# Prominent expectations from 3DIT for the Detectors at the International Linear Collider (ILC)

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related talks: R. Yarema, L. Andricek, M.Demarteau

▷ More information on ILC Web site: http://www.linearcollider.org/cms/

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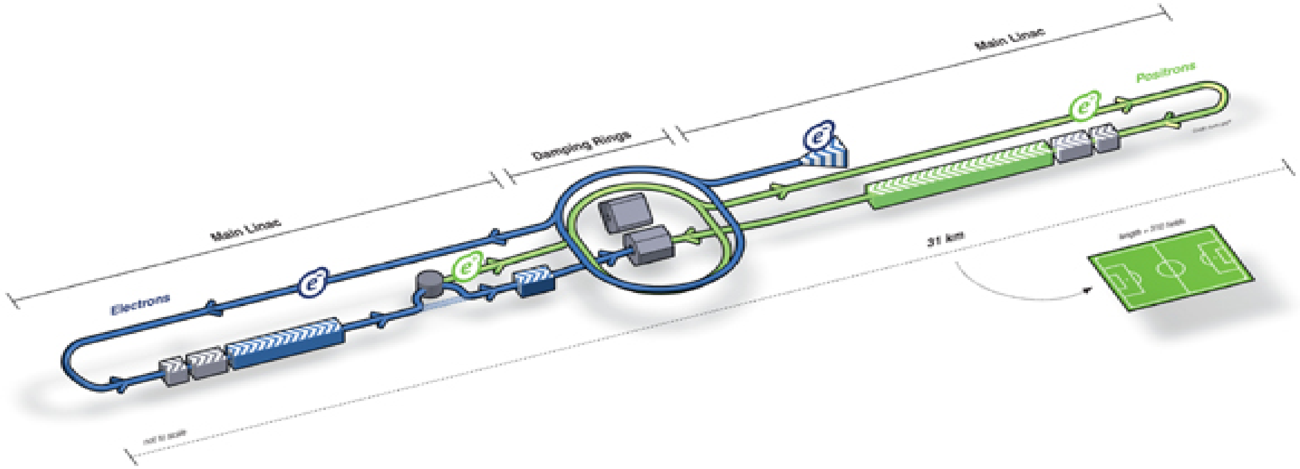
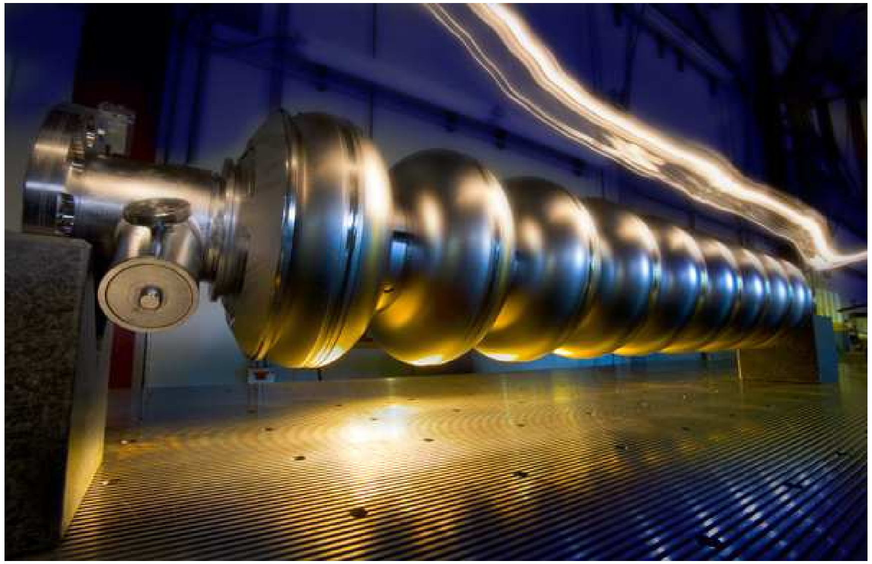
- What are the scientific goals which may benefit from 3DIT ?
- Concrete applications of 3DIT to ILC (charged) particle detectors
- Summary & Outlook

# What is the ILC Project ?

- **ILC $\equiv$ next large scale accelerator after LHC :**
  - ▷ *it is an electron - positron linear collider : c.m. energy up to 1 TeV ; 31 km long site;*
  - ▷ *it will deepen discoveries made at LHC and extend the experimental sensitivity to new phenomena underlying the history of Universe (laws of Nature) and its present mysteries (Dark Matter, Dark Energy)*

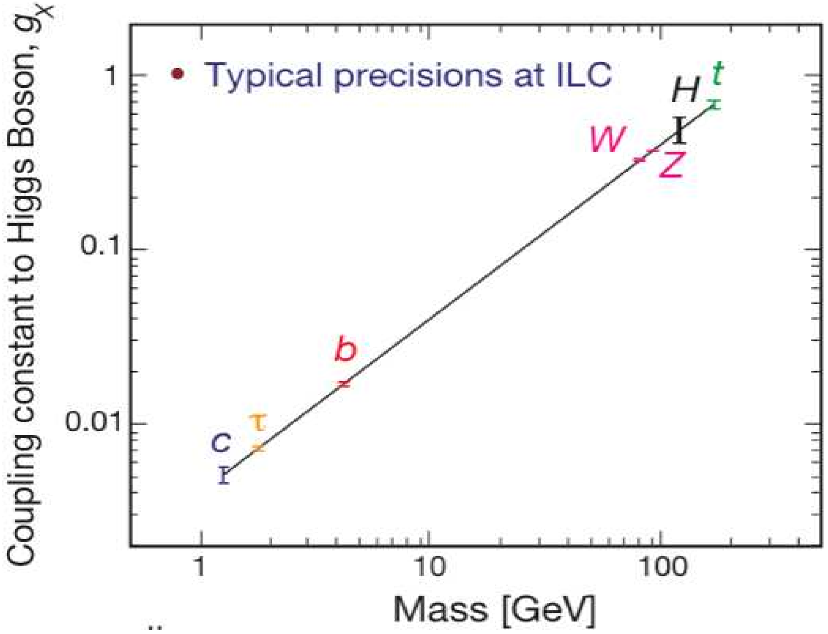


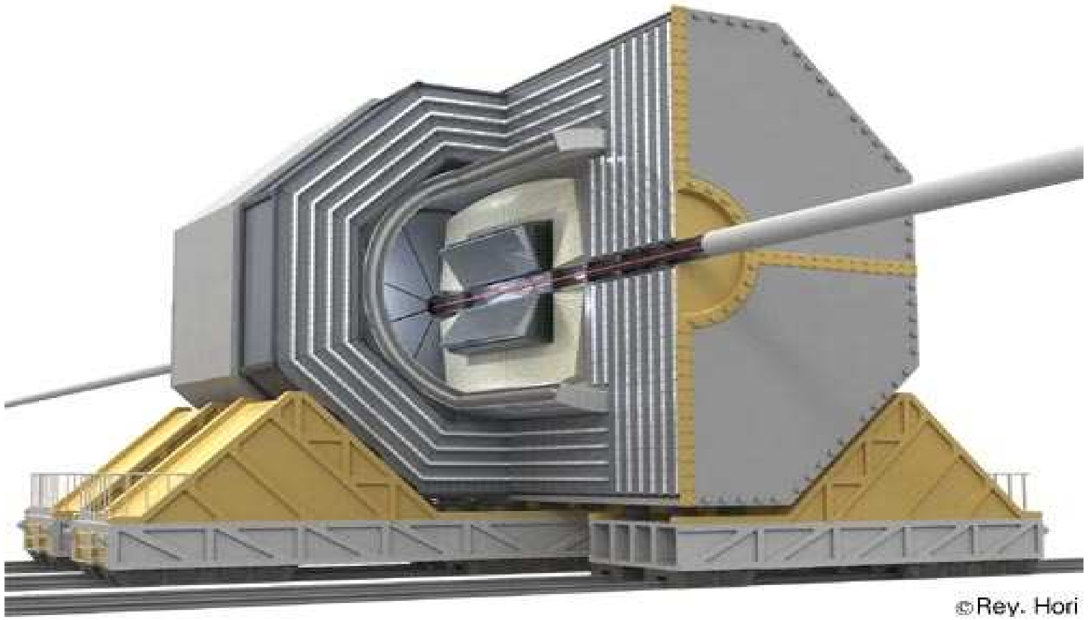



- **ILC design expected to be technically ready for construction $\lesssim$ 2012 (... R&D started $\gtrsim$ 10 years ago ...)**

- **ILC is a high precision machine :**
  - ▷ *electron - positron collisions are relatively background free*
  - ▷ *physics conditions of elementary interactions are particularly well defined and tunable*

⇛ **Very high precision/sensitivity studies accessible if detectors are extremely sensitive**



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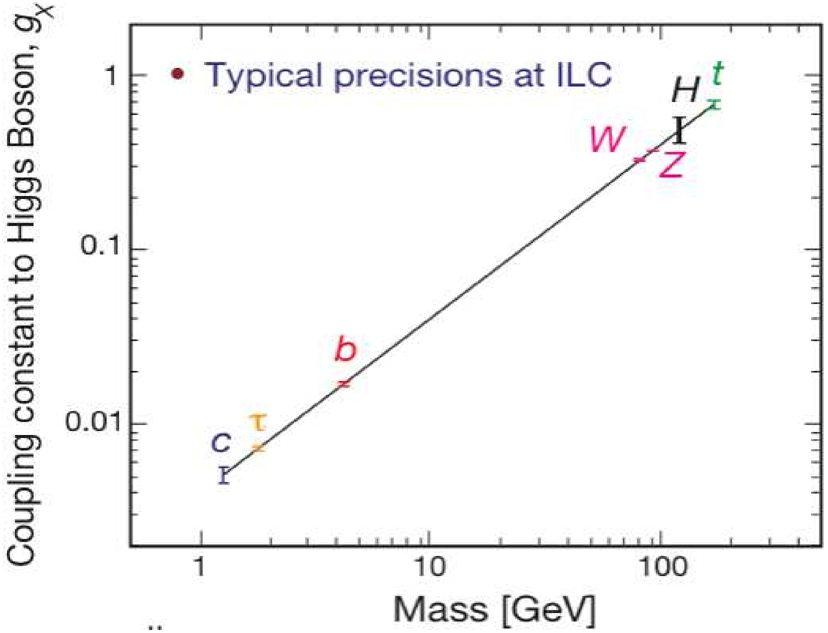
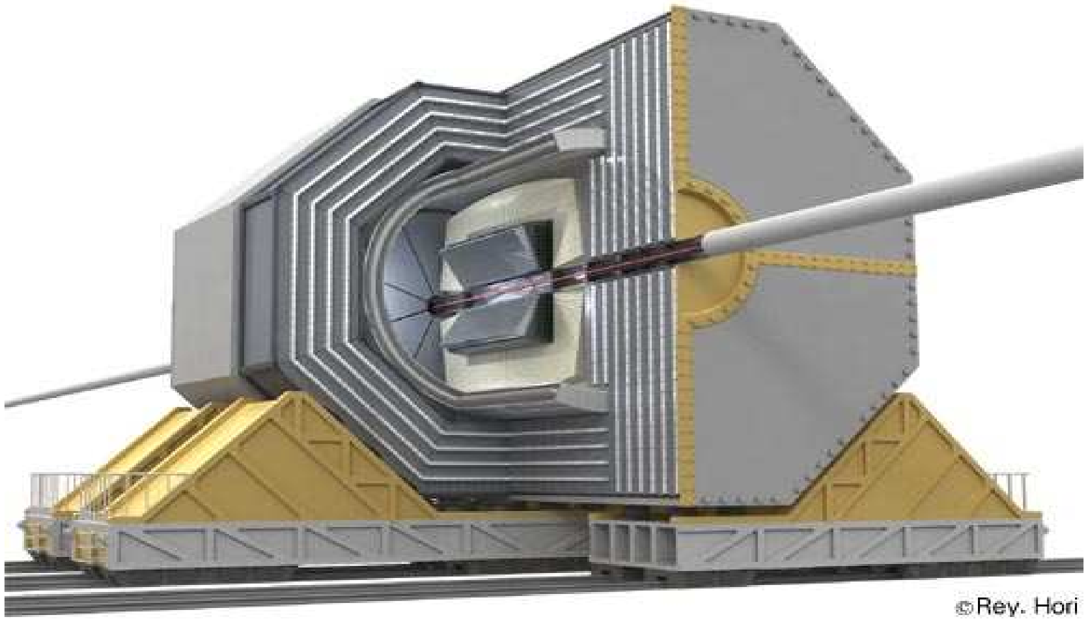



**► 3D Integrated Technologies may help us to reach the ultimate limit in precision and sensitivity**

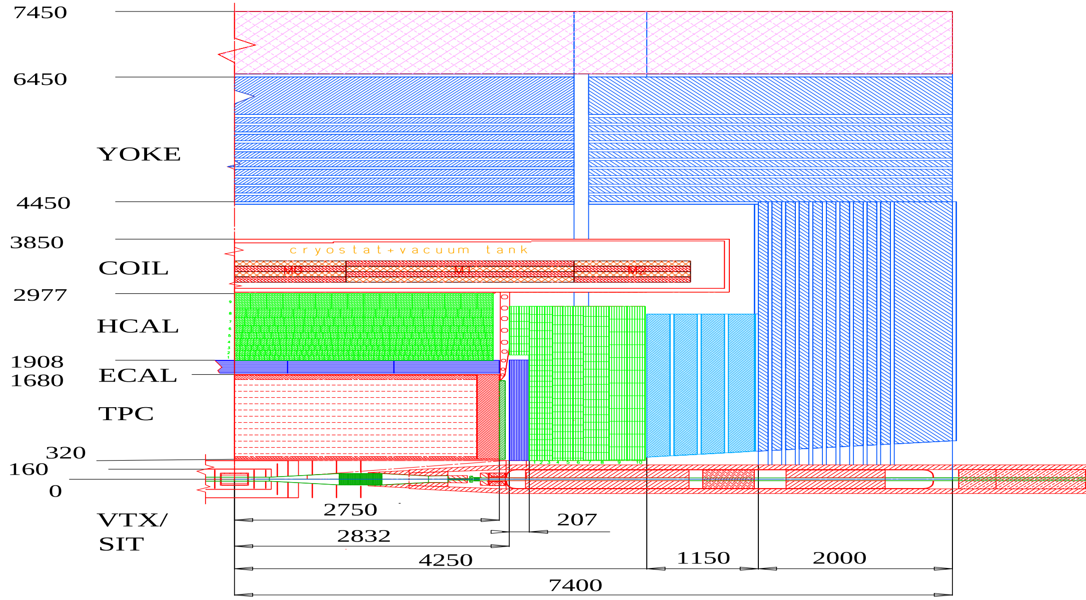
- **Experiments are designed to allow detecting and measuring energy, momentum, spatial origin, etc, of nearly all particles produced in the collisions of interest**
- **Intense R&D programme going on all over the world on detector concept and detection technologies**
- **9 French laboratories involved (8 IN2P3, 1 CEA) :**

▷ **Calorimetres : HCAL, ECAL,** VFCAL

*IPN-Lyon, LAL-Orsay, LLR-Palaiseau, LPSC-Grenoble, LAPP-Annecy, LPC-Clermont*

▷ **Tracking detectors : TPC, SIT, VTX**

*LPNHE-Paris, DSM/DAPNIA-Gif/Yvette, LPSC-Grenoble, IPHC-Strasbourg*



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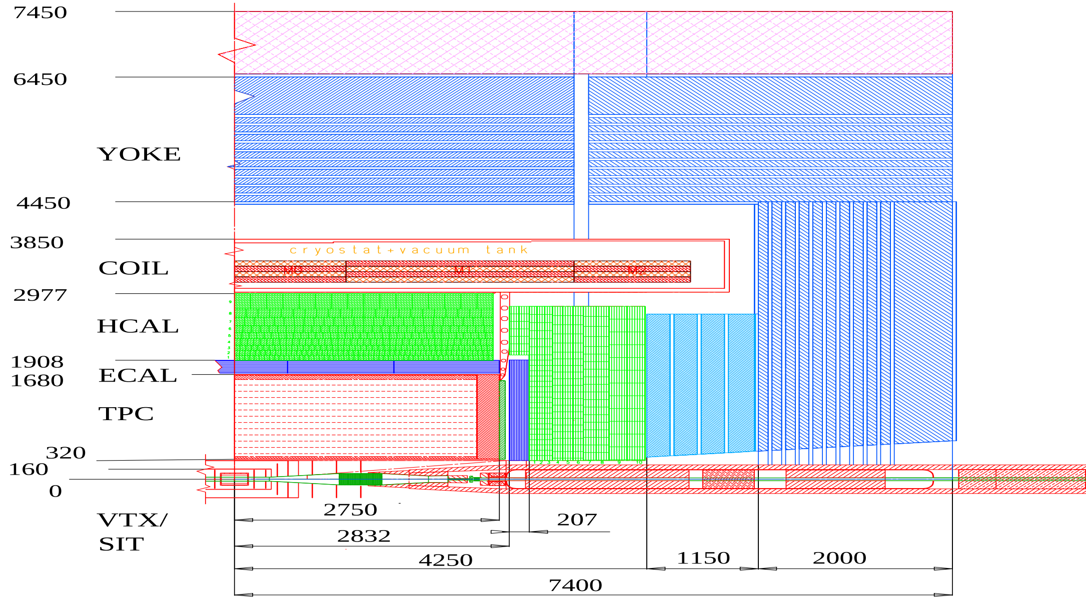
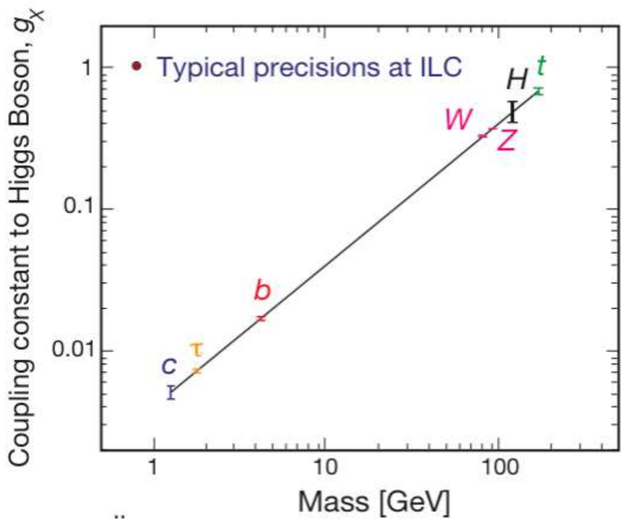


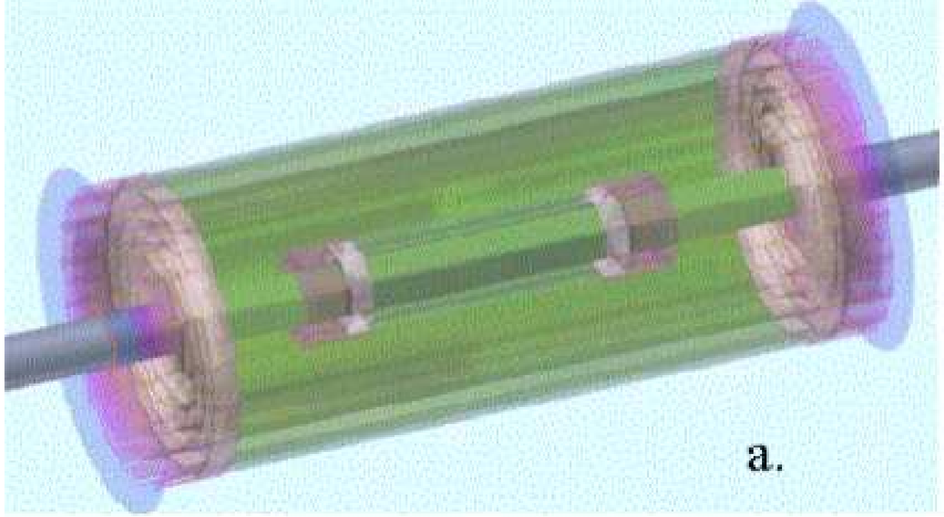

► **3D Integrated Technologies are predominantly attractive for**

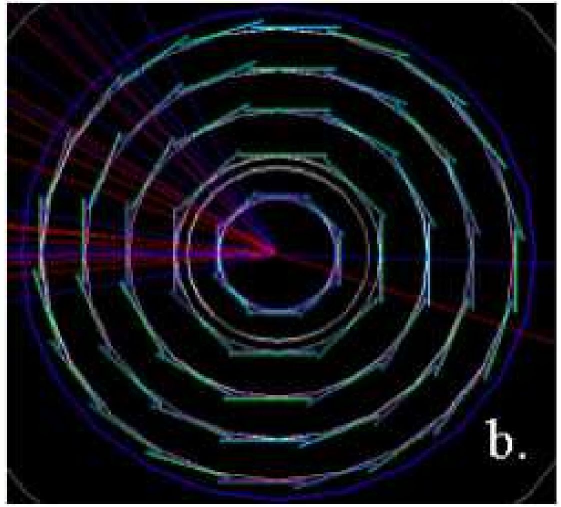
**Charged Particle Tracking Detectors ⟶ VTX, SIT, TPC ⟶ Pixels !!!**

- **ILC physics requires finding evidence of very short lived particles which decay $\gtrsim$ 100 $\mu m$ away from the Interaction Point (e.g. Higgs $\rightarrowtail$ charmed mesons) , inside the vacuum beam pipe (R $\sim$ 15 mm)**

  $\hookrightarrow$ *reconstruct trajectories of electrically charged daughter particles with high resolution pixel detectors installed as close as possible to the Interaction Point*



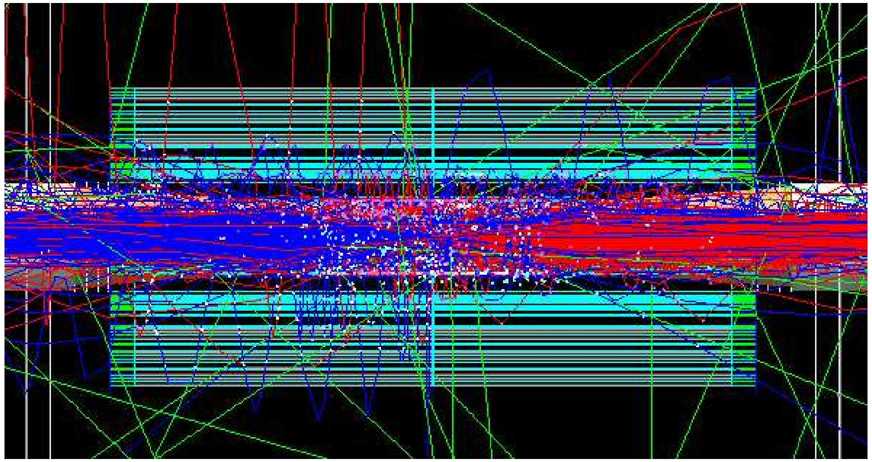




- **Pixels close to beam line ($\sim$ 1–2 cm) are exposed to high rate of backgrounds $\rightarrowtail$ saturation, irradiation**

  $\Rrightarrow$ *Present pixel technologies have limitations which forbid coming as close to the IP as ambitionned*

  $\hookrightarrow$ **3DIT are expected to allow approaching much closer to the Interaction Point**



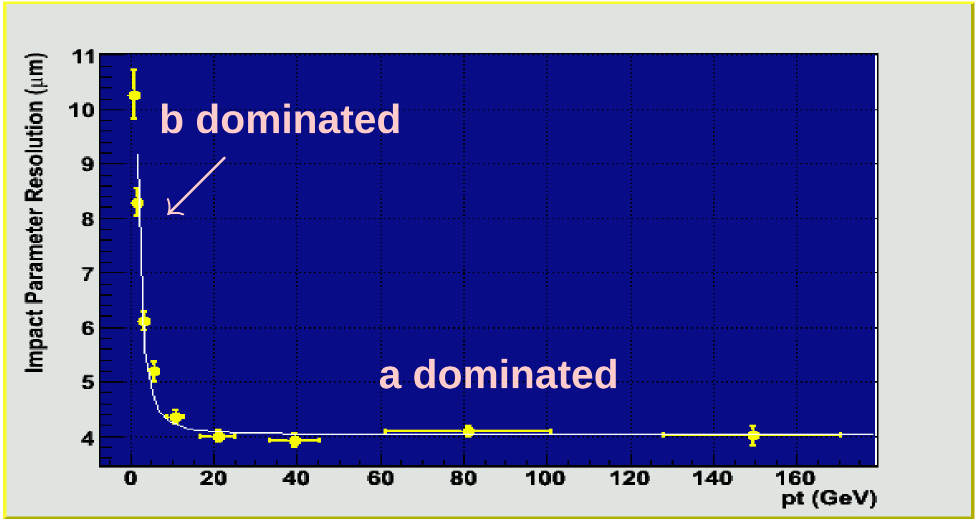
# Granularity and Transparency

- **How to achieve high spatial resolution : small pixels (pitch) and reduced material ($\equiv$ weight)**

$\hookrightarrow$ *Figure of merit :* $\sigma_{\mathbf{ip}} = \mathbf{a} \oplus \mathbf{b}/\mathbf{p_t}$ $\rightarrowtail$ $\mathbf{b}$ *governs low momentum (~ 30 % particles < 1 GeV/c)*

$\mathbf{a}$ *governs high momentum*

| Accelerator | a ($\mu m$) | b ($\mu m \cdot GeV$) |
|---|---|---|
| LEP | *25* | *70* |
| SLD | *8* | *33* |
| LHC | *12* | *70* |
| RHIC-II | *14* | *12* |
| ILC | $<$ *5* | $<$ *10* |




- **Expectations from 3DIT :**

  ◇ *high degree of functionnality integration in very small pixels* $\rightarrowtail$ $\mathbf{a} \searrow$

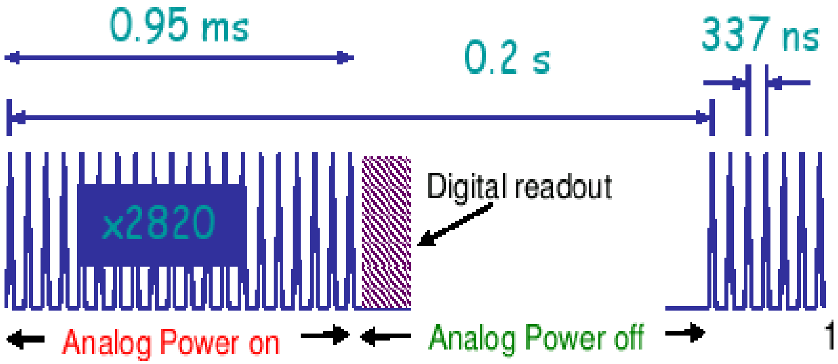
  ◇ *thinning and connection technologies allowing very low material budget* $\rightarrowtail$ $\mathbf{b} \searrow$

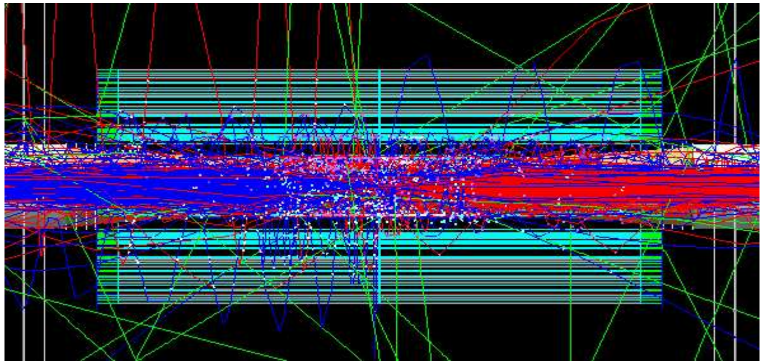
# Ultimate Goal : N.N. in Pixel

- **Goal $\equiv$ achieve very fine grained and thin pixels with fast and sensitive decision capacities**

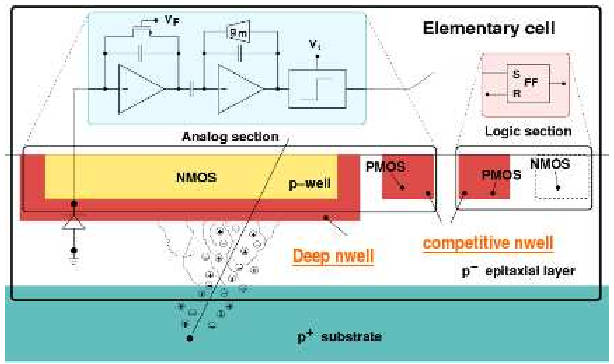
  ◇ *ILC time structure includes 5, $\sim$ 1 ms long, "trains" made of $\sim$ 3000 bunch crossings / second*

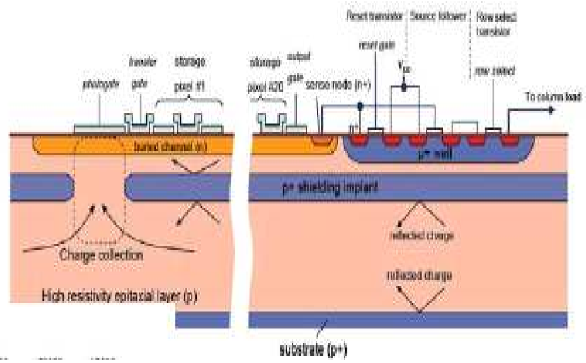
  *$\rightarrowtail$ only a few contain relevant Physics info. but all contain large amounts of Background $\longrightarrow$ remove them !*



◇ *Integrate in each pixel :*  *for zero suppression, ADC and time stamp (bunch crossing nb)*

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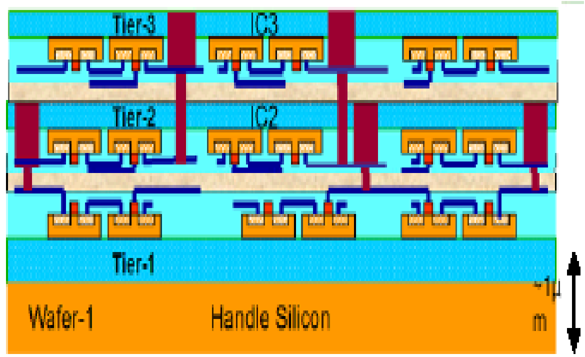



**Today :** *CMOS pixels with shaping + discri.* *CCD pixels with memo. & delayed r.o.* $\rightarrowtail$ **Tomorrow :** *3D pixels*

- **Minimise multiple scattering inside detector material wherever possible ($b \searrow$)**

  $\hookrightarrow$ *thickness, amount and choice of material for mechanical support, gluing, electrical connexions, thermal conductivity, power dissipation (avoid active cooling), ...*

- **Goal : $<$ 0.2 % radiation length / layer** *(including chip + support + services) ( $\Leftrightarrow$ $<$ 200 $\mu m$ of silicon )*

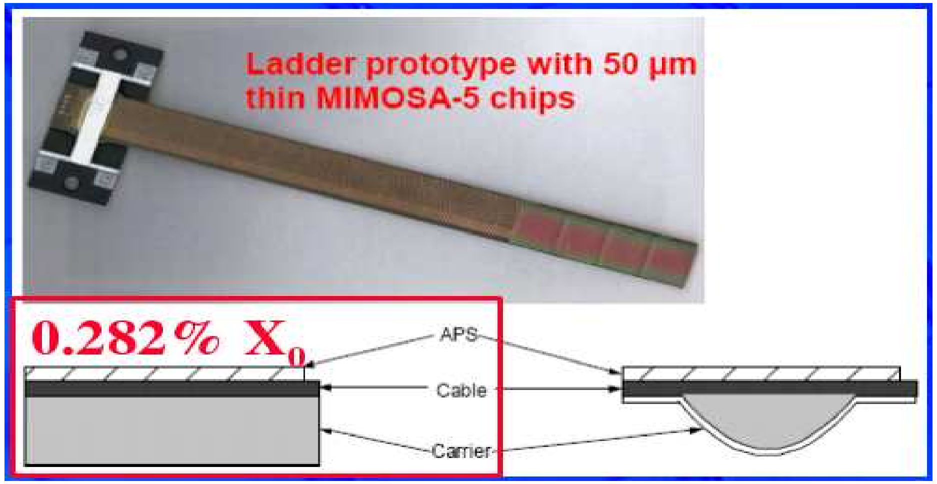
- **Presently $<$ 3 % seems achievable** *(STAR vertex detector)*

- **STAR ladder : kapton cable contributes with 0.090 %**

  **and carrier with 0.110 % of radiation length**

  $\Rrightarrow$ **replace them with aluminised CVD diamond ?**

  $\hookrightarrow$ *bonus in thermal transport*

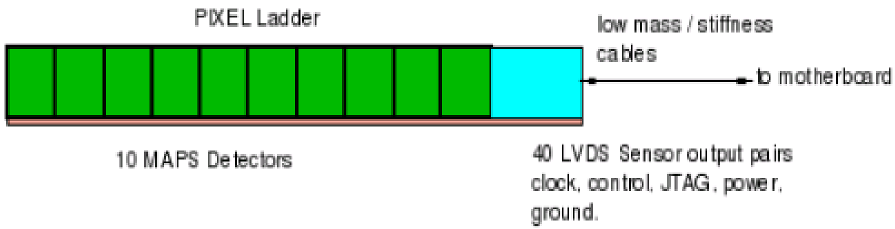



- **(CMOS) Sensor fabrication yield is a concern**

  $\Rrightarrow$ **diced sensors prefered to stitched sets of 5–10 sensors**

  $\hookrightarrow$ **inactive zones ($\gtrsim$ 40 $\mu m$ wide ) at sensor edge from dicing**

  $\Rrightarrow$ **can these zones be reduced to $\lesssim$ few $\mu m$ with plasma etching ?**



# The Economy of Material Budget

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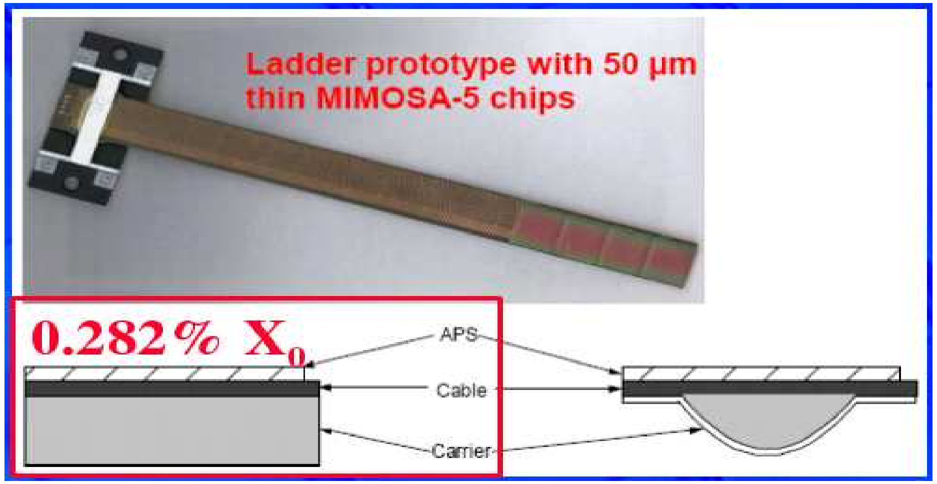


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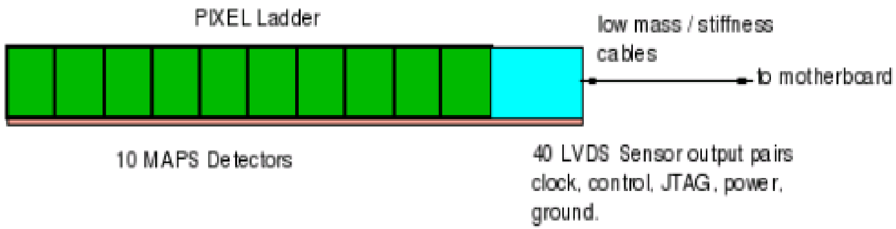



► **3D Integ. Techno. include thinning and dicing capacities of great interest**

- **Provided signal identification (zero suppression) and formatting can be achieved right near the sensing volume, pixels can even be used on large areas, translating into improved spatial and temporal resolution**
  *( watch power consumption and material budget ! )*

- **Sub-Detectors evolving towards pixel sensing :**

  ◇ **Si strip detectors $\rightarrowtail$ 3D Pixel Arrays**

  *( LPNHE )*

  ◇ **TPC read-out system $\rightarrowtail$ pixellised anodes (TimePix) combined with $\mu$Megas chambers**

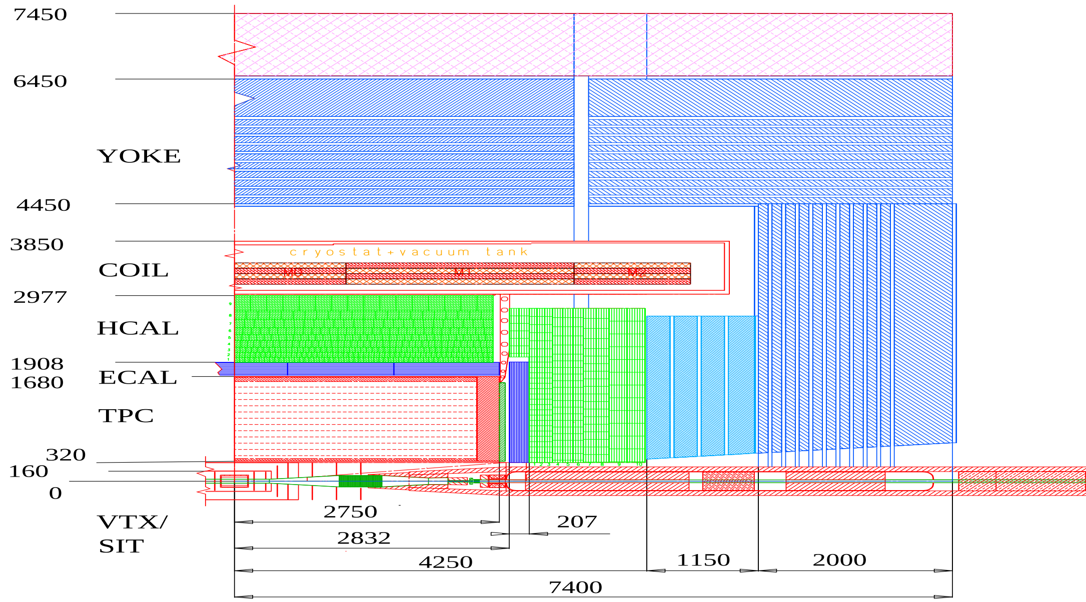
  *( LAL, DAPNIA )*

  ◇ **VFCAL (5–30 mrad) $\rightarrowtail$ radiation hard pixels**

  **$\gtrsim 10^5$ e$^+$e$^-$ pairs (5 GeV) per $\mu s$**

  **$\Rrightarrow$ 3D integrated read-out would improve SNR by removing bump bondings & long cables**

  *( LAL )*



# Summary & Outlook

- **ILC provides a framework for very challenging R&D on 3DIT at the world wide scale**

  $\Rrightarrow$ **unprecedented performances expected**

- **The R&D addresses two areas: Pixel and System integration performances**

- **Time line of ILC allows for two steps :**

  ▷ **evaluate the R&D potential for ILC** *(together with LHC activity)*

  ▷ **contribute to technology evolution** *( Ex: specific designs, prototype characterisation )*

  $\Rrightarrow$ **R&D supported by large E.U. programme**

- **Numerous spin-offs** $\rightarrowtail$ **imaging** *( see talk by R.Barbier )*

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**Great opportunity to work together for the benefit**

**of fundamental science and technology**