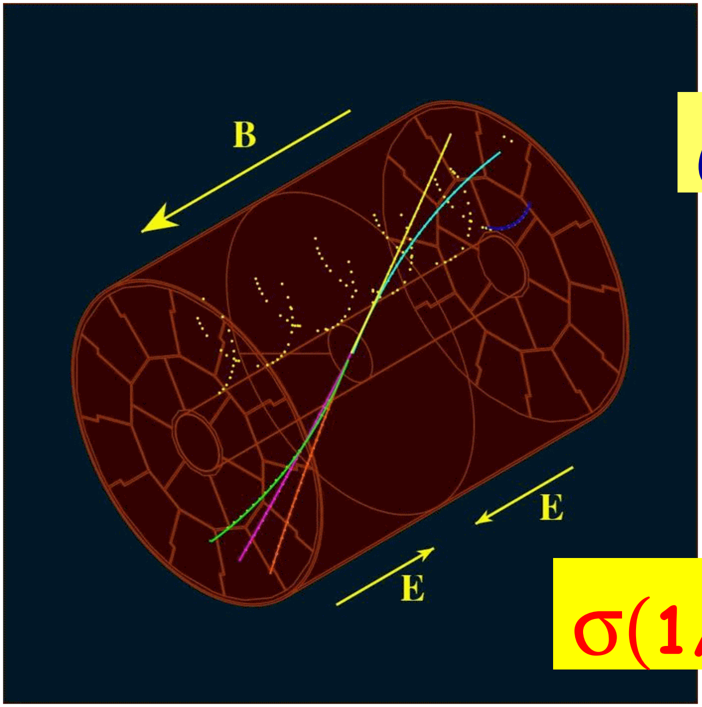
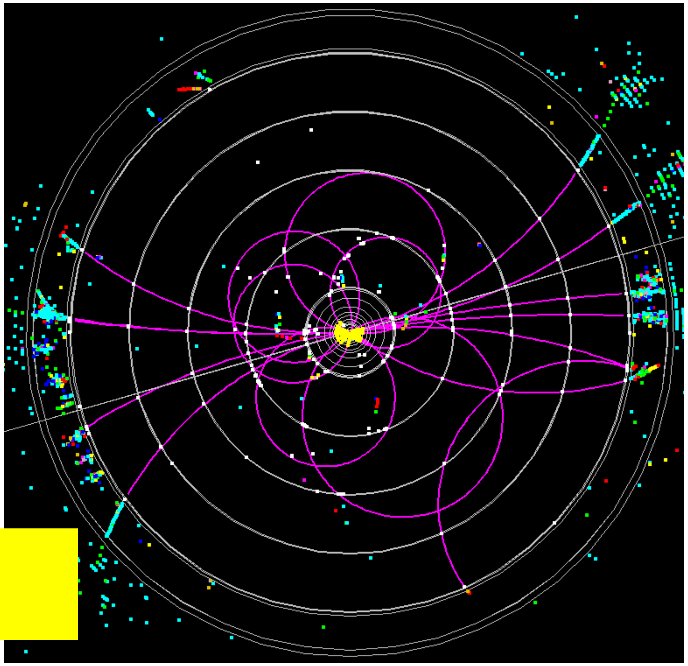
Munich

Central Tracker



Gaseous or Silicon



$\sigma(1/p) = 6 \times 10^{-5}\ GeV^{-1}$

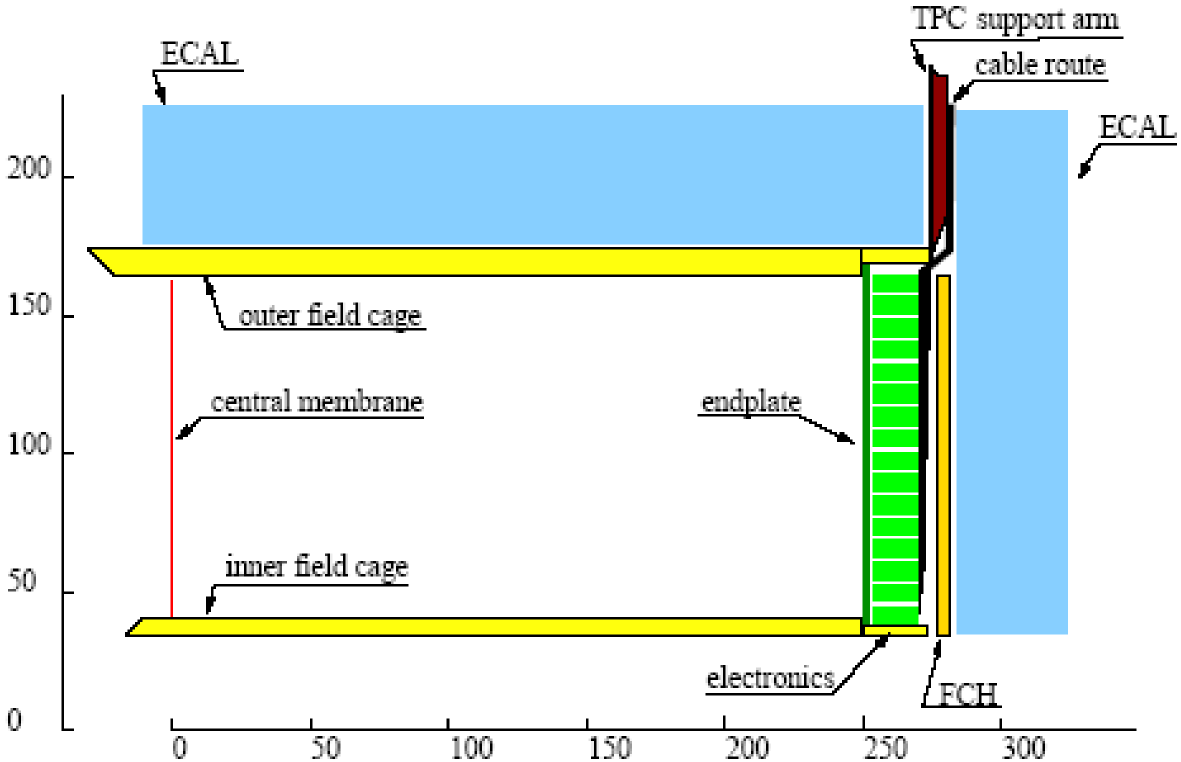
- Field Cage- homogeneous E field
- Mechanical Frame (< 3% X_0)
- Novel Gas Amplification System
- Gas Mixture

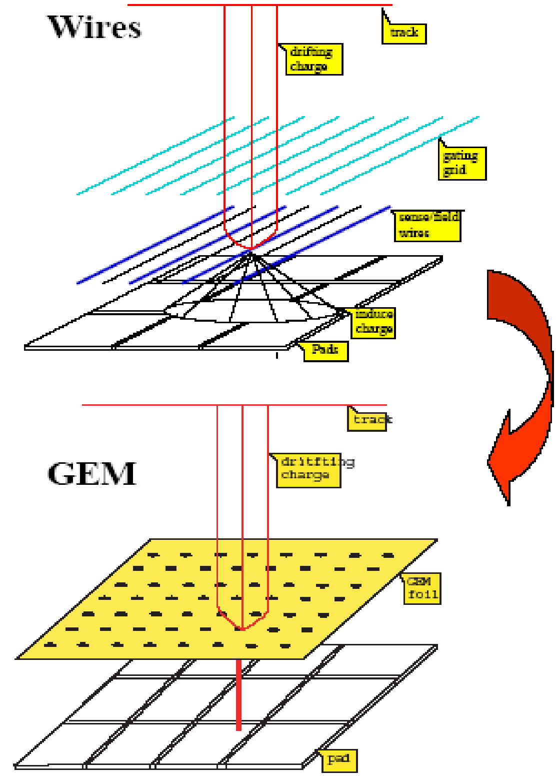
Performance at High B –Field (100μm (Rφ) Resolution)

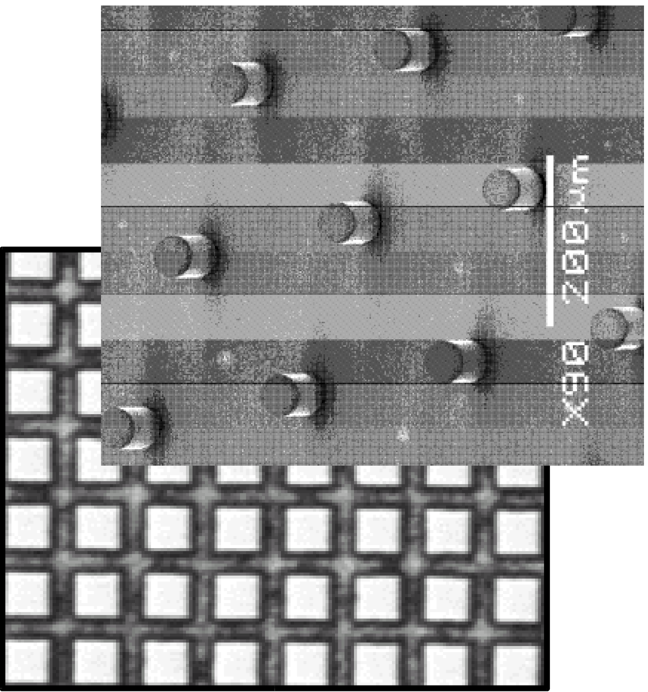
- Track reconstruction efficiency
- Long Silicon Strip sensors (Barrel)
- Mechanical Support (<1% X_0 per layer

FE Electronics (low noise, digitisation)

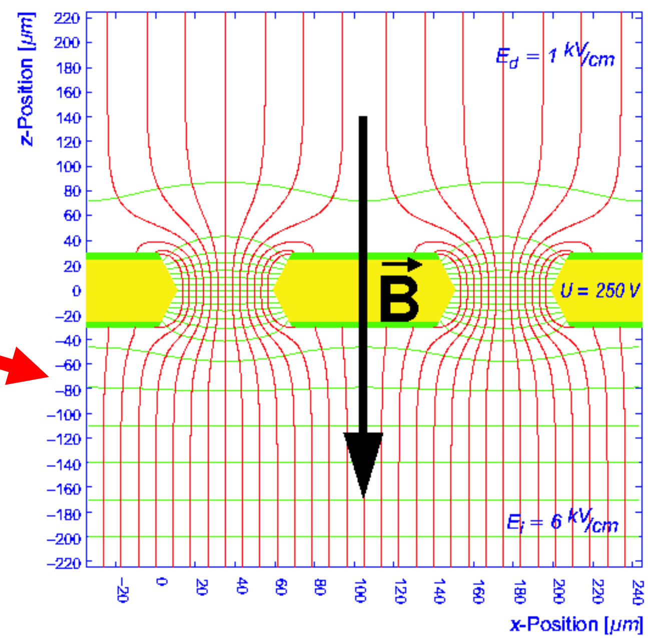
Central Tracker - TPC



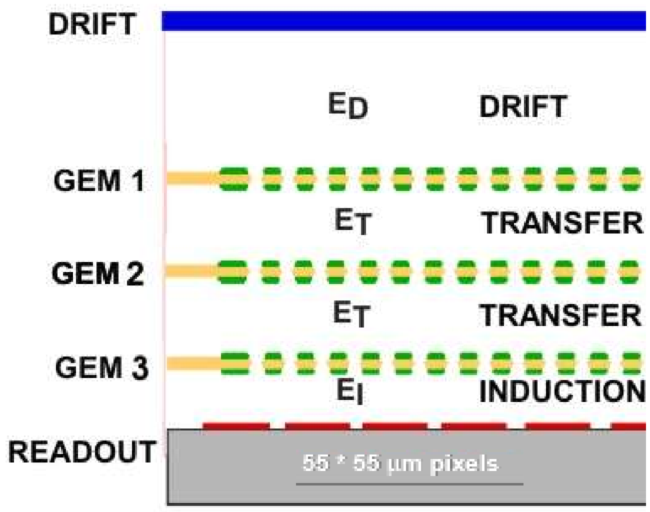


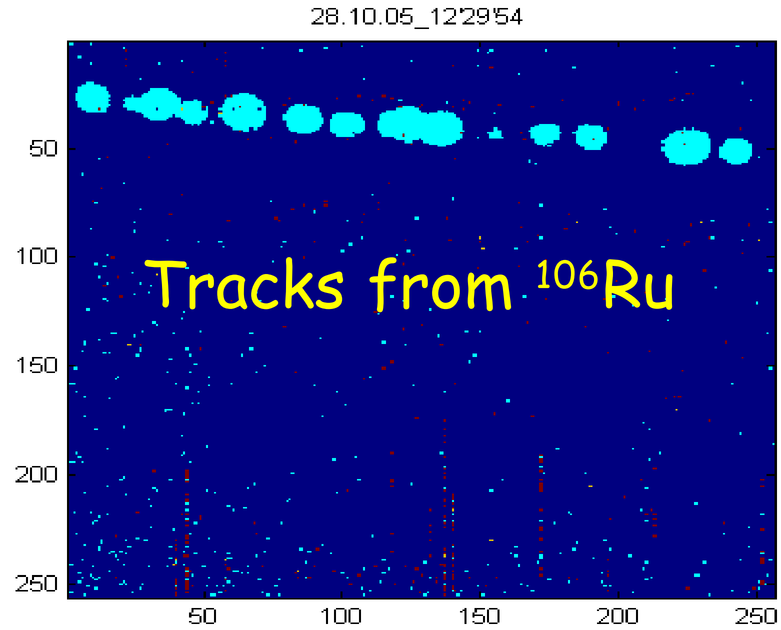


Gas amplification:
Micromegas, GEMs

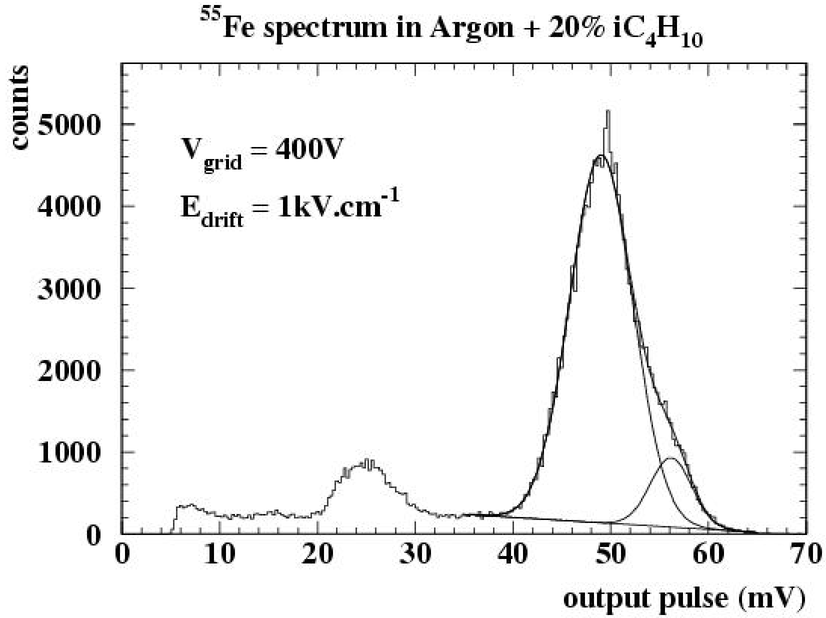


Digital TPC





very interesting to measure dE/dx via cluster counting



Resolution σ_E/E = 6.5%
(FWHM = 15.3%)
Gain variations < ±5%

TPC status and next steps

- A large international community is engaged in TPC R&D
- Both GEMs and MicroMegas seem to work
  - Point resolutions < 70μm with both (close to diffusion limit)
- For the moment just small (~80cm) prototypes
- Next step:
  - Construction of a "Large prototype"
  - Full System Test in a beam
- On going R&D
  - Gas mixture, magnetic field homogeneity
  - Backscattered pairs (background)
  - Readout electronics (pad density)

collaboration CALICE

http://polywww.in2p3.fr/flc/calice.html

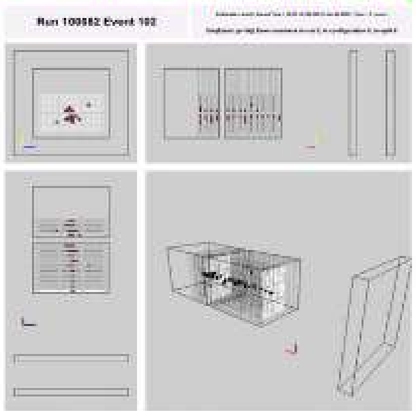
Approved PRC-DESY n°02-01
Presented at PAC-FNAL

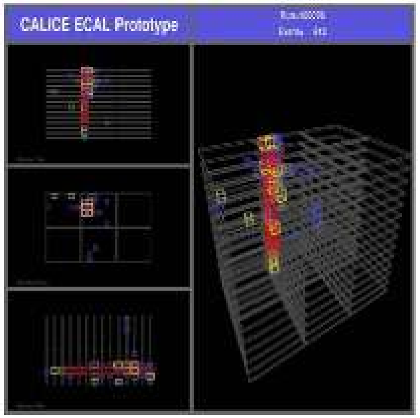
The CALICE Project

CAlorimeter for the LInear Collider with Electrons

A high granularity calorimeter optimised for the Particle Flow measurement of multi-jets final state at the International Linear Collider running at a center-of-mass between 90 GeV and 1 TeV

- **Last collaboration meeting at NIU**, De Kalb, IL, USA All info here
- **Electron interactions in ECAL prototype** at DESY TB – 28/01/05





- The collaboration
- The ECAL project
- The HCAL project
- The software corner
- Meeting and news
- Publications, talks

190 phys./engin.
32 laboratories
9 countries
3 regions

Missing flag here …

The proposed solutions

ECAL : Sampling calorimeter

tungsten (density) – silicon (pixel size ~ Molière radius)

Pixels size $<1cm^2$ and about 20–30 readout layers
(15 to 250 Millions channels)

HCAL

Solution 1 :

Sampling calorimeter tungsten/Stainless steel (density) -digital readout (pixel size)

Pixel size $1cm^2$ and about 50 readout layers
(~50 Millions channels)

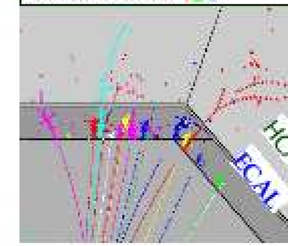
Solution 2 :

Sampling calorimeter tungsten/Stainless steel (density) – scintillator tile (small size)

Pixels size $16cm^2$ and about 50 readout layers
readout by silicon PM !!

ECAL

The electromagnetic calorimeter

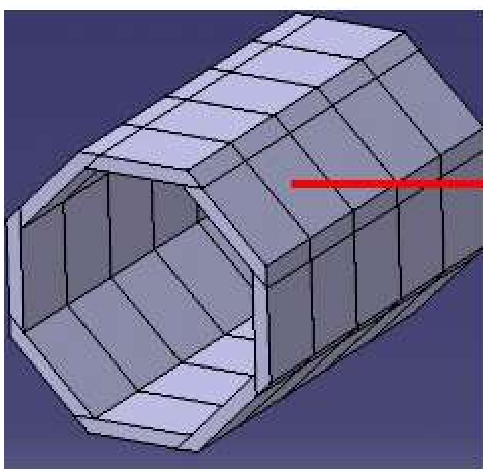


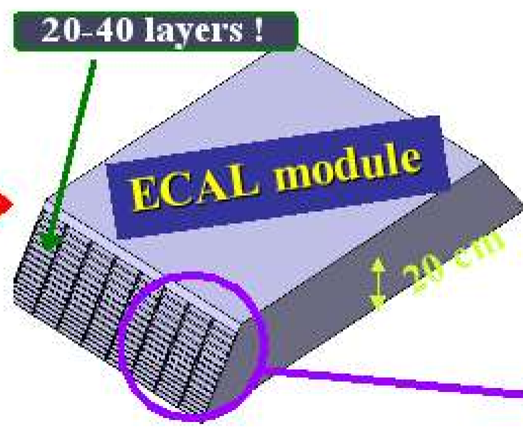
CALICE - ECAL

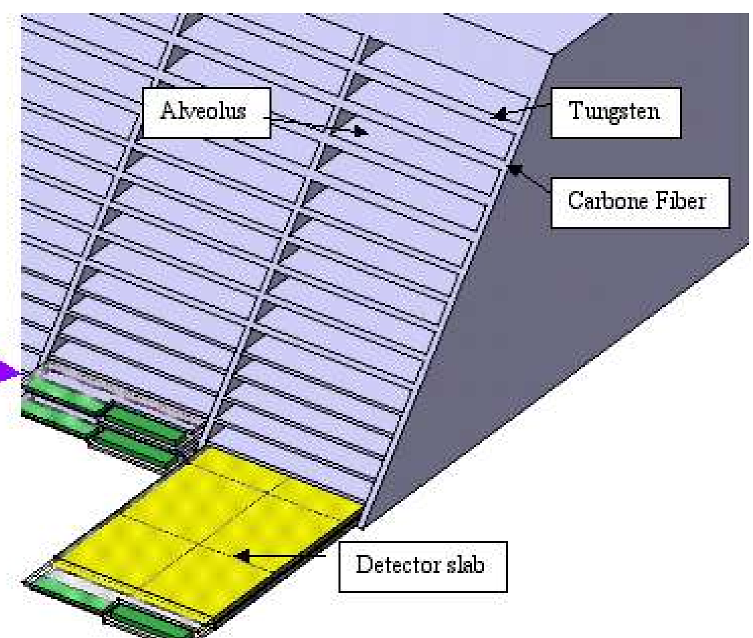
- Ewha Univ., Sungyunkwan Univ., Kangnung NU , Yonsei Univ.
- LAL,LLR,LPC-Ct, LPSC, PICM
- ITEP,IHEP, MSU
- Prague(iop-ascr)
- Imp. Coll, UCL, Cambridge Birmingham, Manchester,RAL, RHUL

- 130T de tungsten
- An octogonal geometry
- High level of density

(20-40 layers, 24X0 in ~170mm)







- No large area of dead zone
- All modules are identical (Tungsten wrapped by Cfi)
- The detector slabs would be tested before assembling

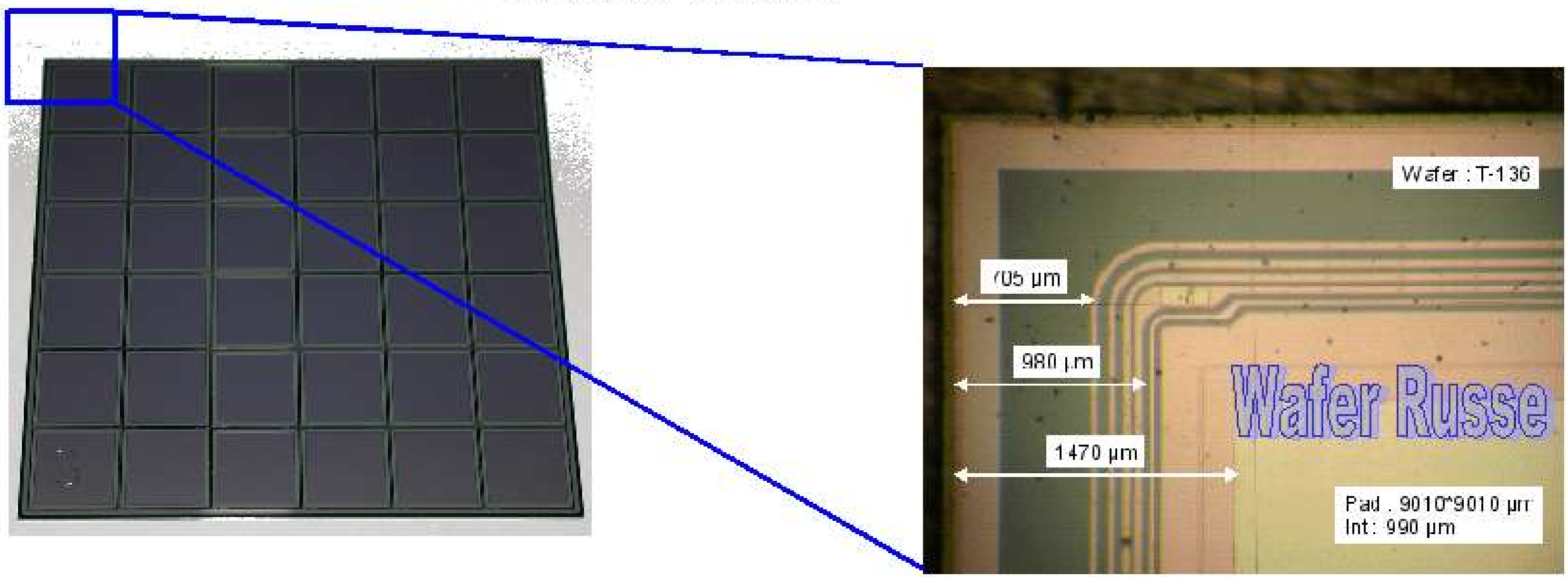
ECAL

Contraint on the ECAL calorimeter

- Small Molière radius ⇒ small thickness for non-W material
- Threshold <mip ⇒ large mip signal ⇒ wafer not thin (500µm)
- S/N at mip > 10 ⇒ small noise
- Weak coherent noise ⇒ pick-up, ground, power supply etc…
- Large dynamic (16bits) ⇒ bi-gain two time 10 bits
- Weak power dissipation (electronics) ⇒ power cycling
- Behavior of the VFE chip when 500-600 GeV em shower goes through
- Keep under control the silicon cost ⇒ labos in contact with privates companies

DETECTORS MATRIX

Relatively crude object when compare to a microstrip Matrix for a tracker



ECAL

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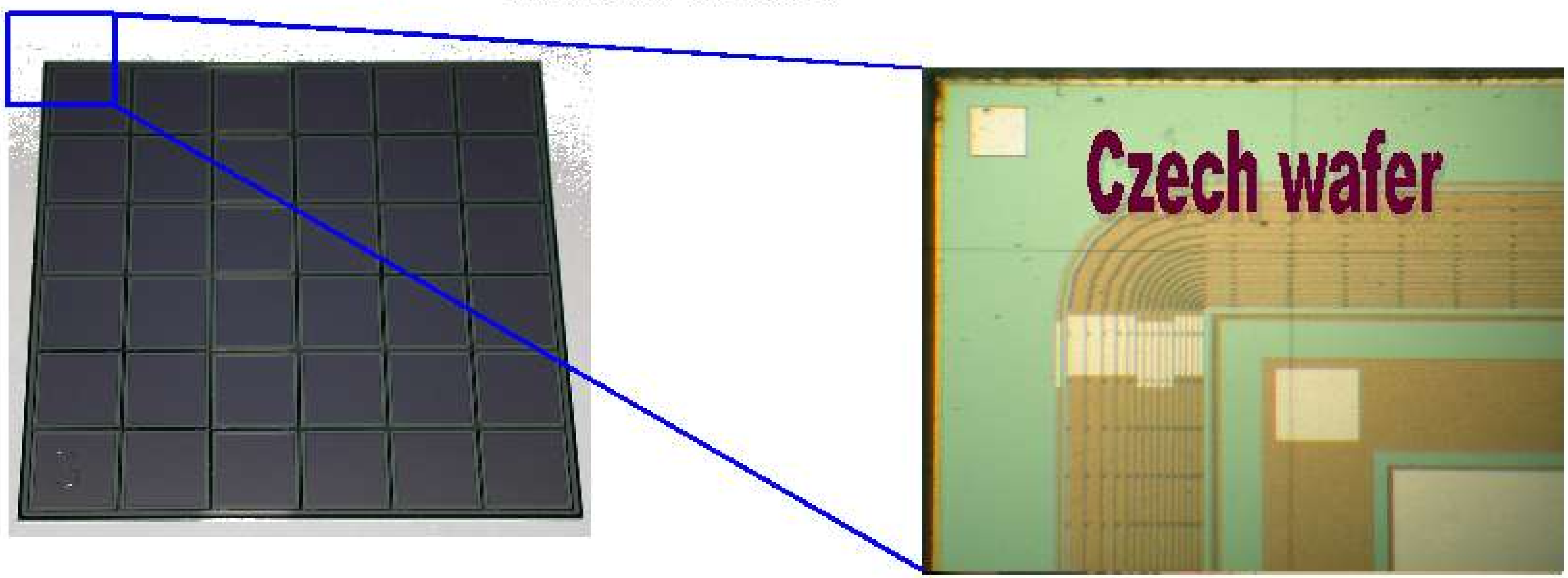
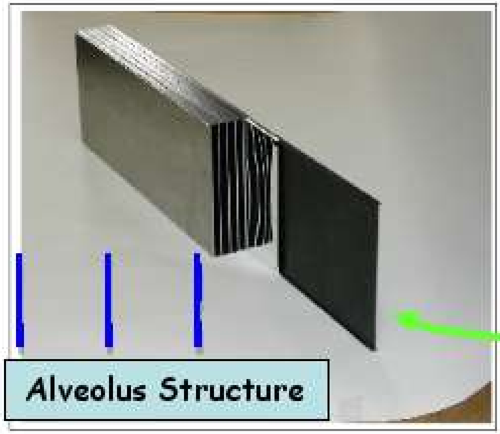
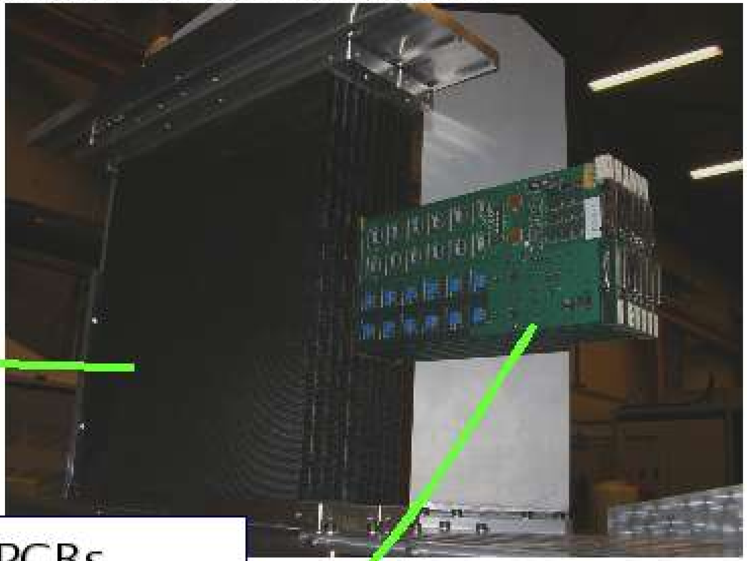


ECAL

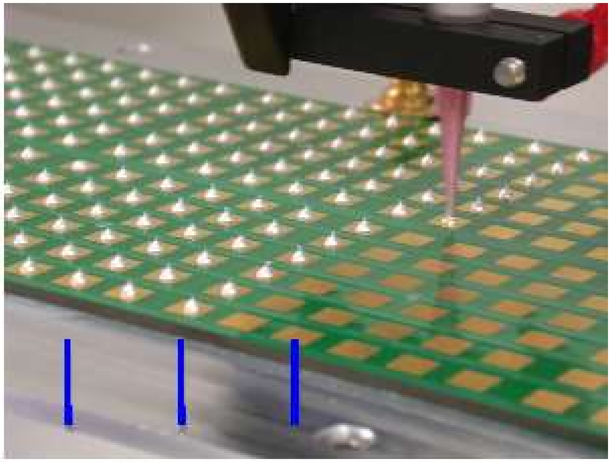
the prototype is in final phase of construction



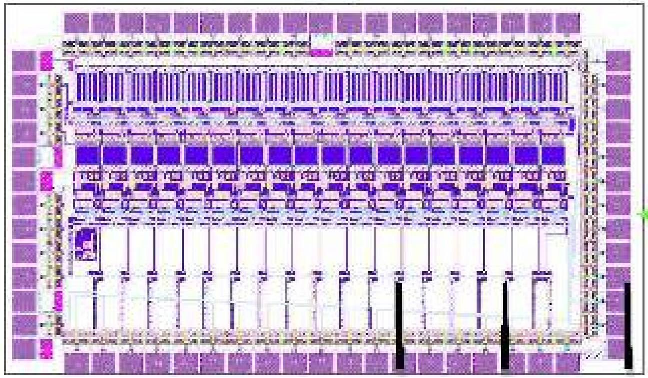


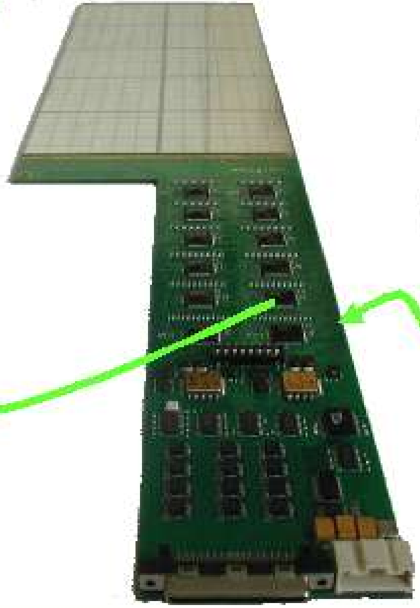
PCBs

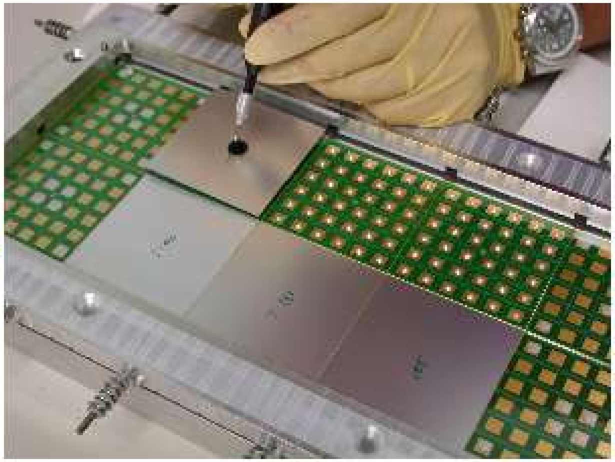
KNU

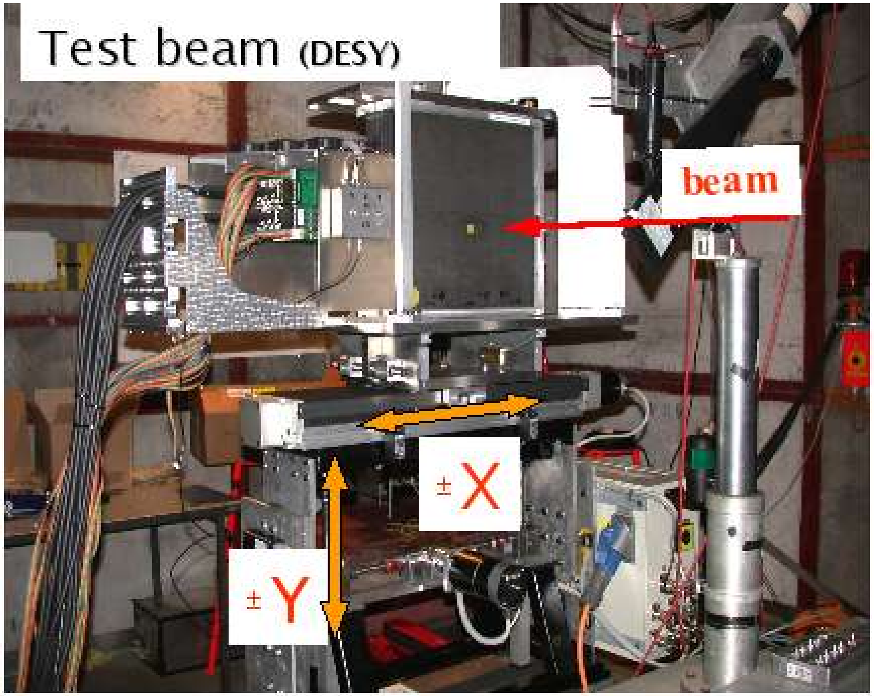


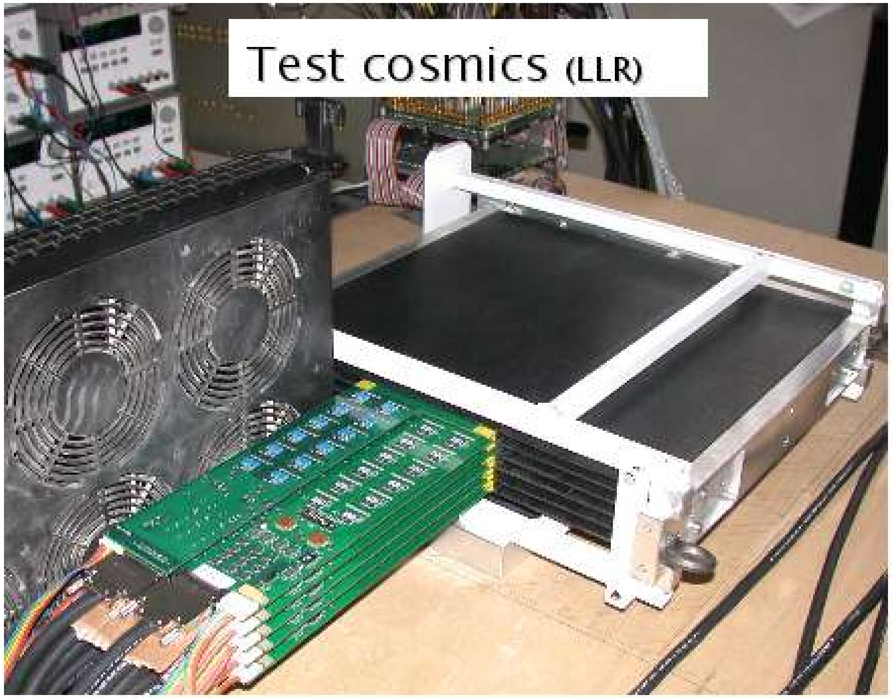
Front-end electronic analog part



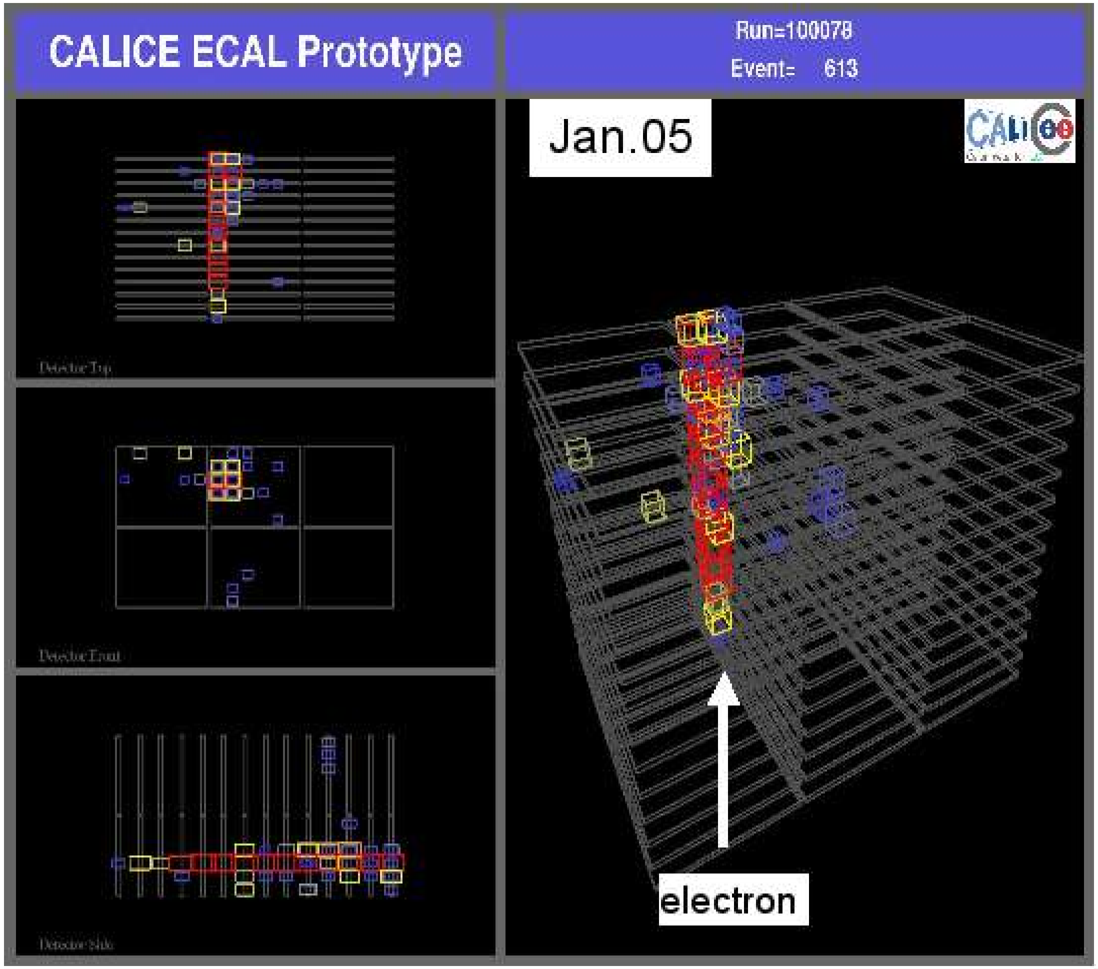




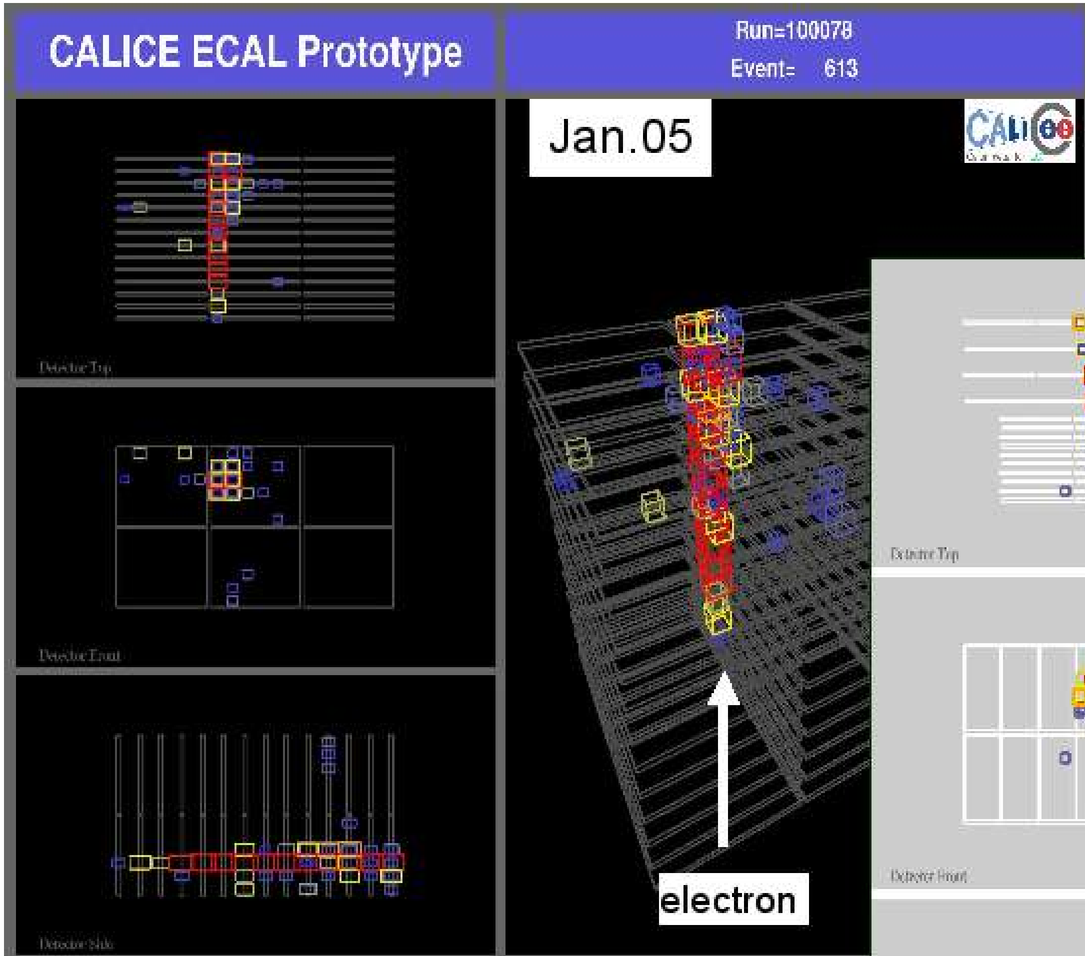

Test beam (DESY)
beam
±X
±Y


Test cosmics (LLR)

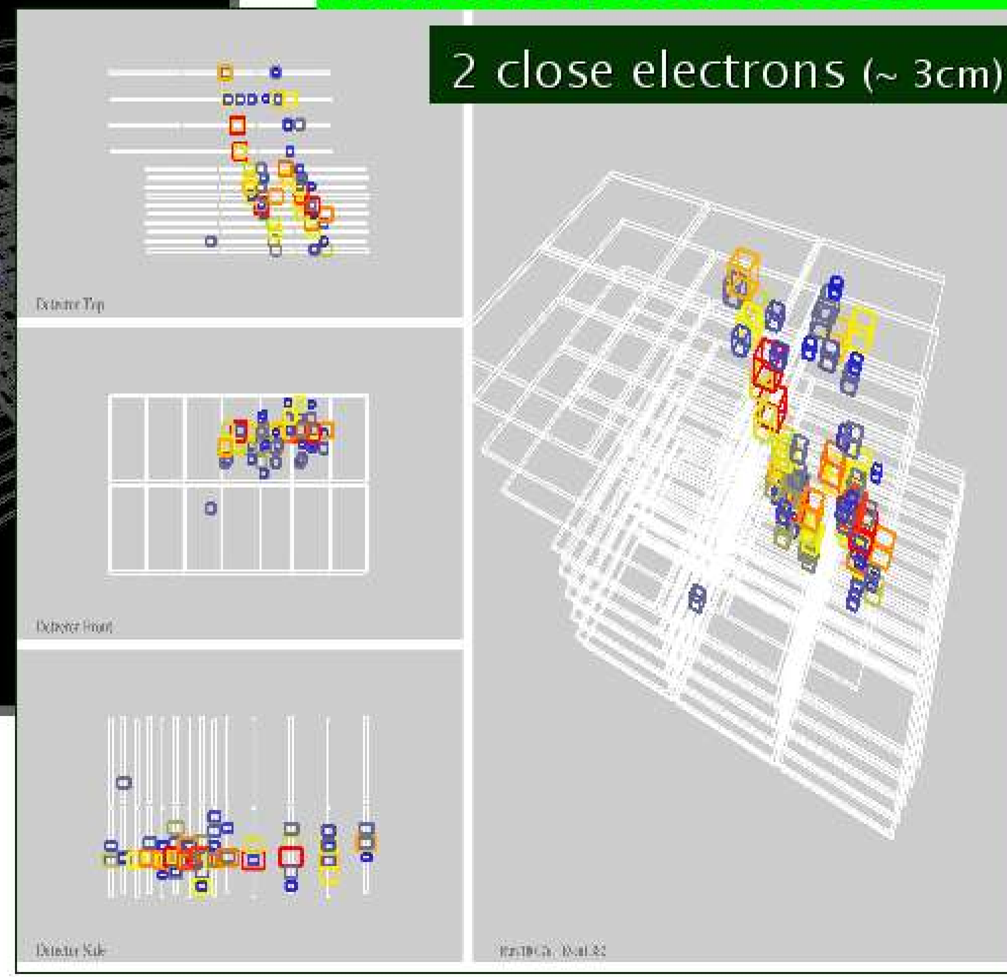
ECAL prototype – first test at DESY (FNAL/CERN 2006…)



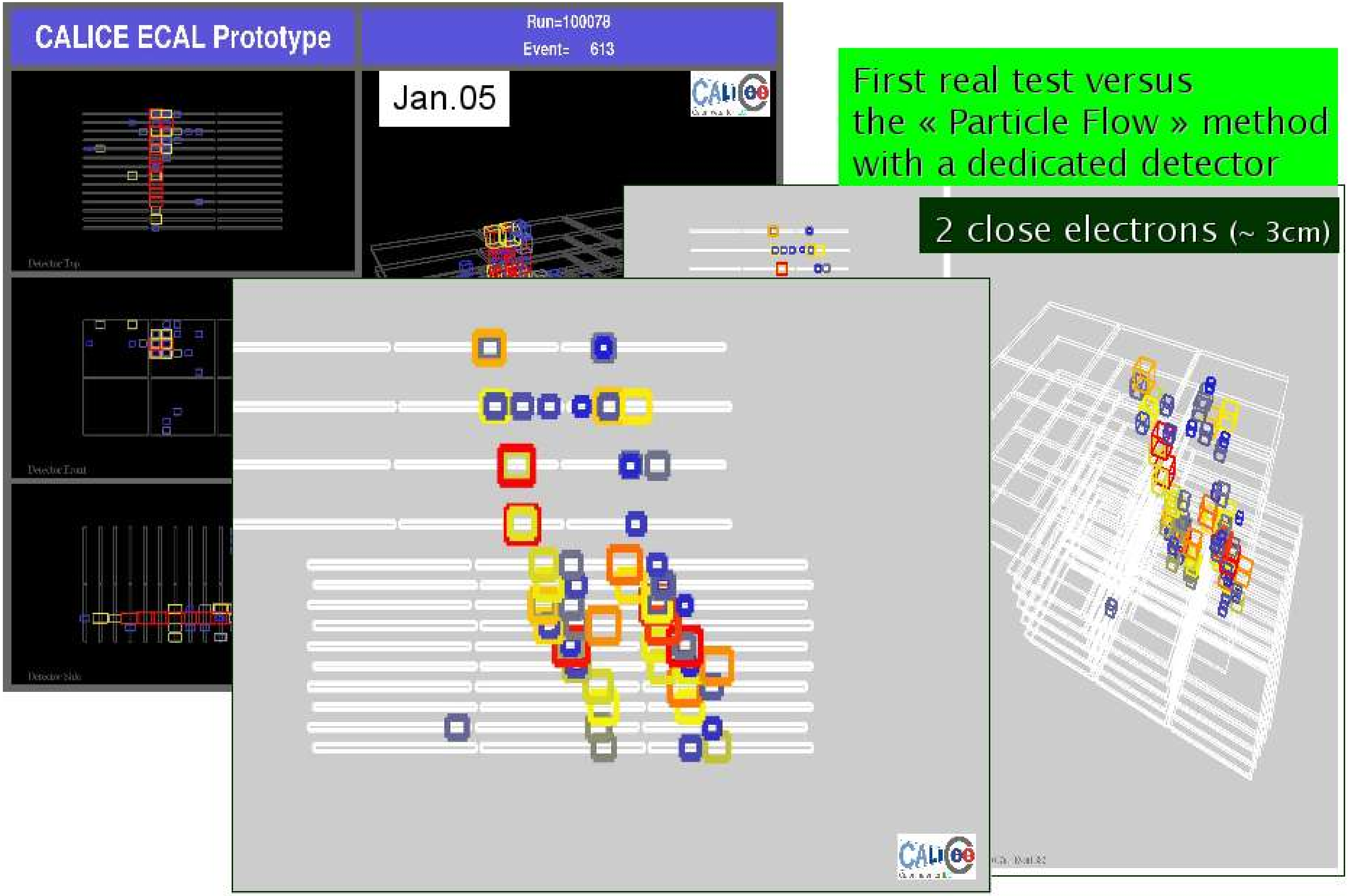
ECAL prototype – first test at DESY (FNAL/CERN 2006…)



First real test versus the « Particle Flow » method with a dedicated detector



ECAL prototype – first test at DESY (FNAL/CERN 2006…)



First real test versus the « Particle Flow » method with a dedicated detector

2 close electrons (~ 3cm)

AHCAL

Analog hadronic calorimeter

CALICE AHCAL

- Prague
- LAL
- DESY, Hamburg
- ITEP, JINR, LPI, MEPhI
- Imperial
- NIU

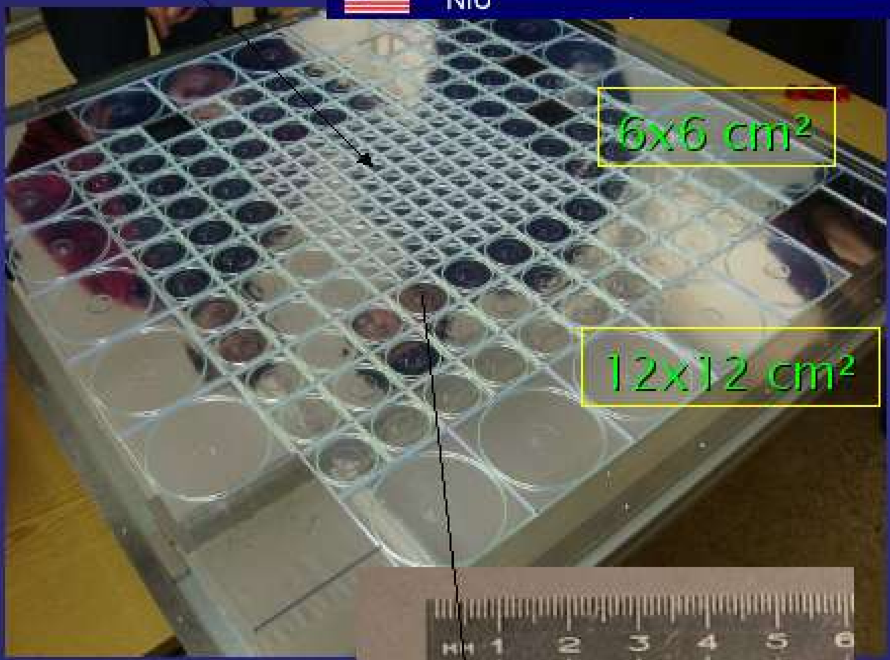
Prototype 1m³ (4.5λ)

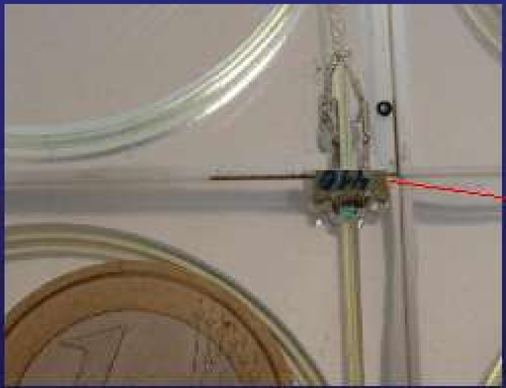
Scintillator tiles
- > Tile size : 3 x 3 cm^2 → 12 x 12 cm^2
- > Wavelength shifting fiber imbedded in tiles illuminating photo-detector

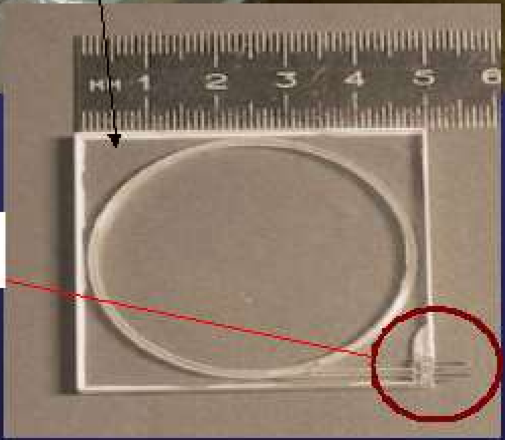
8000 readout channels in total

Silicon – Photomultiplier readout
- > New development
- > Located directly on tile

+ a tail catcher of 10λ







DHCAL

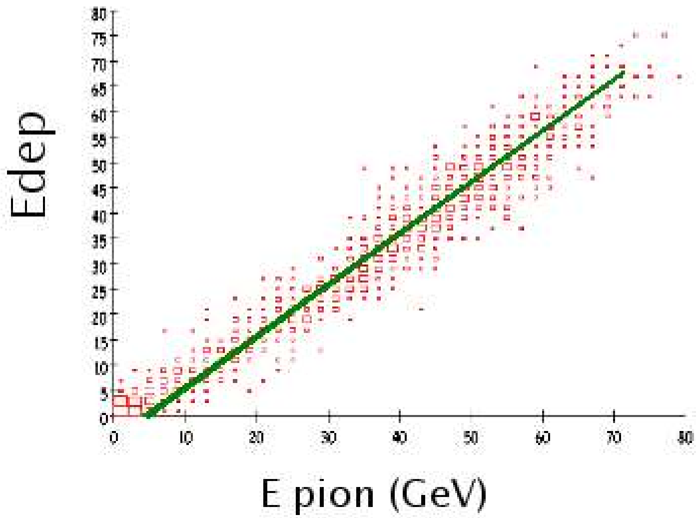
Digital hadronic calorimeter

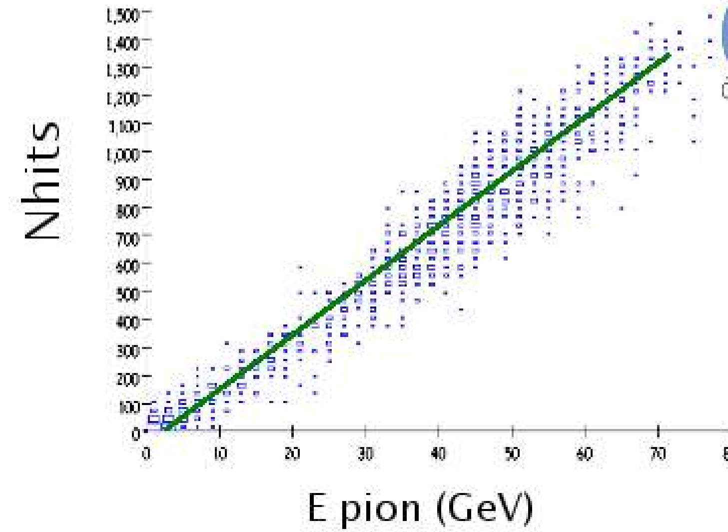
⇨ Sampling Calorimeter , gas detector/radiator

- 40-60 readout layers (RPC, triple-GEM,…)
- Readout (1bit) per pad of 1x1 cm^2 (energy given by cells counting)
- 50-70 millions channels (but electronics is supposed to be cheap and simple, no d'inter-calibration,…)

Following the simulation (GEANT)

Better than a "classical" calorimeter for
- the separation between close shower
- a better energy resolution **(specially if we do more than a cells counting)**
- identification of the muons
- the sensibility to noise,
- the cost of the detector **(warning to the cost of the electronics readout)**



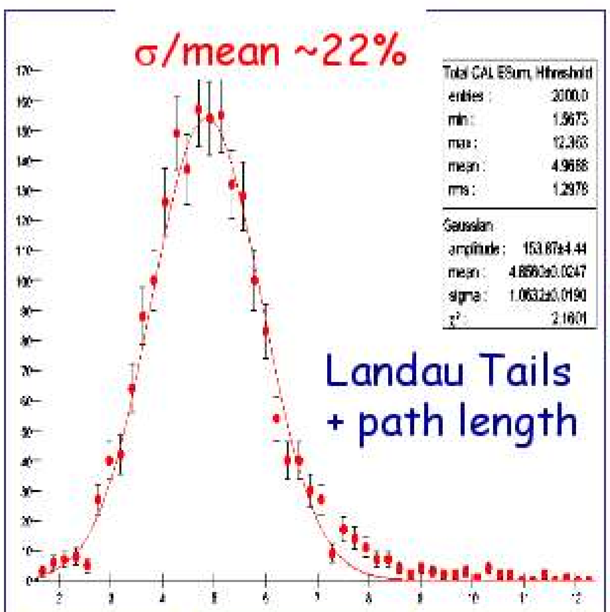


SIMULATION

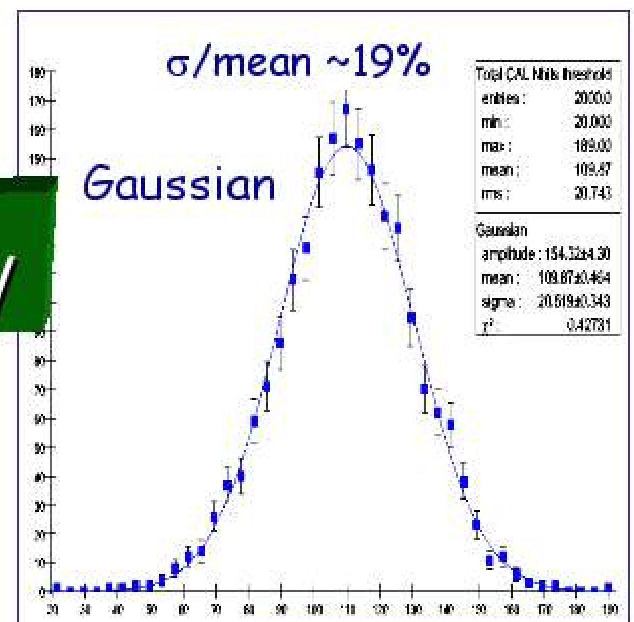
Analog

Digital

π^+ 5GeV



E (GeV)

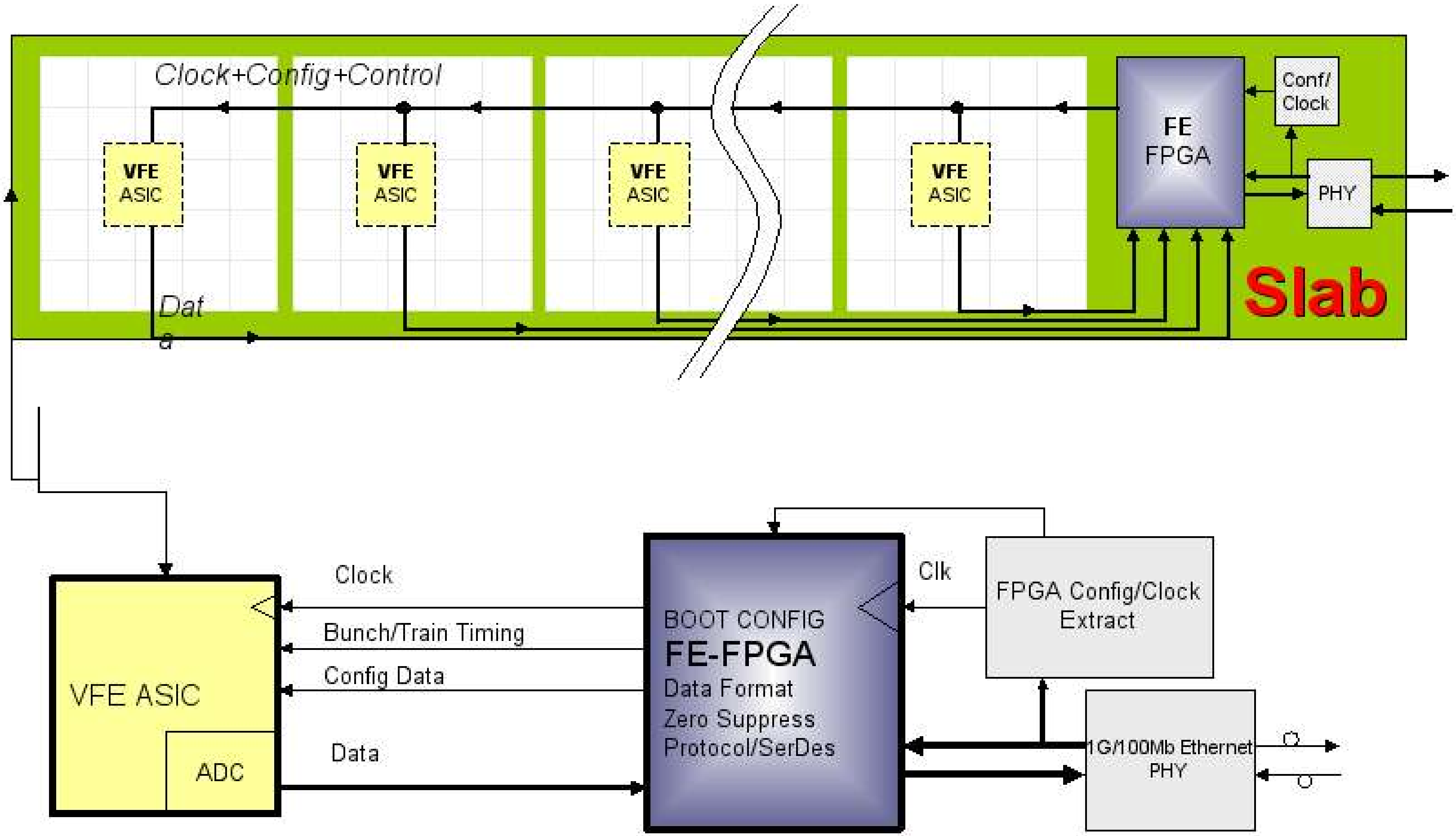


Number of Hits

Exemple of R&D

ECAL, AHCAL, DHCAL

detector readout



News groups enter in the collaboration Recently (less than 3 months)

- Korean groups on the silicon wafers
- Iowa, Boston, Chicago on the DHCAL
- LPSC on the ECAL endcap mechanics
- McGill, Univ.Regina on the scint. hadronic calorimeter

There is clearly room "relatively" empty today, **(the ones I think about are)**

- The electronics and the DAQ of the Digital/Analog HCAL
- The mechanical integration of the DHCAL
- The power supply distrib. and slow control for the ECAL
- The analysis of test beam
- The algorithm of particle flow (PFA) for neutral hadron(s)

\+ difficulties with

- Digital HCAL (RPCs production for prototype)
- End-Cap design (always difficult in collider)
- PFLOW performance (a~30% on Z at rest , need test at HE)
- Real design of the calorimeter (design of principle now)
- etc...

More informations , just contact me

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Conclusion

- The ILC is the future of HEP (post LHC)
- The detector R&D for ILC has begun (agenda established)
- The calorimetry sector is already structured,
  A very large collaboration (CALICE) + a west coast SLAC-Oregon ECAL project + few single lab. proposal !! + Japanese work on SiPM
- There is still a lot of place for ideas and contributions
- The next 3-4 years R&D will designed the future calorimeter for the ILC. It is a good time to join ...

.... y el CIEMAT??

- No existe ninguna actividad en marcha en el CIEMAT (detectores)
  - Retraso respecto a otros labs (IFIC,Santander)
  - Reparto de tareas se está realizando ahora
- Puntos fuertes del CIEMAT
  - Unidad de Electrónica
    - Posiblemente una de las mejores en España
  - Talleres mecánicos
    - Bien dotados tanto en maquinaria como en personal
    - Masa crítica de ingenieros
- ¿Existe interés en participar en el ILC?
  - Proyecto a muuuuy largo plazo (post-LHC???)
  - Hay que definir en qué queremos participar, empezando por el I+D.

Electrónica de Front-End

- TODOS los proyectos presentados muestran una tendencia
  - Mayor granularidad
  - Mayor velocidad de lectura

→ ASICs

- La idea básica en la parte “analógica” no ha variado desde que en los años 50 cuando E. Gatti inventó el amplificador de carga.
  - Mayor integración
  - Mejora en la parte “digital”
- Cada detector fija diferentes “constraints” mecánicas
  - Variación de “pitch” e integración
  - Test de nuevas tecnologías → menor potencia por canal
- El CIEMAT cuenta con personal técnico capacitado para el desarrollo/adaptación de ASIC
  - Primer paso para pasar de seguir las proposciones de otros laboratorios a proponer experimentos

Mi propuesta

- Creación de un laboratorio para la investigación y desarrollo en detectores de pixeles.
  - Tecnología compartida por muchos de los detectores actualmente.
    - ILC: detectores de traza, TPC, calorímetros
    - Astropartículas: CCD, DEPFETs(?)
  - Colaboración con “productores” de sensores (MPI,CNM,IReS)
    - Test eléctrico de prototipos
    - Diseños mecánicos (pasar de sensores a detectores)
  - Semilla para la creación de un grupo de microelectrónica
- Primer trabajo ya lanzado.
  - DES: Dark Energy Survey
    - Prototipo de la cámara DES (CCD) junto con el IFAE y el IEEC
- Habilitación de una zona experimental
  - Sala limpia
  - Infraestructura común (criogenia,bancos ópticos,pool electrónico,etc)

Conclusiones

- El I+D en el ILC propone una nueva generación de nuevas técnicas de detección.
- Aún no es demasiado tarde para coger el tren del I+D para el ILC
- La selección del camino a tomar se debe elegir en función de la física que se quiera estudiar a largo plazo.
  - Cualquier camino pasa por la “pixelización” de los detectores
    - Astropartículas → desarrollo de CCDs (DEPFETs???)
    - Partículas → “Particle Flow” abre de nuevo el campo en calorimetría

      → Desarrollo de TPCs digitales

      → Contribución al tracking desde el hardware
  - Hay que lanzar un programa de I+D a largo plazo
    - Base de futuras colaboraciones