TREND IN HEP DETECTOR R&D

Junji Haba

KEK Detector Technology Project

These days there are so many regular **Detector** conferences, workshops…

- General topics only
  - IEEE Nuclear Science Symposium And Medical Imaging Conference (NSS MIC 20xx)
  - Topical Seminar On Innovative Particle And Radiation Detectors (Siena.. IPRD XX)
  - International Conference On Technology And Instrumentation In Particle Physics (TIPP XX)
  - Vienna Conference on Instrumentation (Vienna VCI 20XX)
  - *International Conference on Advanced Technology and Particle Physics* ICATPP (Villa Olmo)
  - International Conference On Instrumentation For Colliding Beam Physics (INSTR XX)
  - Pisa Meeting on Advanced Detectors (Elba)
  - Symposium On Radiation Measurements And Applications (SORMA XI)

- Photon
  - International Workshop On New Photon Detectors (PD07)
  - 1st Workshop On Photon Detection For High Energy, Medical And Space Applications
  - 5th International Conference On New Developments In Photodetection (NDIP08)
- Calororimeter
  - 12th International Conference On Calorimetry In High Energy Physics (CALOR 06)
- Gaseous
  - 3rd Symposium On Large TPCs For Low Energy Rare Event Detection
  - Micro-Pattern Gas Detectors (RD51) Workshop
  - International Conference on Micro Pattern Gaseous Detectors (MPGD 20XX)
- Vertex/Pixel/3D
  - VERTEX 2006: 15th International Workshop On Vertex Detectors
  - Vertex 2007: 16th International Workshop On Vertex Detectors
  - 6th International Symposium On The Development And Applications Of Semiconductor Tracking Detectors (STD6 Hiroshima)
  - 8th International Conference On Large Scale Applications And Radiation Hardness Of Semiconductor Detectors (RD 07)
  - 6th International Conference On Radiation Effects On Semiconductor Materials, Detectors And Devices
  - PIXEL 2008: International Workshop On Semiconductor Pixel Detectors For Particles And Imaging

Almost impossible

~~Too hard~~ to review this active field in only 20min.

- Previous talk successfully gave experimentalist a clear image of
- String theory

This talk

For theorist to learn how to cook the strings with modern detectors

For a comprehensive view,
attend new series of IUPAP conference

Technology and Instrumentation in Particle Physics

Chicago,
June 2011

What to measure with detectors?

- *Two Lorentz four vectors,* x_μ and p_μ

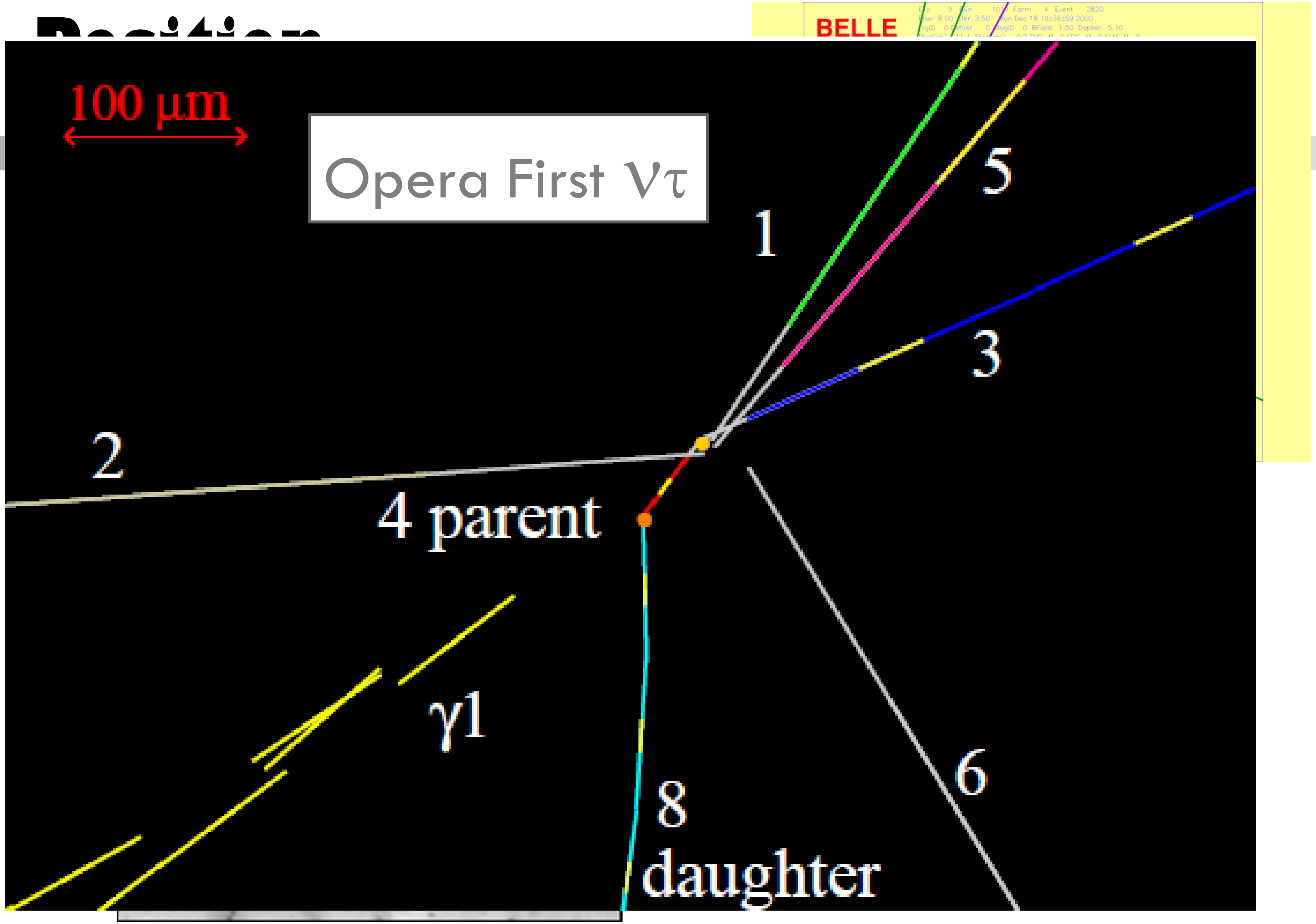
  (theorists know well) or

  (t,$\boldsymbol{x}$) and (E, $\boldsymbol{p}$):

  time, position, energy and **momentum**

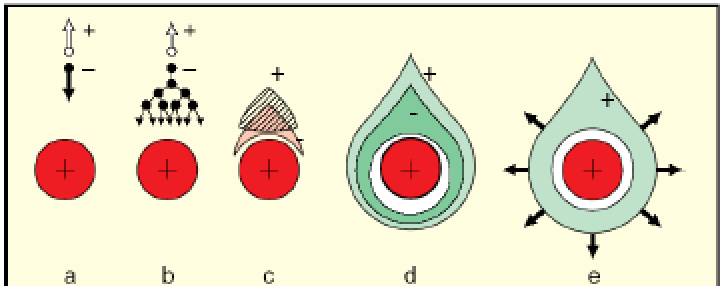
- That's it ?

  Q (charge) and ***mass*** (particle species) necessary for Particle identification. To be skipped today.


BELLE
100 μm
Opera First ντ
1
5
3
2
4 parent
γ1
8
daughter
6

1968: Georges Charpak revolutionizes detection

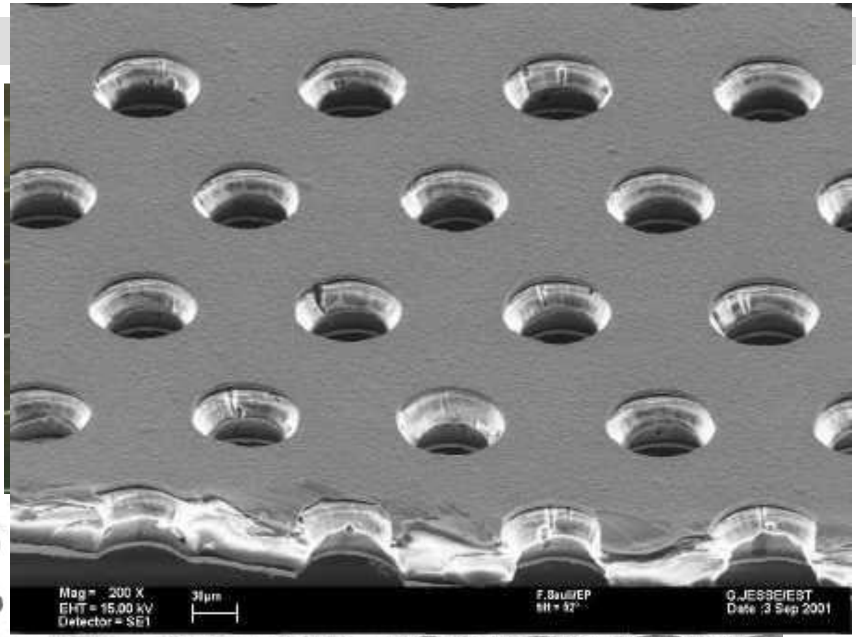
- In the 1960s, detection in particle physics mainly involved examining millions of photographs from bubble chambers or spark chambers. This was slow, labour intensive and not suitable for studies into rare phenomena.
- However, the revolution in transistor amplifiers was to trigger new ideas. While a camera can detect a spark, a detector wire connected to an amplifier can detect a much smaller effect. In 1968, Georges Charpak developed the 'multiwire proportional chamber', a gas-filled box with a large number of parallel detector wires, each connected to individual amplifiers. Linked to a computer, it could achieve a counting rate a thousand times better than existing detectors. The invention revolutionized particle detection, which passed from the manual to the electronic era.
- (CERN archive)

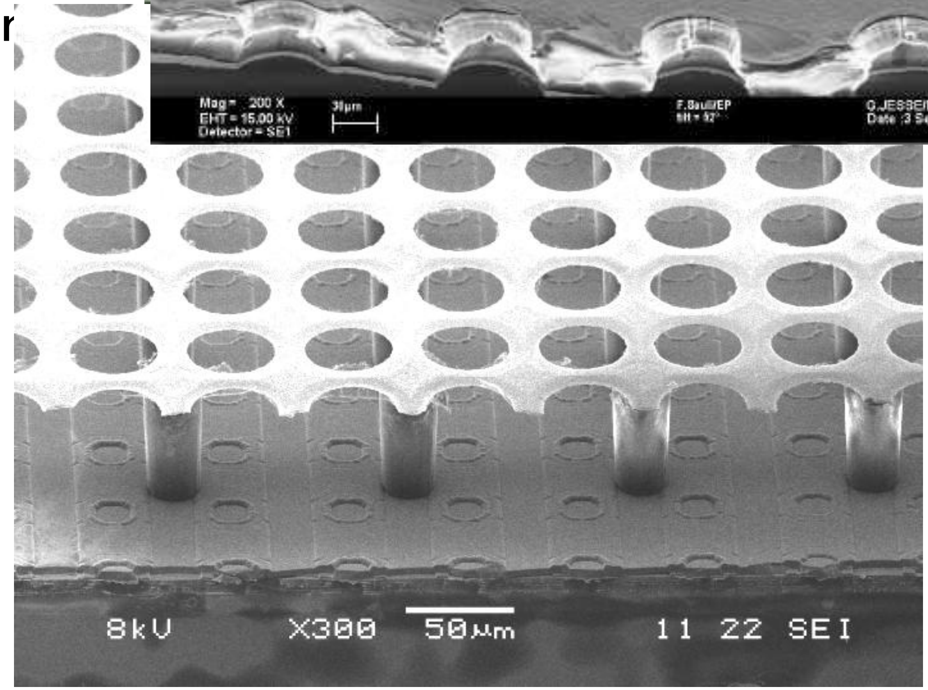


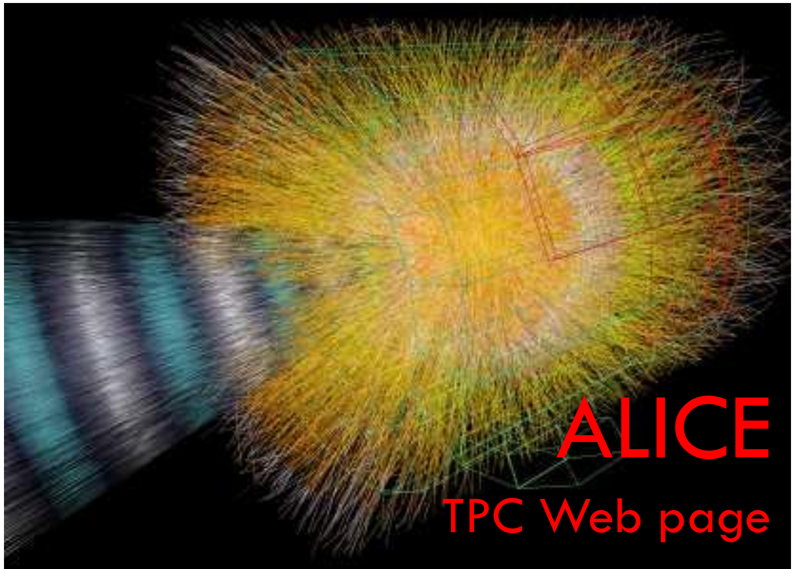
Detectors @High luminosity

More and more particles occupy the elements

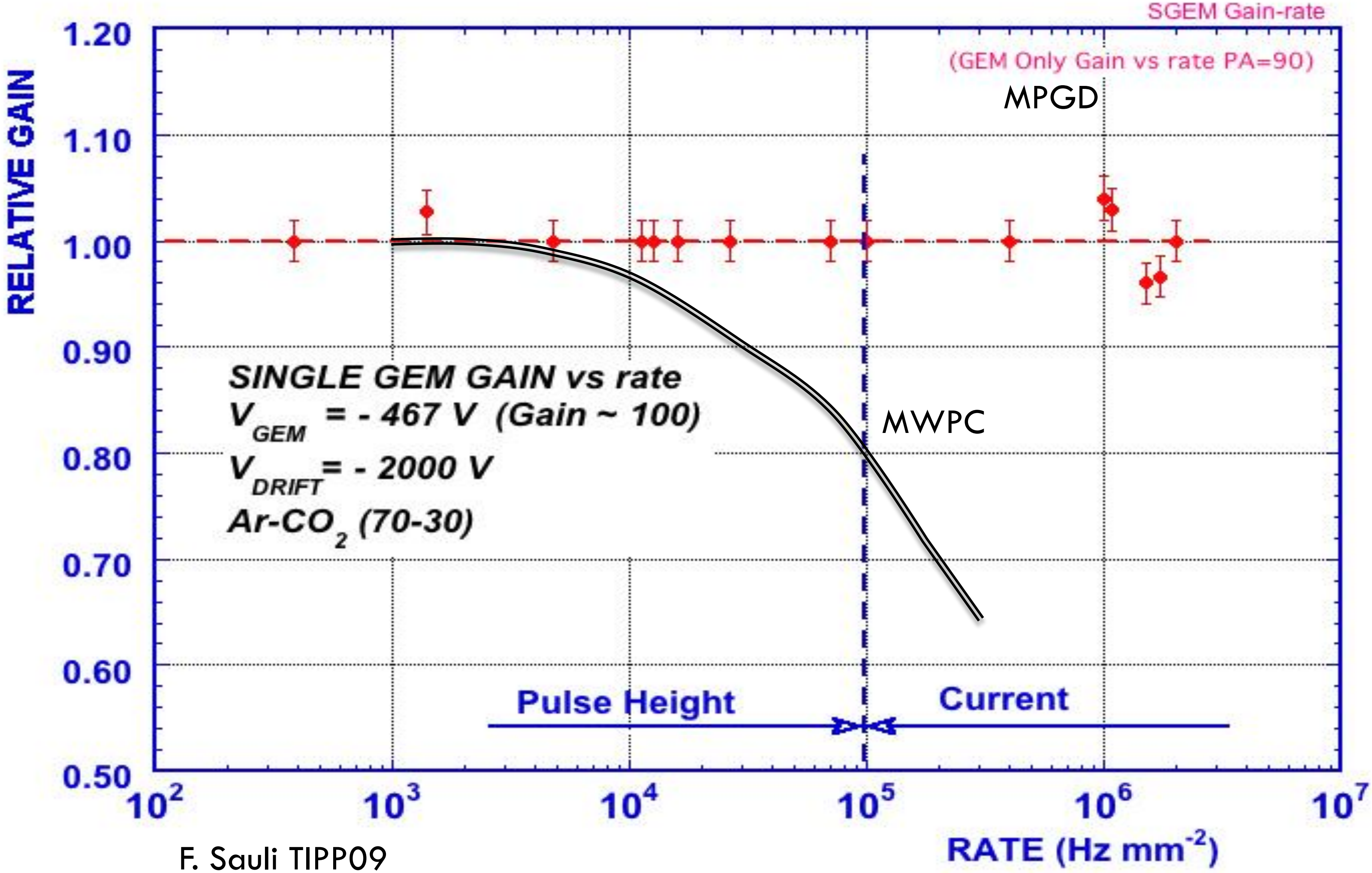
- Higher rate, high occupancy
  - 1D easily saturated→ 2D
    - Wire chamber →Wireless MPGD
    - Silicon strip → pixel
    - To distribute hits in 2D elemer





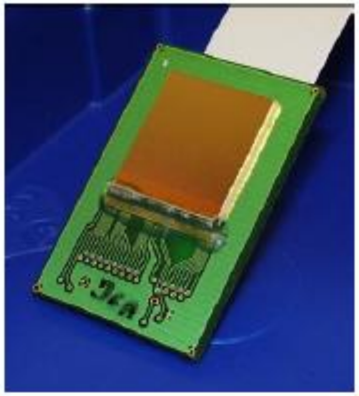


Wireless chambers, MPGD



F. Sauli TIPP09

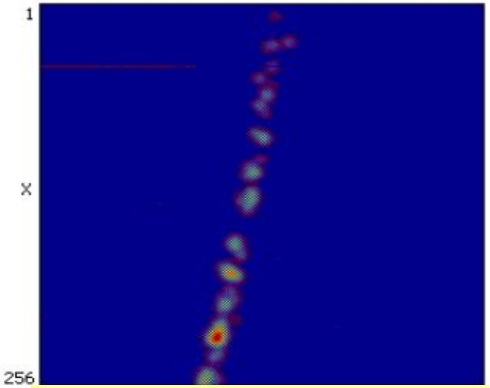
Very fine but small



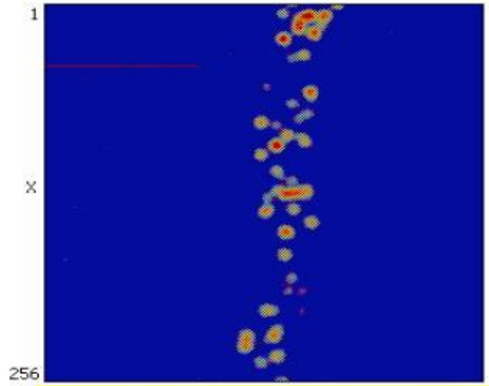
Timepix derived from Medipix-2

256 × 256 pixel of size 55 × 55 μm²

Each pixel can be set to:
- Hit counting
- TOT ≈ integrated charge
- Time between hit and shutter end



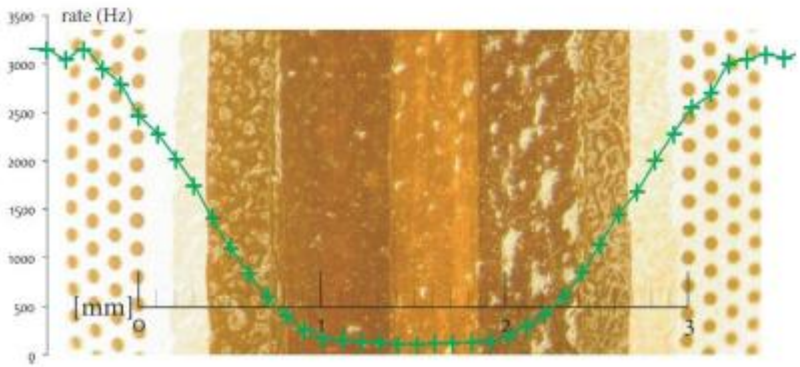
Short Drift



Long Drift

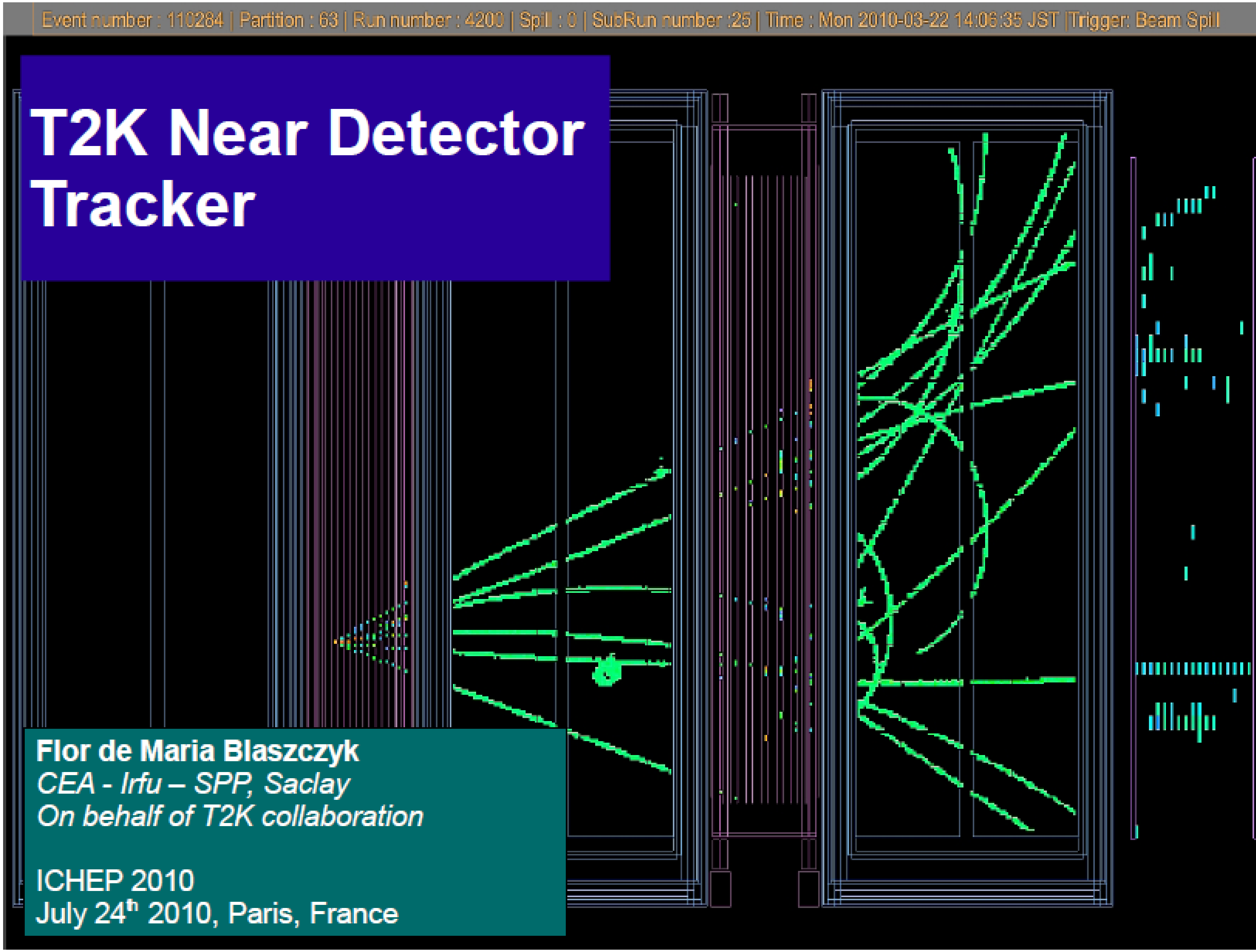
Larger

- The base material is only 457 mm wide
- Get larger width by splicing GEMs
- 2 mm wide kapton overlay on GEM edges
- Pressed and heated up to 240 °C



Spherical

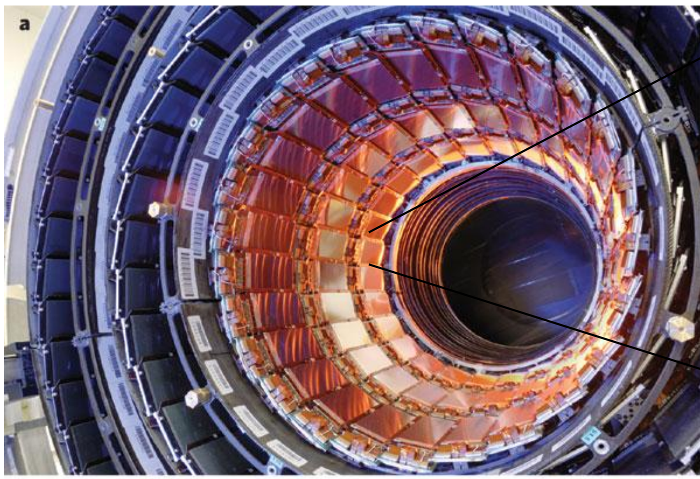
J. Kaminski

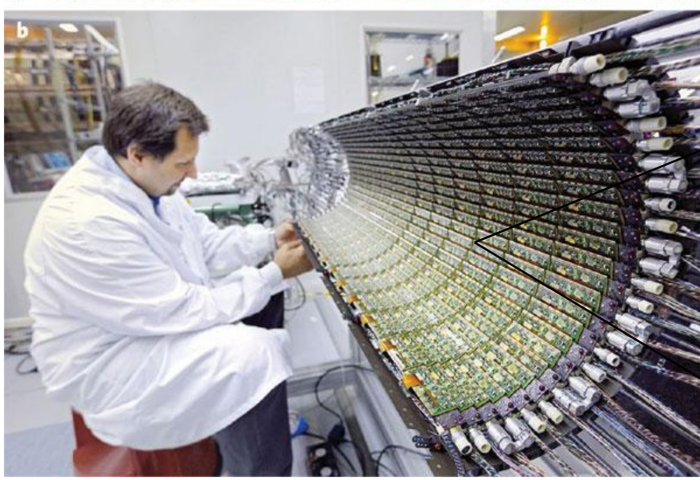


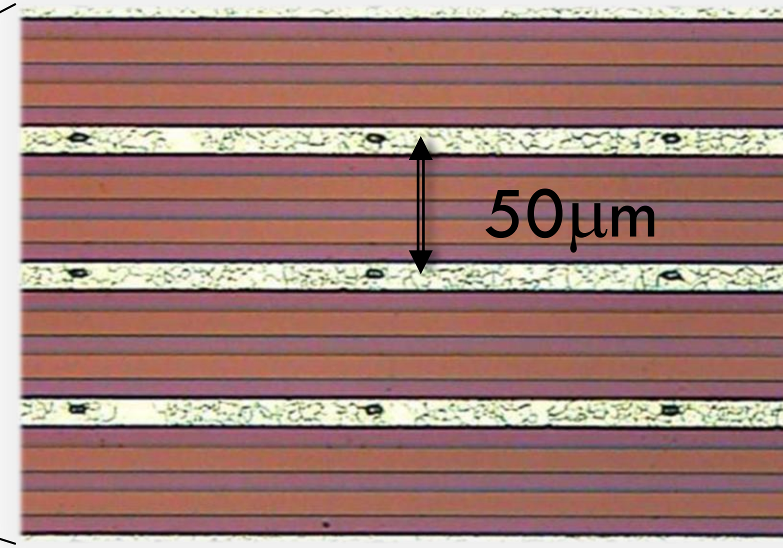
Large area MicroMegas successfully applied in the T2K TPC

Silicon detectors also go 2D

Strip → Pixel







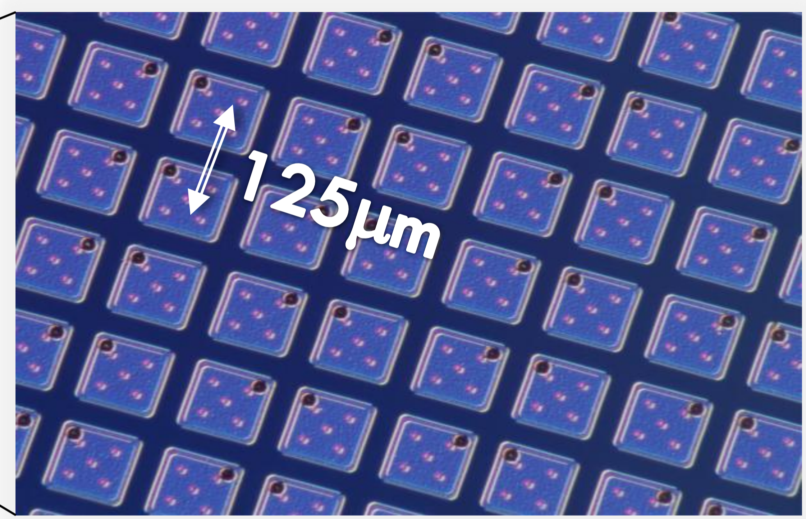
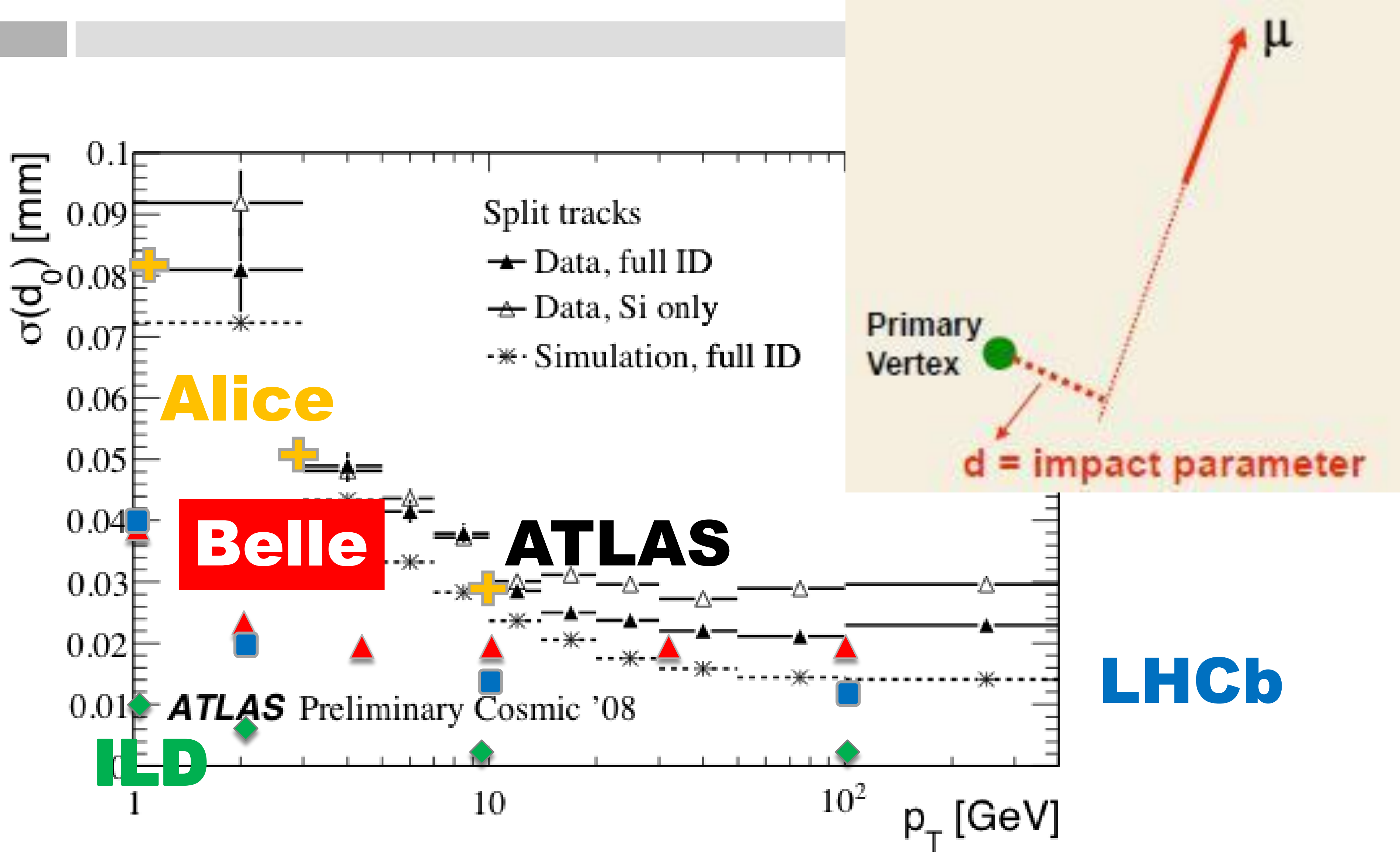


Photo from Stapnes, Nature 448

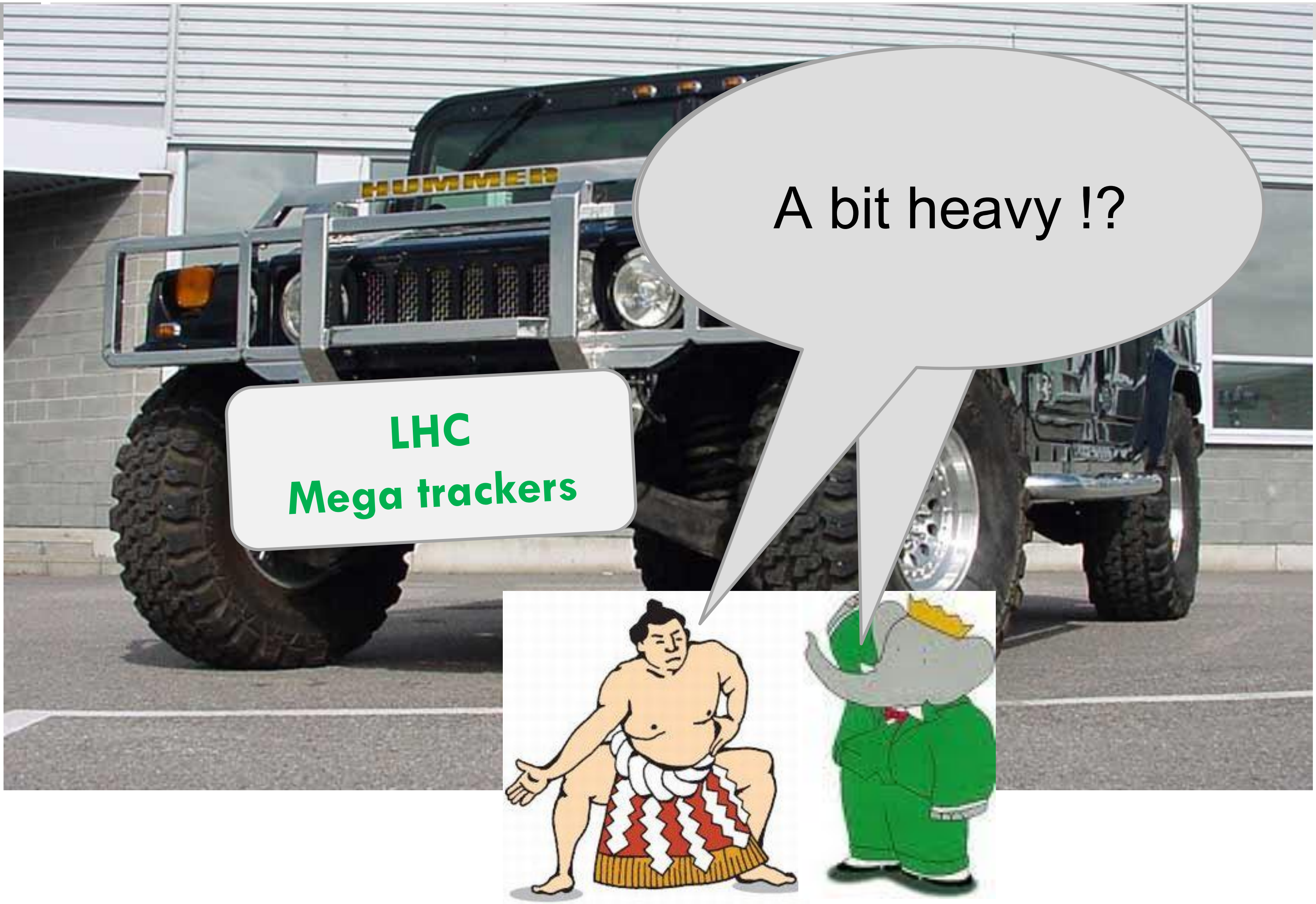
Tiny pixel modules, huge # of channels

		ALICE	ATLAS	CMS	LHCB
Pixel	# channels	9.8M	80M	66M	
	# modules	240	1788	1440	
Strips	# channels	2.6M	3.2m	9.3M	86k
	# modules	1698	4088	15148	43

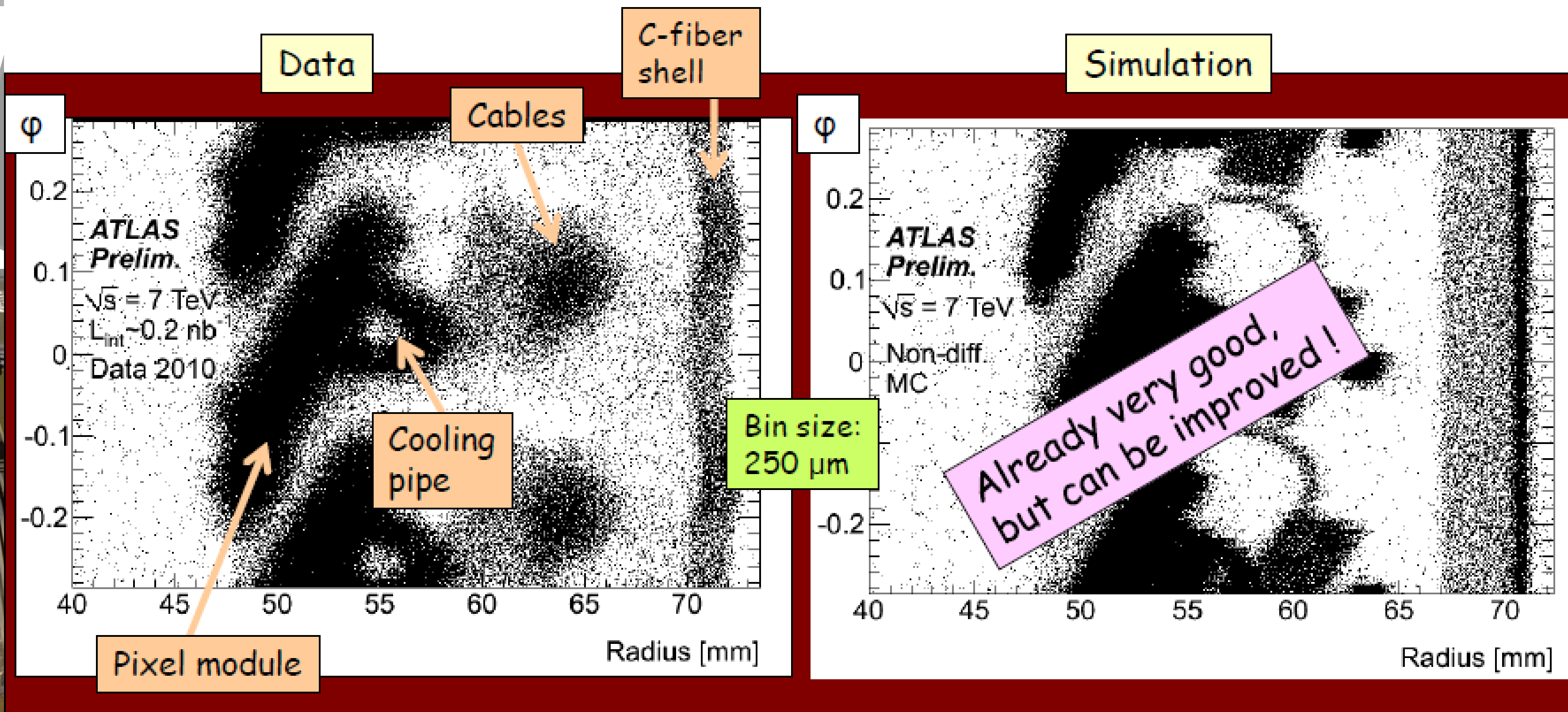
Impact parameter resolution



LHC detectors are miracles but …



Reconstructed secondary vertices due to hadronic interactions in minimum-bias events in the first layer of the Pixel detector
(sensitive to interaction length λ → complementary to γ conversion studies)

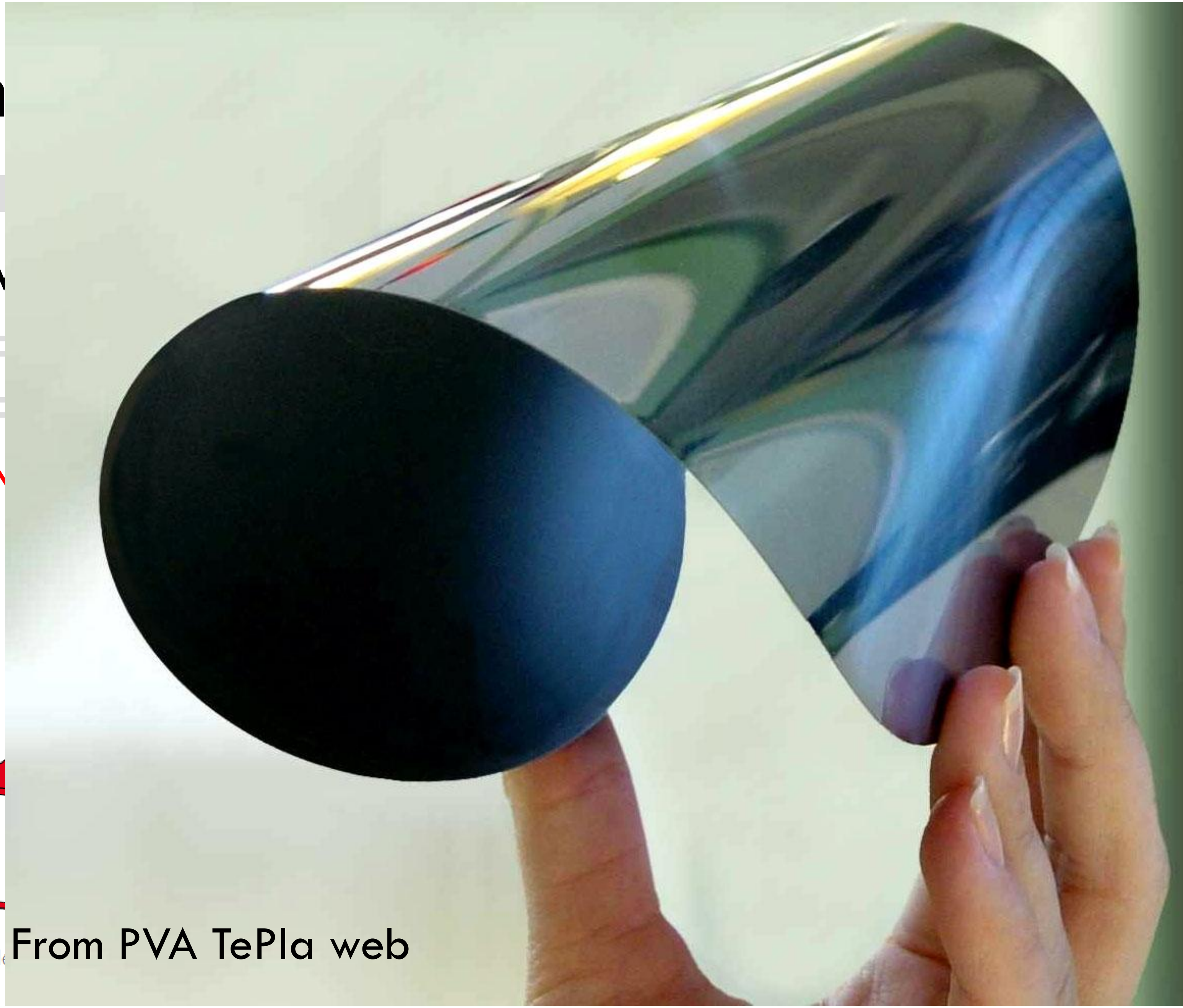


- ❑ Vertex mass veto applied against γ → ee, K_S^0 and Λ
- ❑ Vertex (R, Z) resolution ~ 250 μm (R <10 cm) to ~1 mm

Fabiola

Th

- M
- N



From PVA TePla web

Cl

DEPFET

Highly Pixelated Transparent Devices for Future Vertex Detectors

Marc Winter (IPHC-Strasbourg)

(on behalf of the MIMOSA, PLUME, HP-2 & AIDA collaborations)

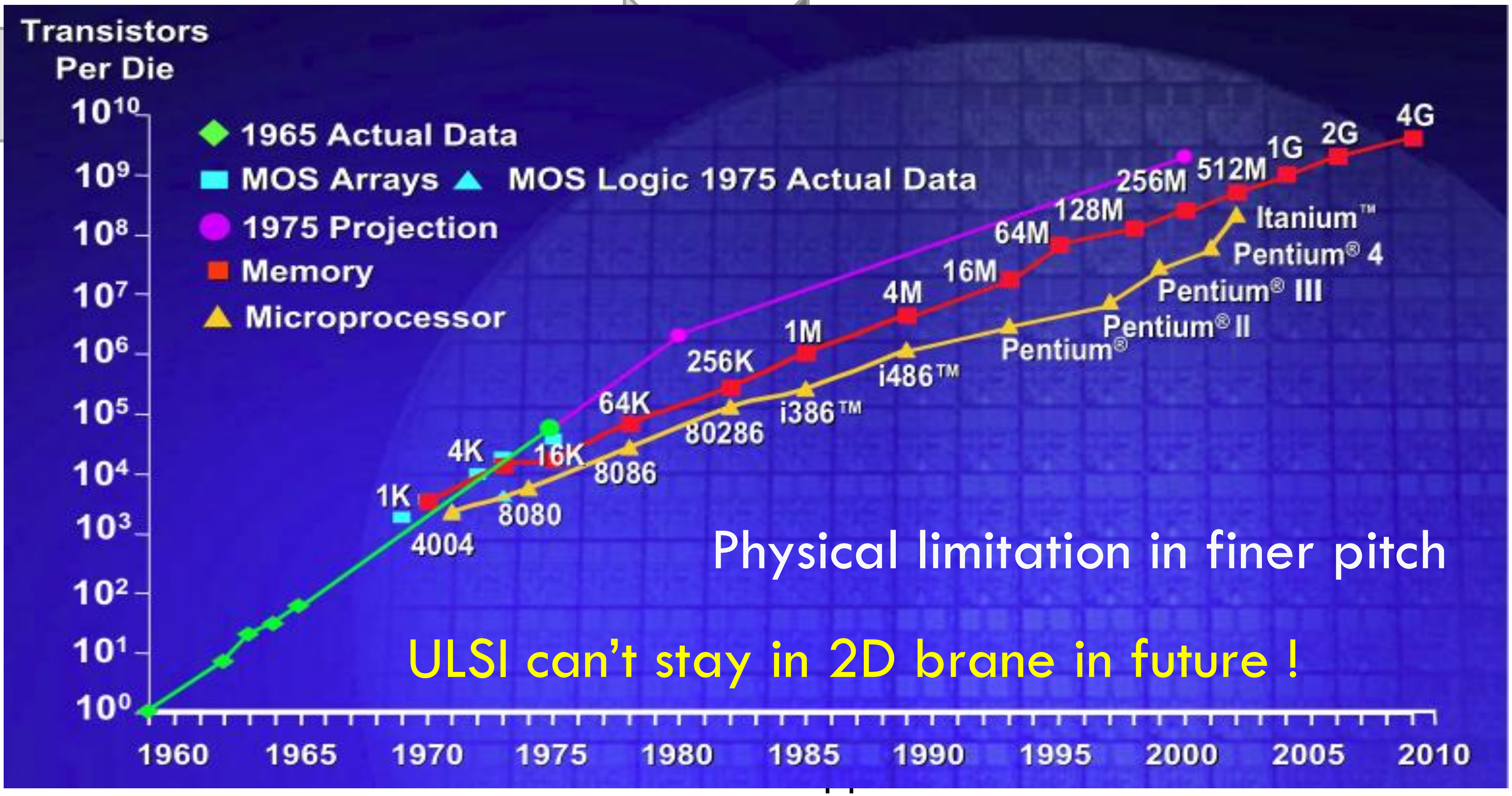
▷ more information on IPHC Web site: http://www.iphc.cnrs.fr/-CMOS-ILC-.html

CONTENTS

Talk given by Marc Winter in this conference

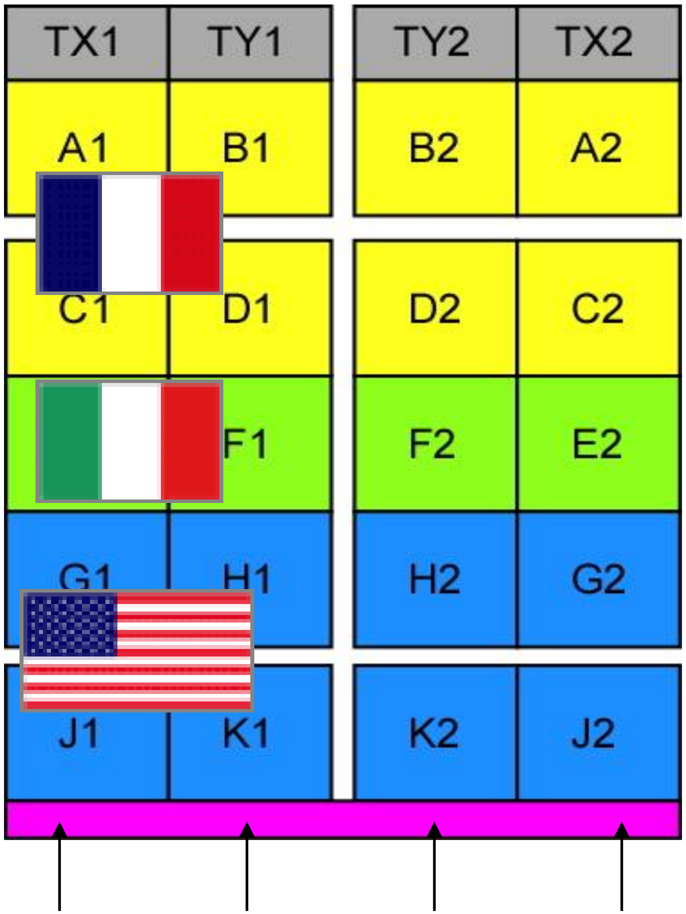
Need more and more functions
Vertical Integration comes next

- Moore's law ("Livingstone plot" in microelectronics) will be slowed down in 10 years only with "2D" technology

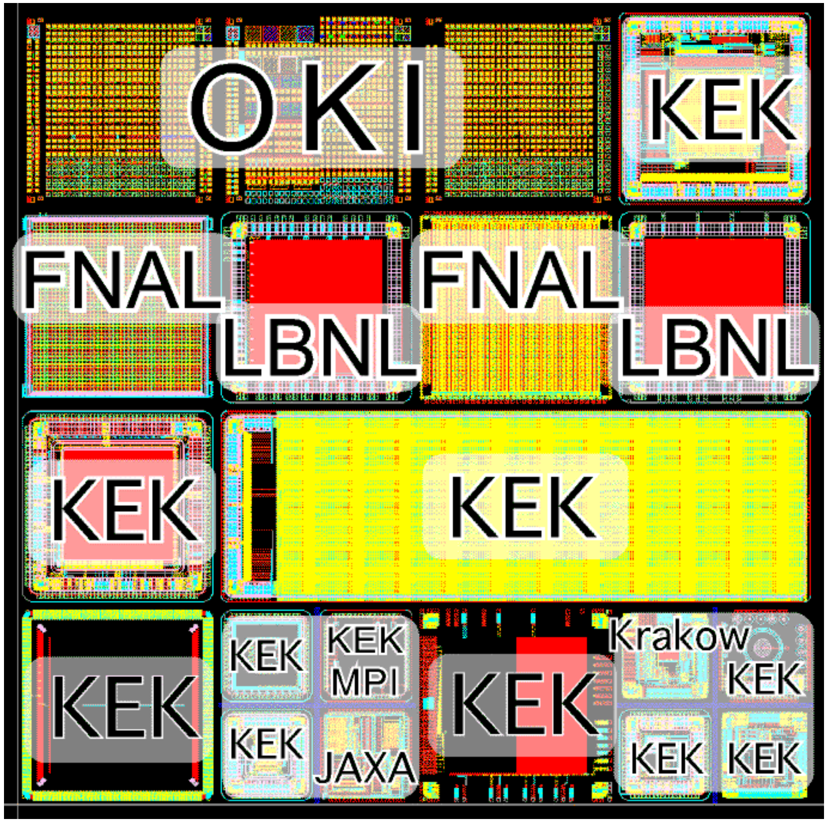


Multi Project Wafer (MPW) to share chip area and enormous cost

- 3DIC collaboration



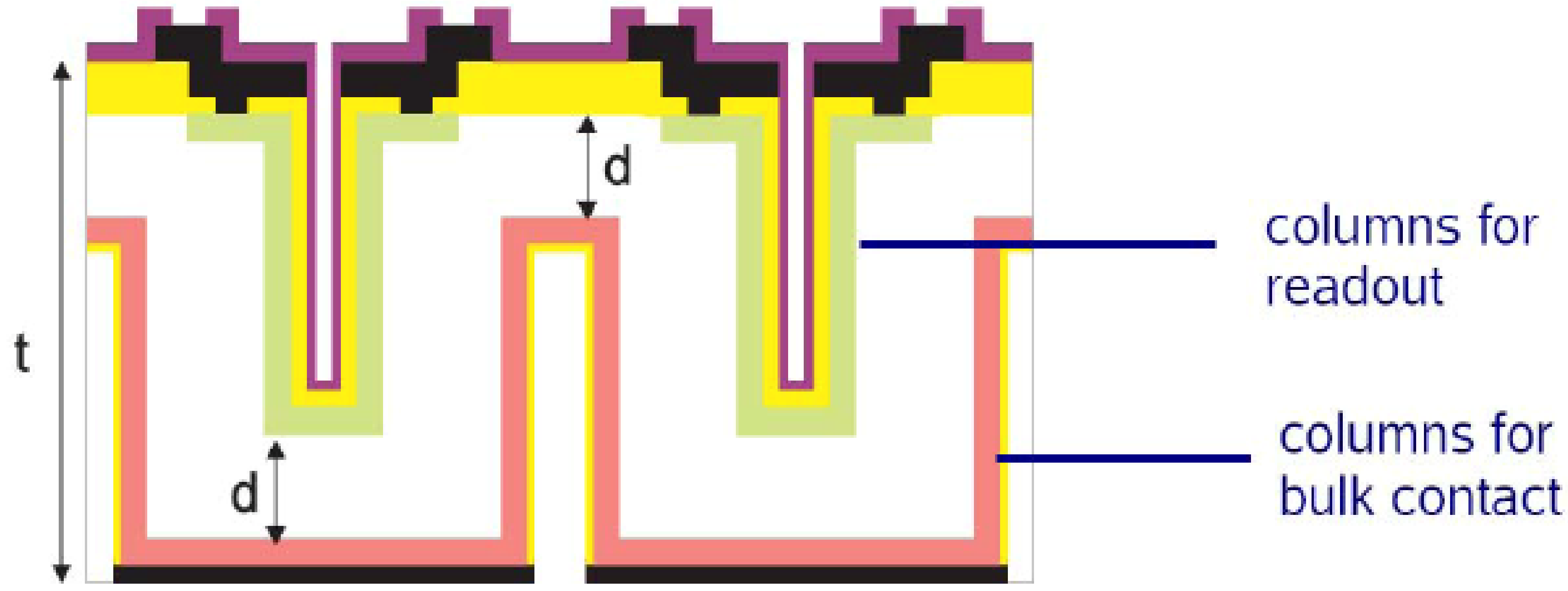
- SOI collaboration



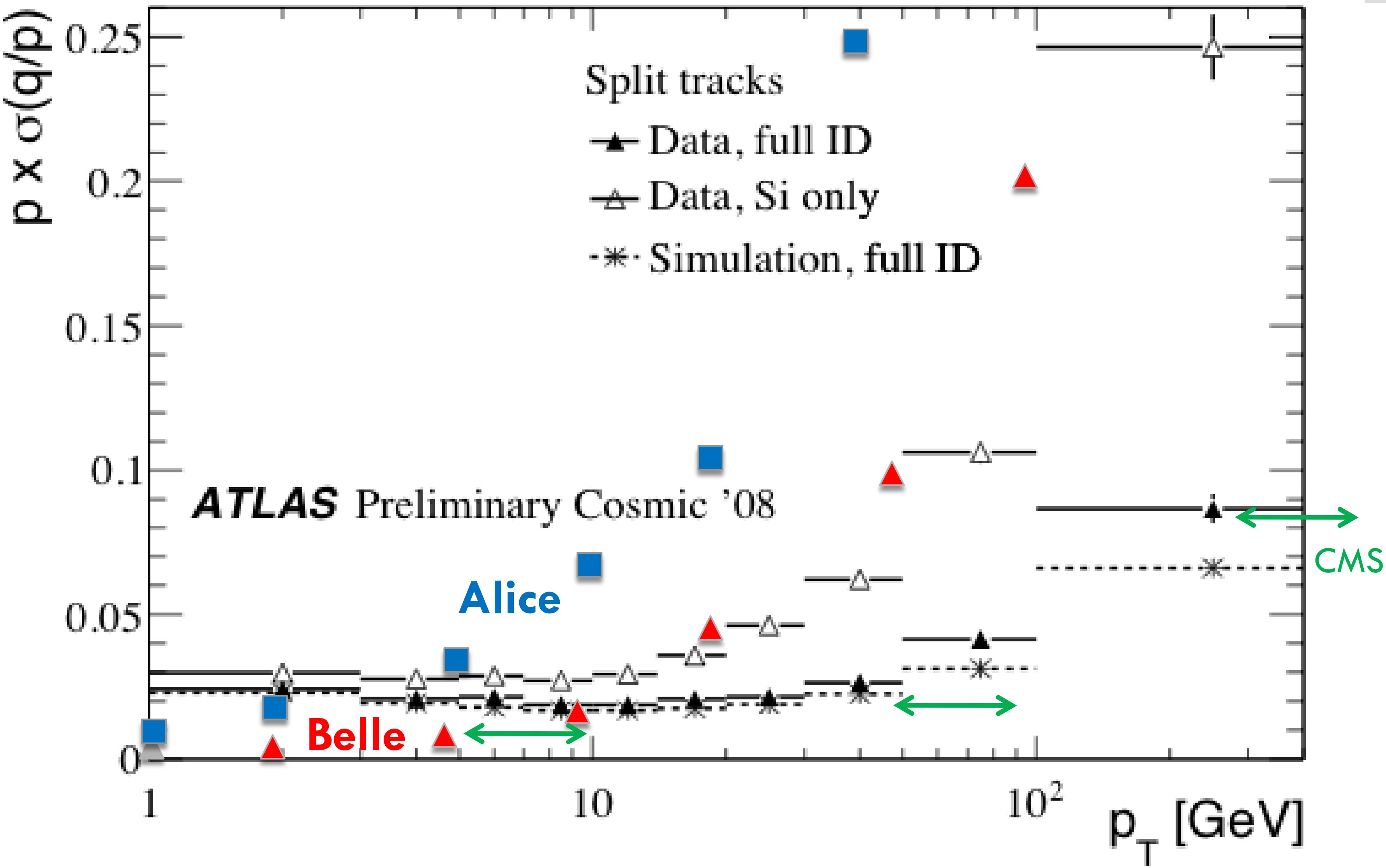
The tougher, the better

- Radiation tolerance is the most serious issue in
- (HL-)LHC
- (Super-)B-factory .

Or another type of 3D device

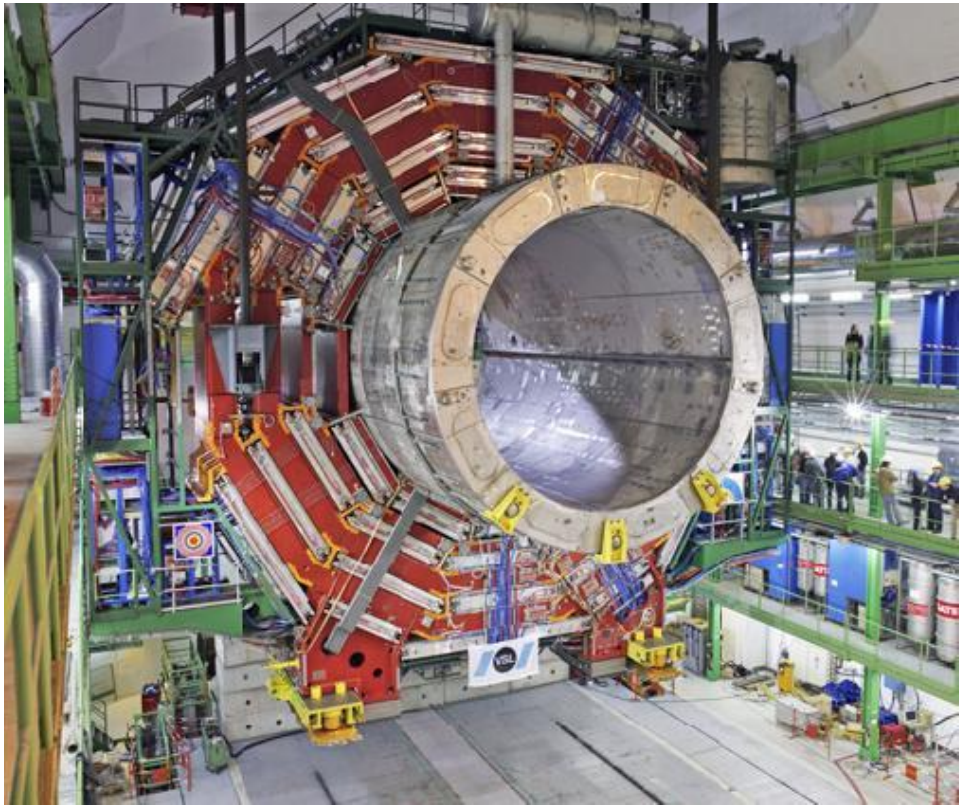


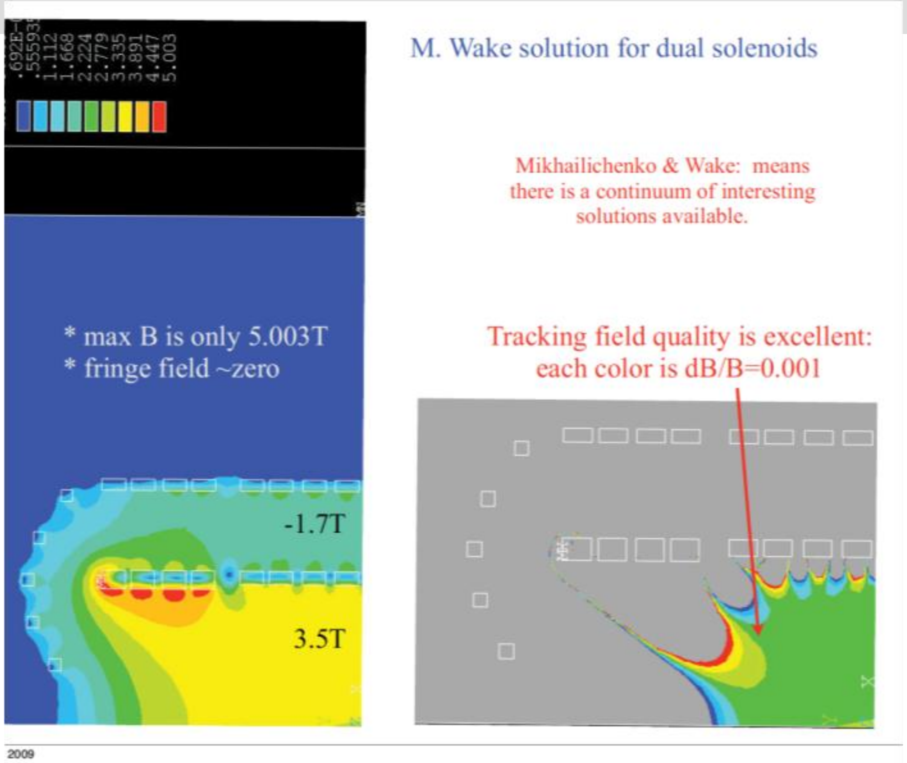
Momentum measurement



Advanced Superconducting Magnets

New conductor development for higher current density
(→higher magnetic field)
Nb3Sn, Nb3Al…



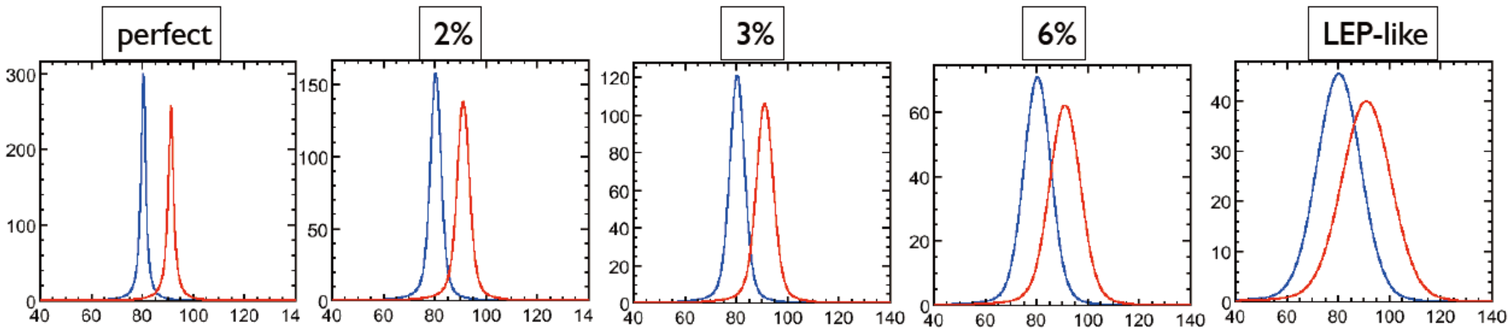


Dual solenoid (w/o yoke)
Popular in MRI system.

Energy measurement: ILC "requirement"

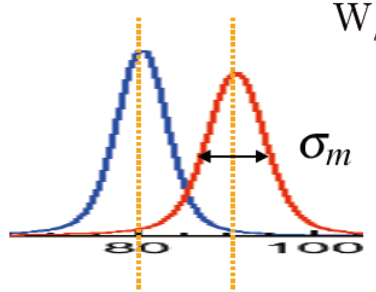
Mass Resolution: Requirements for separation

- Width of gauge bosons sets a natural scale for the required resolution

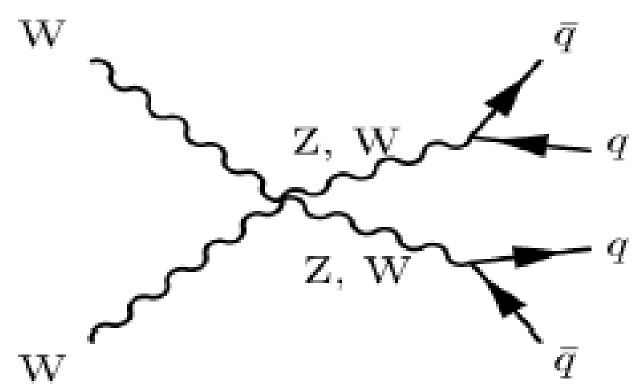


q

Jet E res.	W/Z sep
perfect	3.1 σ
2%	2.9 σ
3%	2.6 σ
4%	2.3 σ
5%	2.0 σ
10%	1.1 σ

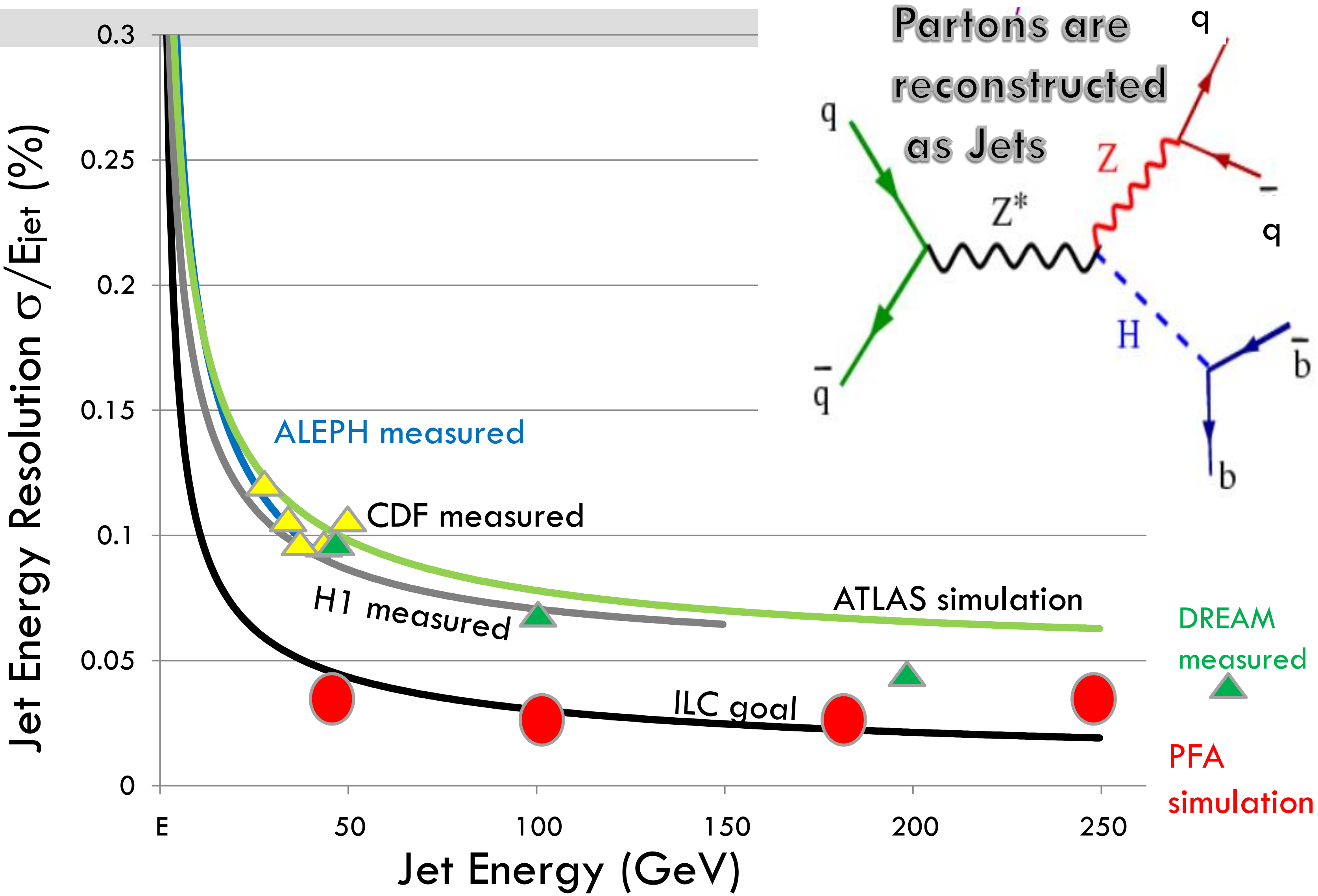


$$\text{W/Z separation} = (m_Z - m_W)/\sigma_m$$



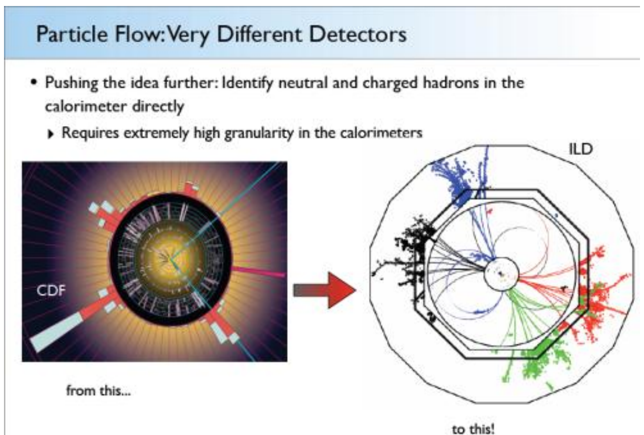
F. Simon from KEK seminar

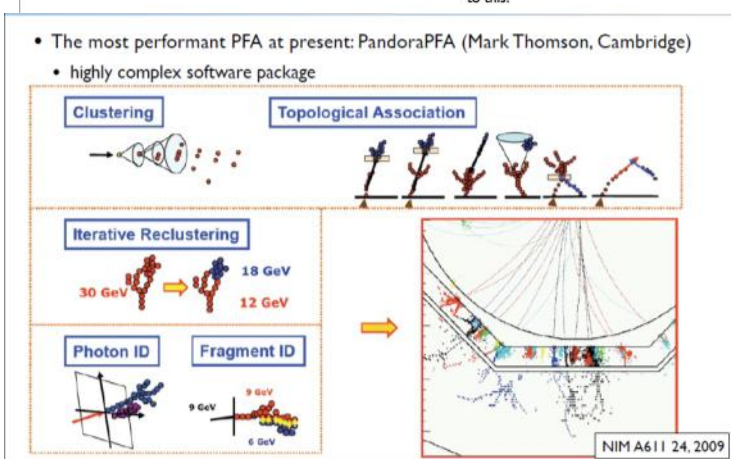
Jet energy resolution



Ideas for better calorimetry

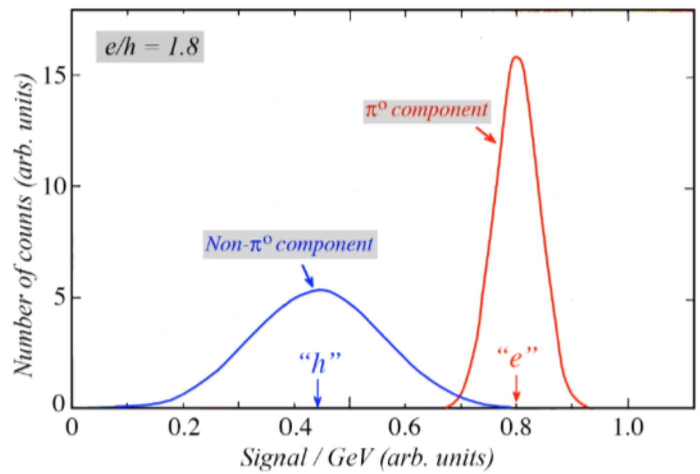
PFA（Particle Flow Algorithm)

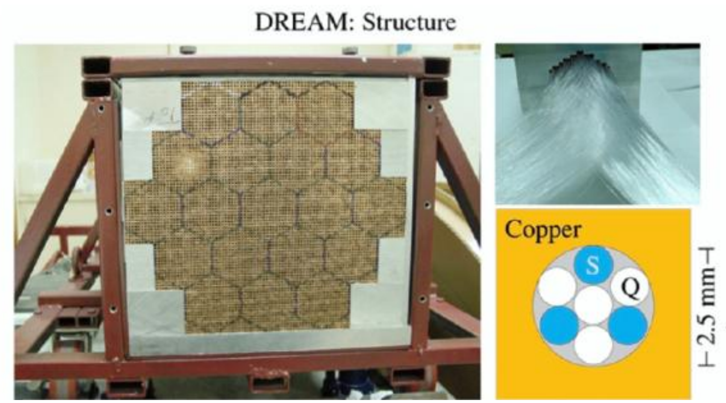




F.Simon, KEK seminar

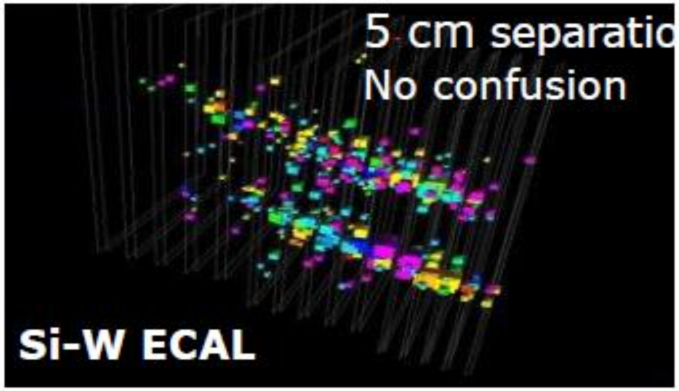
Dual Readout (not adopted in ILC)

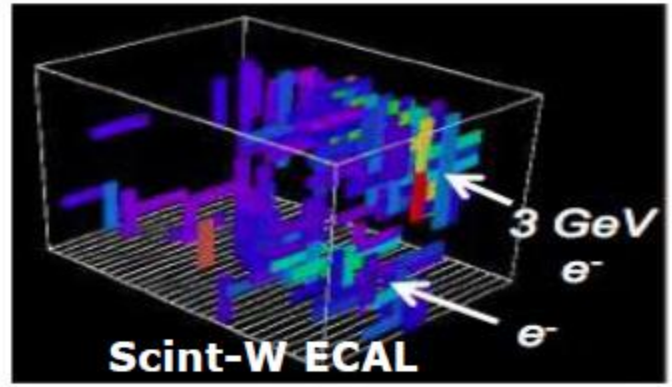




Richard Wigmans*
(Texas Tech University)

High granularity allows for particles separation and PFA application





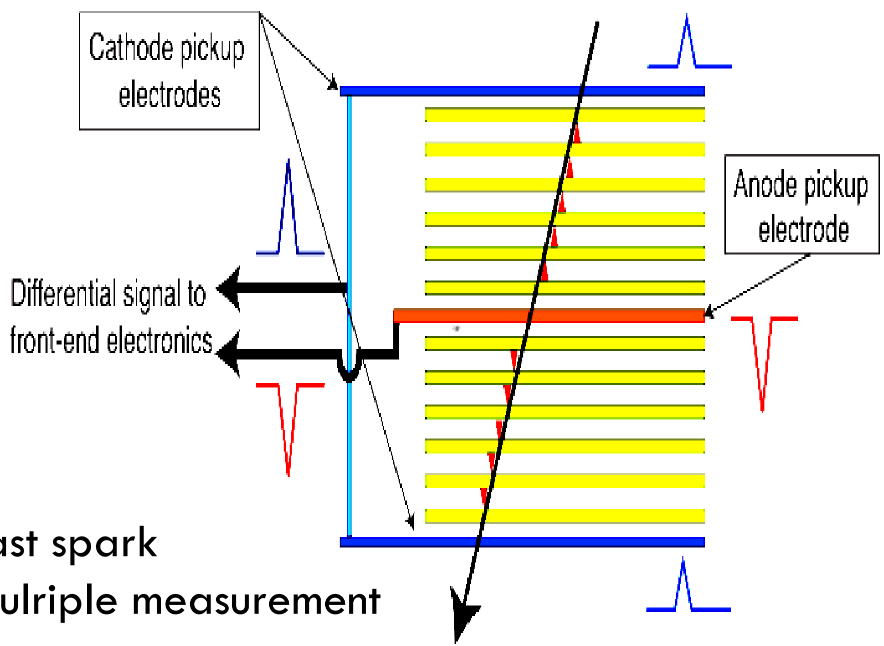
- Explosion of the channel count!
  - ILD: ~100 M channels in ECAL, ~10 M channels in the HCAL
  - Compare to LHC: CMS ECAL: 76 k channels, ATLAS HCAL: ~10 k channels

About a factor of 1000 more channels: A totally different calorimeter technology!

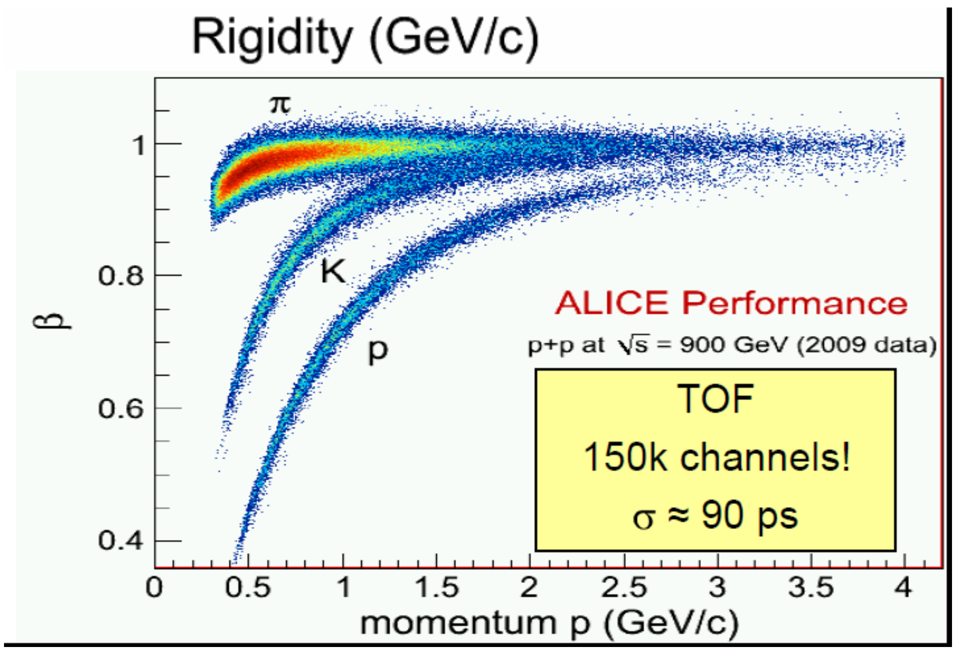
CALICE, talk given by Imad Laktineh in this conference

Time

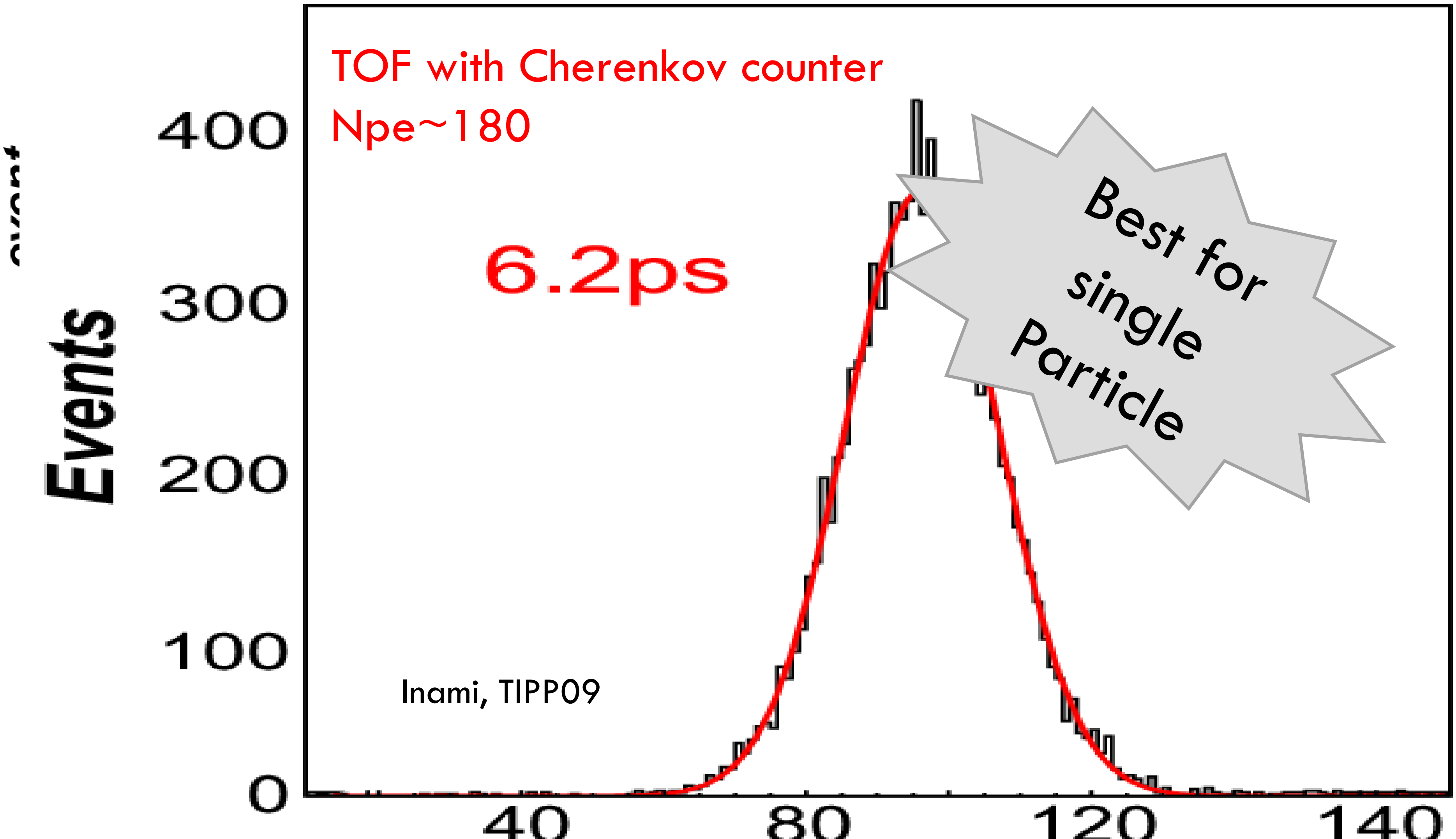
- Relevant scale in HEP experiment
  $t \sim L(m)/c \sim o(nsec)$
- Traditional technique
  - Scintillator + Photo Multiplier Tube ~o(100 *psec*)
- Breakthrough with a spark discharge in gas
  - Pestov counter → ALICE MRPC ~50*psec*



Fast spark
Mulriple measurement



Faster photon detections

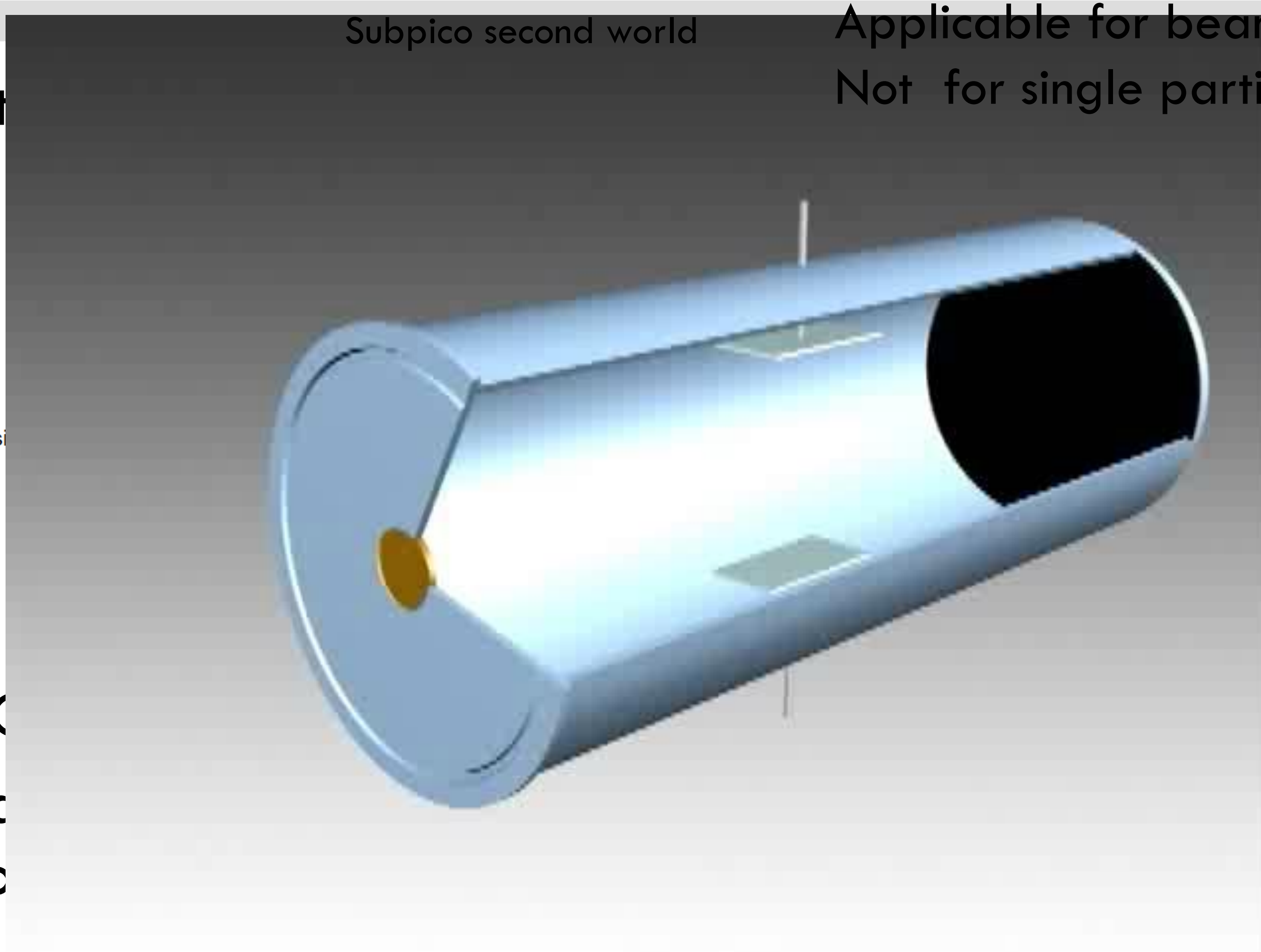


Further precision?

Subpico second world

Applicable for beam pulse
Not for single particle

- St



Light
intensi

on
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Time
Space

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- EC

Fo   e
fo

“Spin off” is another important key word for the HEP labs to survive…