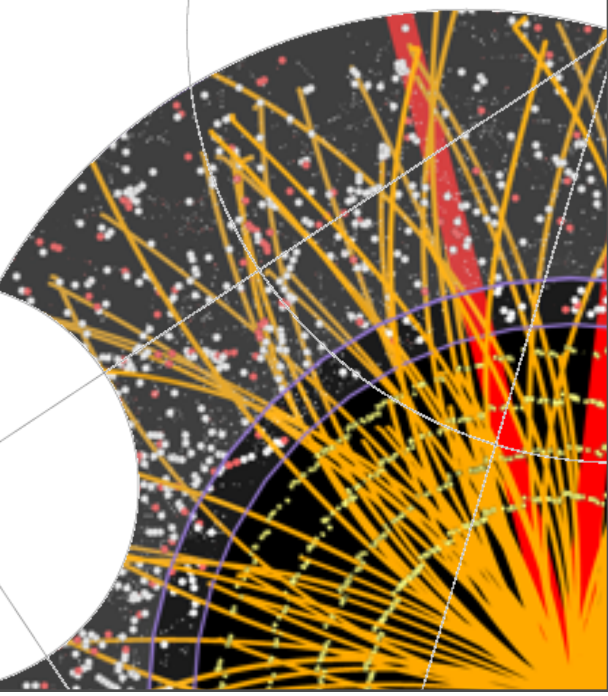
centre for particle physics Discovery

Future Accelerators and Detector Technologies

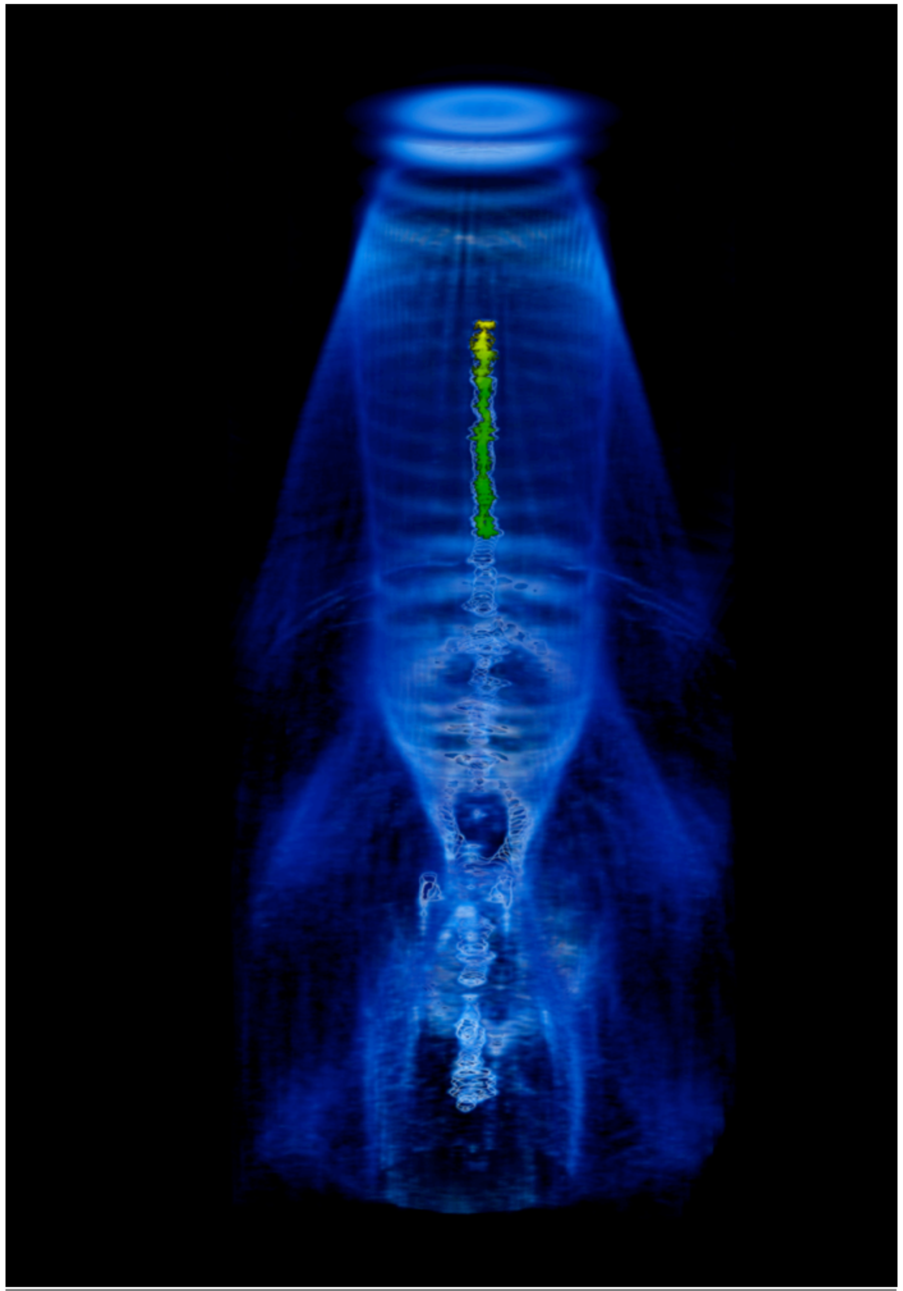
Morten Dam Jørgensen
Niels Bohr Institute
mdj@nbi.dk

ATLAS EXPERIMENT



Overview

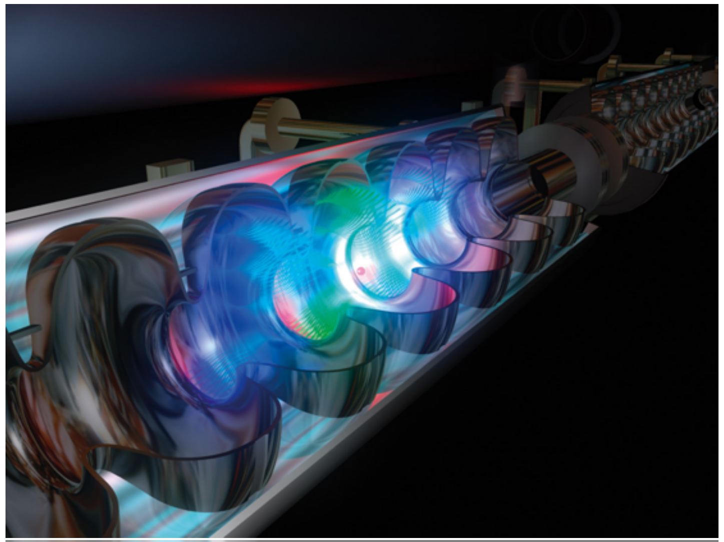
- Introduction
- Detectors
  - Tracking
  - Calorimetry
- Wakefield accelerators
- Where do we go from here?



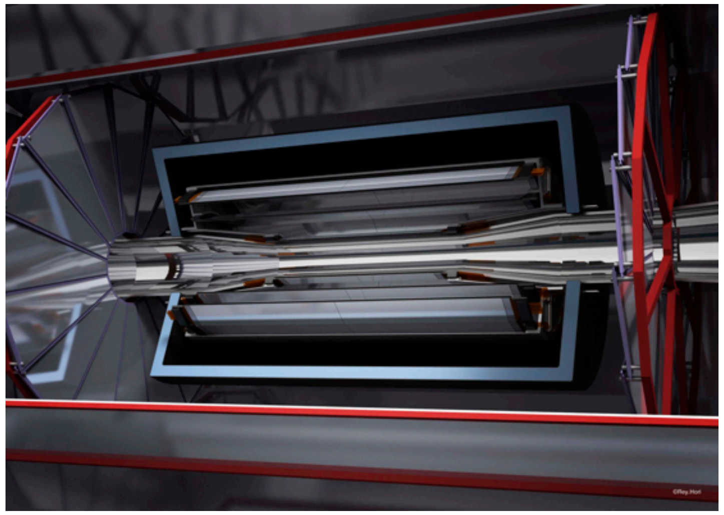
Laser induced plasma wakefield acceleration simulation

Introduction

- Particle physics has always been driven by availability of progressively higher collision energies.
- The available energy dictates the possible detector technologies required
- High-rate experiments additionally have a detection-decision-reconstruction-analysis cycle heavily dictated by DAQ, Bandwidth and computer resources
- Higgs factory, MSUGRA-SUSY 4-TeV Linac, physics-before-the-planck-scale (PBP), energy frontier, collider-less particle physics..?



Superconducting cavity (DESY TESLA)



ILD

Main points at the ESPP from the Detector community

- Efforts spread over small groups or “hidden” within large collaborations
  - A real need for interdisciplinary forums
  - Detector R&D clusters
  - Knowledge sharing between large experiments and smaller groups

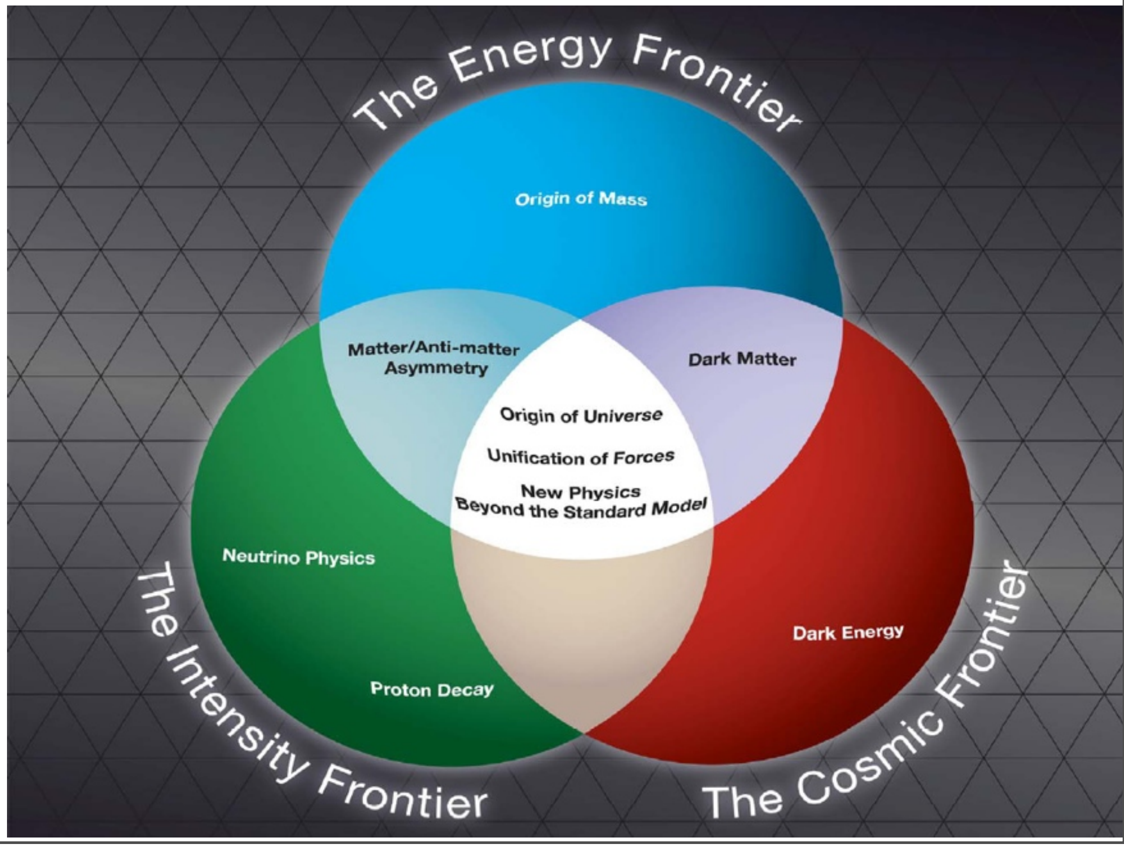
- The commercial industry is ahead in many avenues, *we should look carefully at where the industry is heading to effectively ride the silicon and nano-scale industries*

- Fewer young people are involved in detector R&D, *the “MC generation” needs to learn how to use a soldering gun if we want new technology 10 years from now...*

Detector motivation

- LHC Upgrades
- ILC
- Future accelerators (VLHC, Wakefield...)

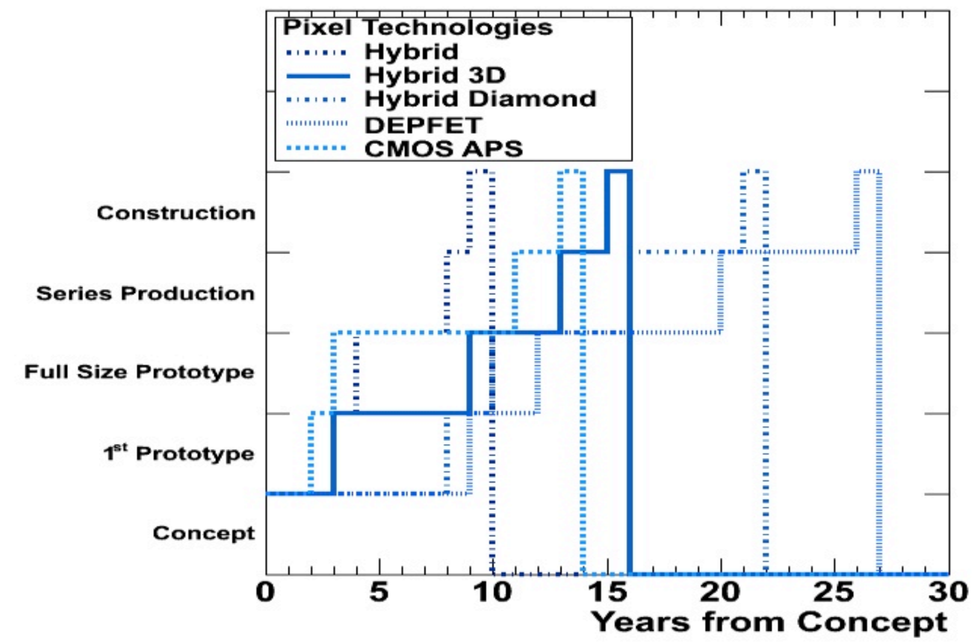
- granularity
- energy, time and space resolution
- speed
- higher trigger and data readout rates
- rad hardness
- purity
- low material budget
- robustness
- integration
- large scale apparatus



Vertex reconstruction

Main challenges:

- Pitch
- Radiation hardness
- Better granularity:
  - better track separation in high-pileup events
  - Track separation in hadronic jet cores

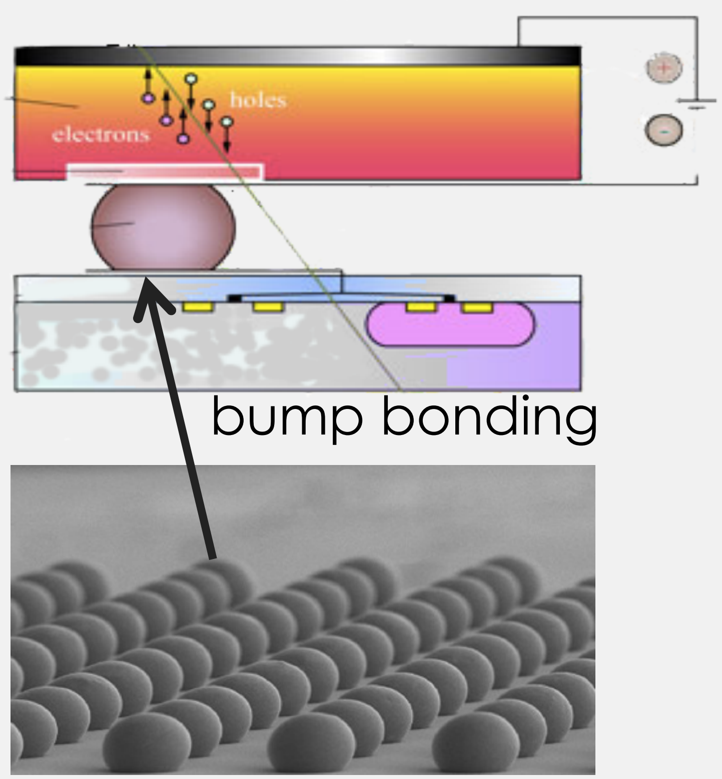


Silicon front-end integration

Today

Pitch: 50 – 100s μm

Hybrid



Tomorrow

Pitch: 50 – 25 μm

→ R&D on connectivity
- bb facilities
- Through Silicon Vias
- micro bb

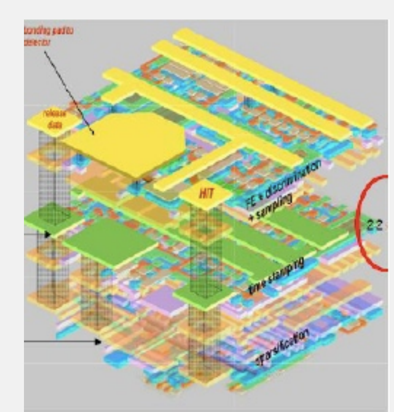
→ MONOLITHIC

less X_0

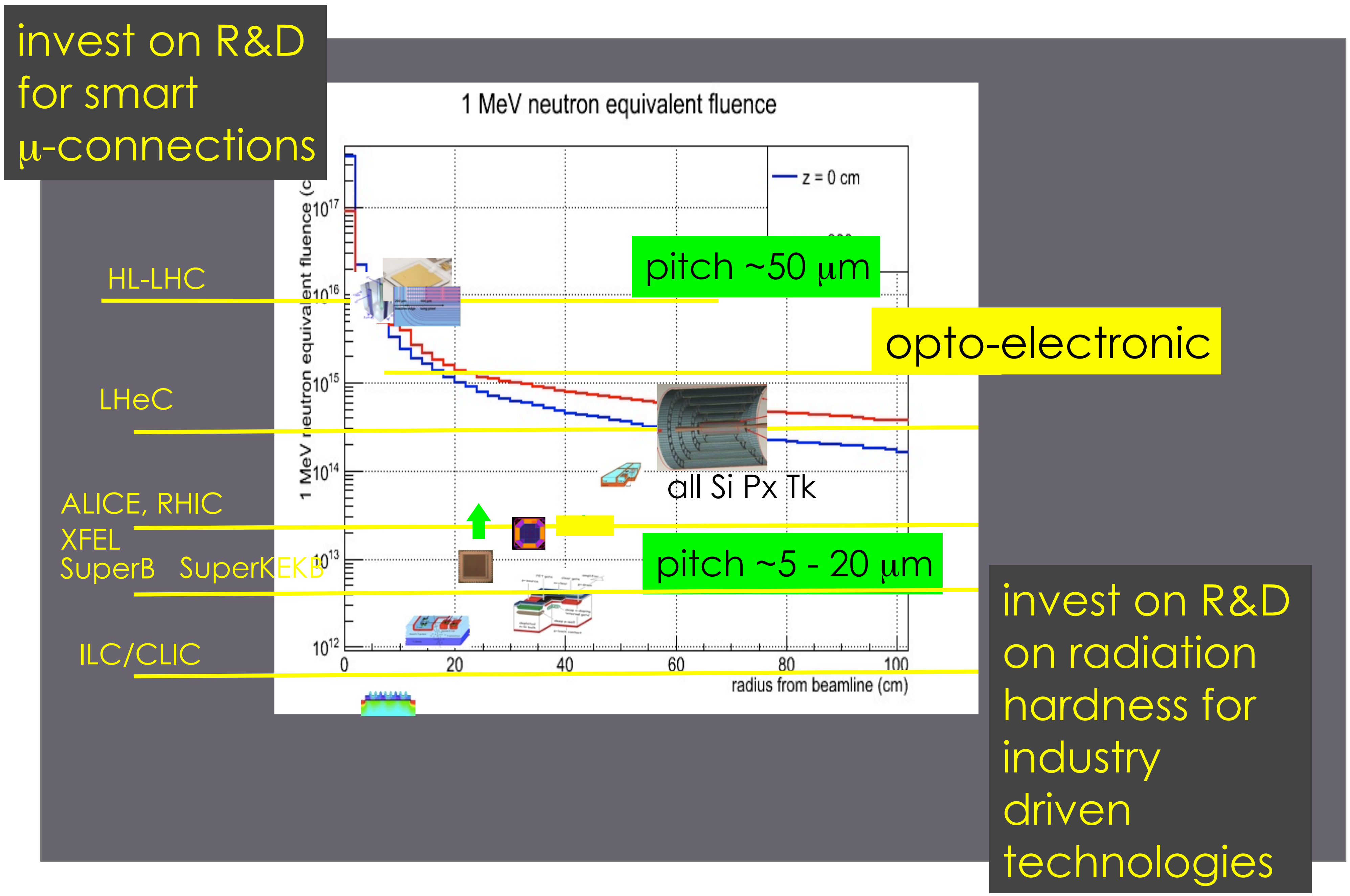
The day after tomorrow

pitch: 25 μm and less

→ Invest on R&D on
Monolithic
3D vertical
integration



Radiation hardness

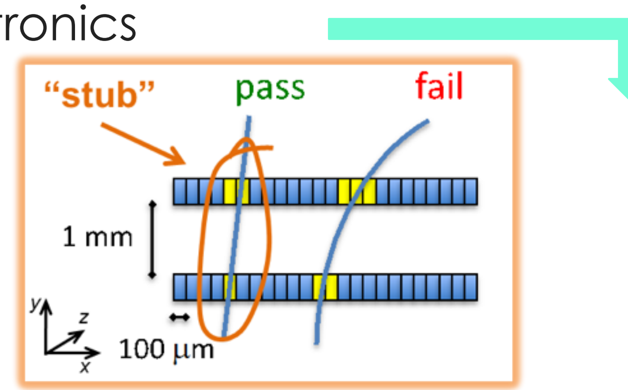


Smarter [tracking]-DAQ

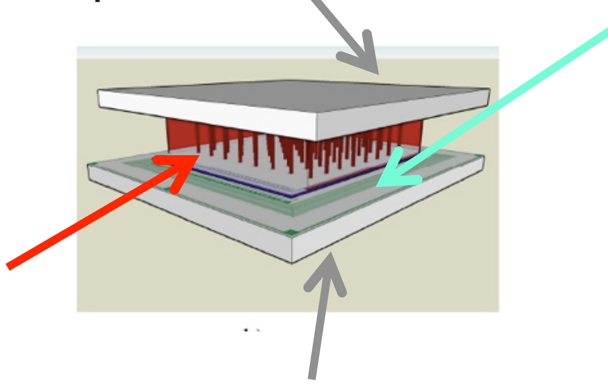
Reduce rate of non-interesting events in case of high occupancy

- Pixel & Trackers exploit new concepts
  - "Tracklets" (track primitives used at L1 and L2 triggering)
  - Local timestamped readout (temporal reconstruction later) CMOS "Chronopix"

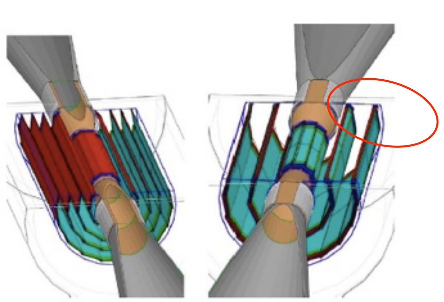
correlation electronics



top sheet (pixel or Si)

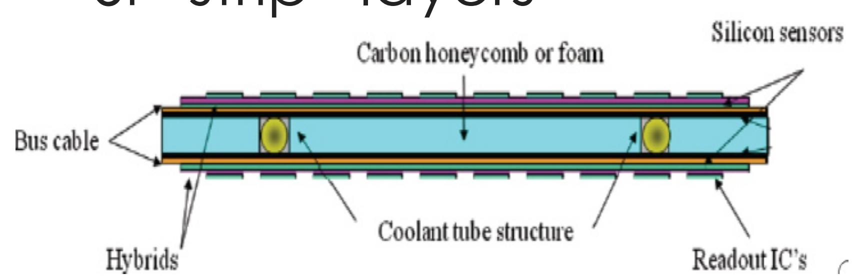


bottom sheet



interconnection layer with vias

top & bottom Si "strip" layers



Power and material budget

Autonomous detectors requires more logical (obviously) i.e. more silicon and more power

- Power busses and material budgets are an increasing concern...

the success of this path is possible only if
R&D in ALL areas below are sustained

•*Advanced powering* → Rad Hard DC-DC converters & serial powering
→ Inter-bunches power pulsing (ILC)

•*Advanced materials and integration*

•*Heat management embedded in the detector design*
→ Micro-cooling, micro-channels

many scattered efforts worth joining

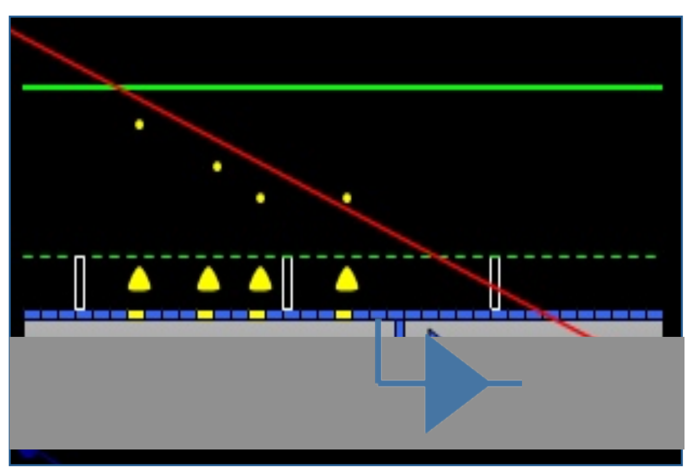
centre for particle physics Discovery

Gas detectors

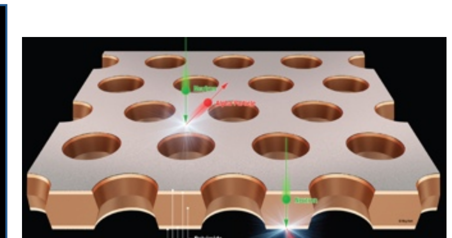
Advantages:

- Large area tracking planes, PID and Calorimetry
- Change of tendency: from wires to rigid structures
  - RPC
  - Micro Pattern Gaseous Detectors (µmegas, GEM etc..)

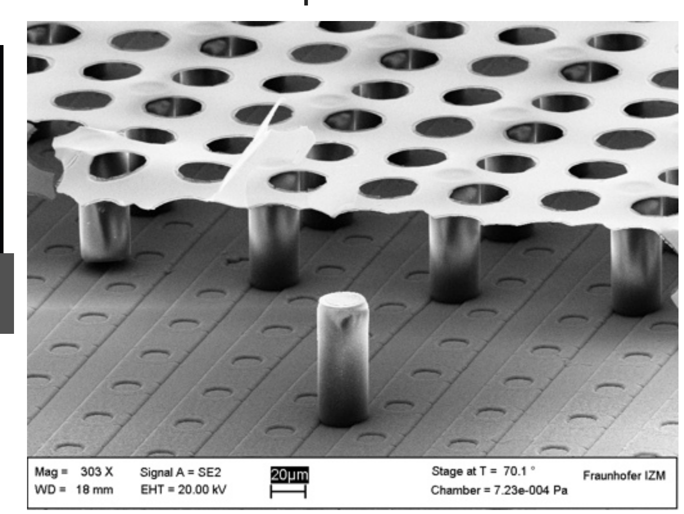
R&D: intriguing µTPC VERTEX
TPC end-plate



read-out: any pad size



metalized foil
~100 µm ~1mm



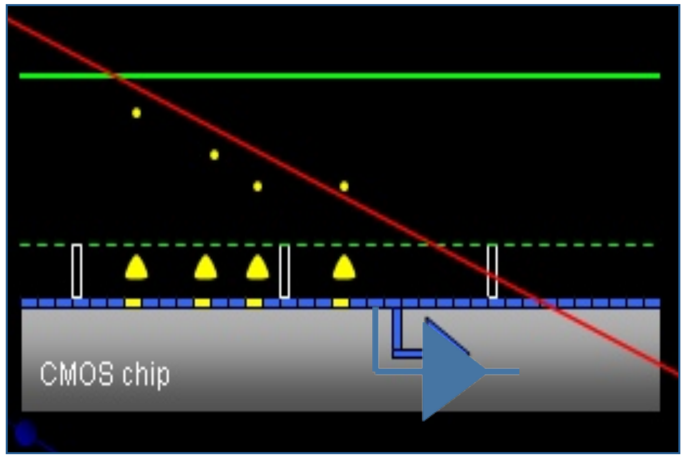
CMOS MediPix chip

Gas detectors

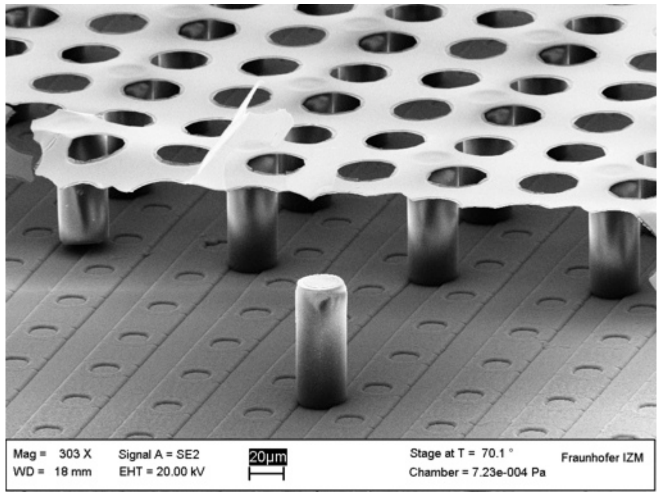
Advantages:

- Large area tracking planes, PID and Calorimetry
- Change of tendency: from wires to rigid structures
  - RPC
  - Micro Pattern Gaseous Detectors (μmegas, GEM etc..)

R&D: intriguing μTPC VERTEX
TPC end-plate



read-out: any pad size



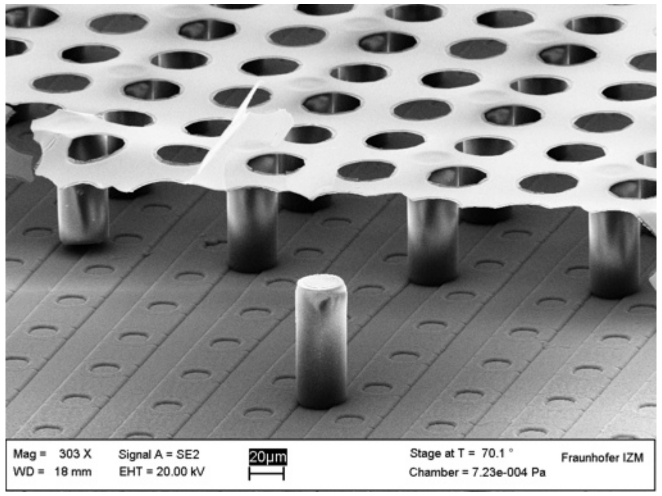
CMOS MediPix chip

Gas detectors

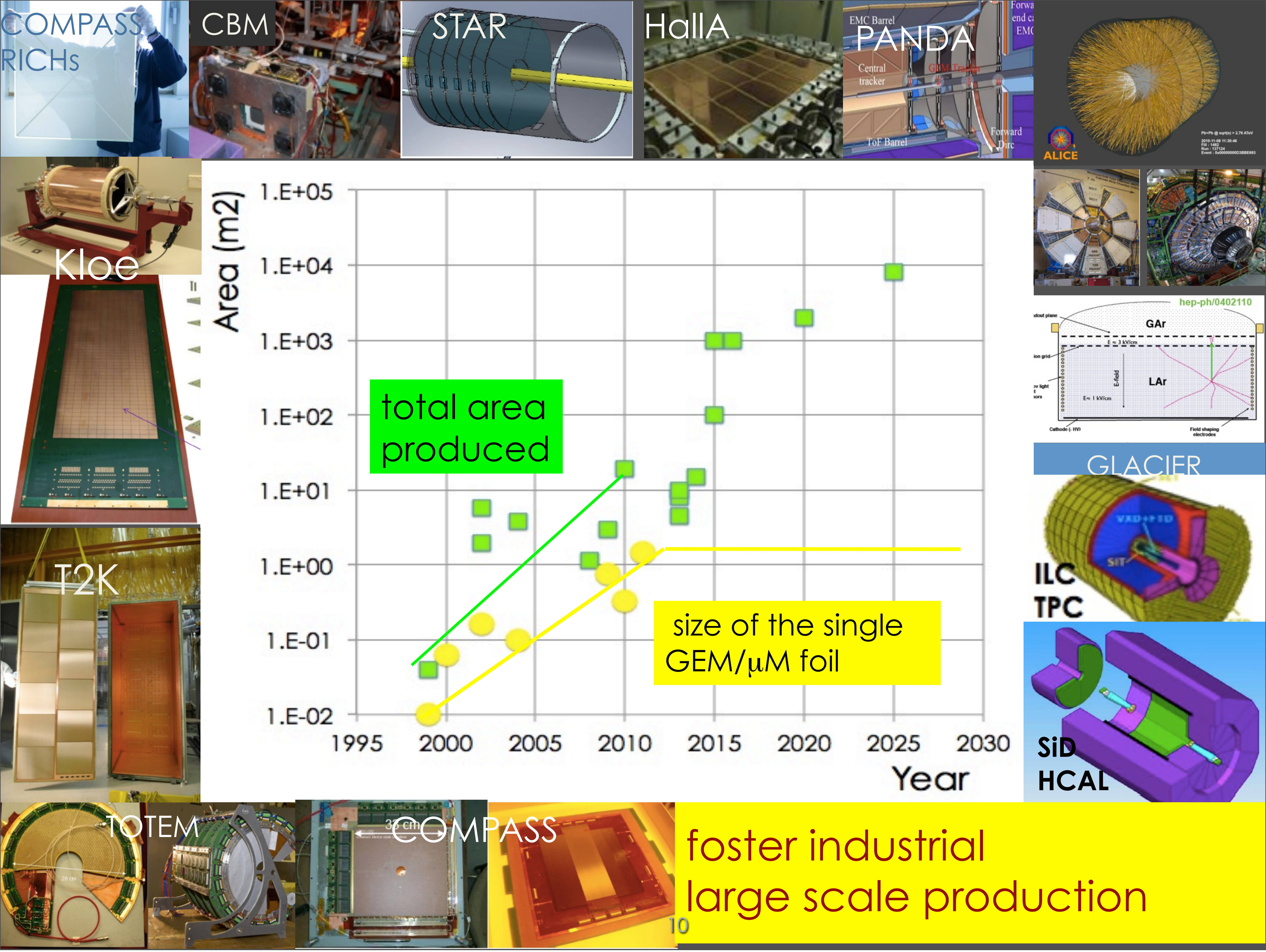
Advantages:

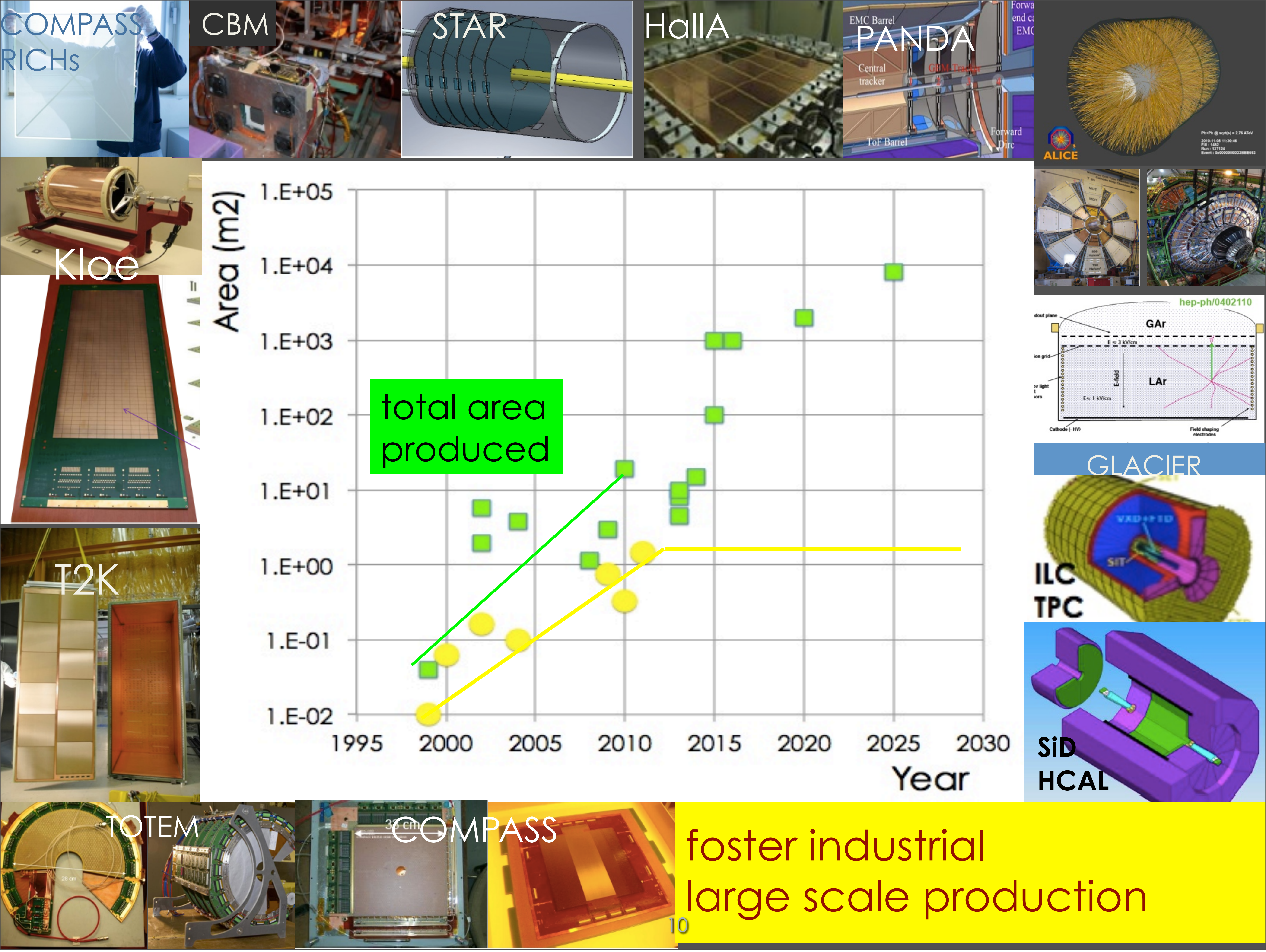
- Large area tracking planes, PID and Calorimetry
- Change of tendency: from wires to rigid structures
  - RPC
  - Micro Pattern Gaseous Detectors (μmegas, GEM etc..)

R&D: intriguing μTPC VERTEX
TPC end-plate

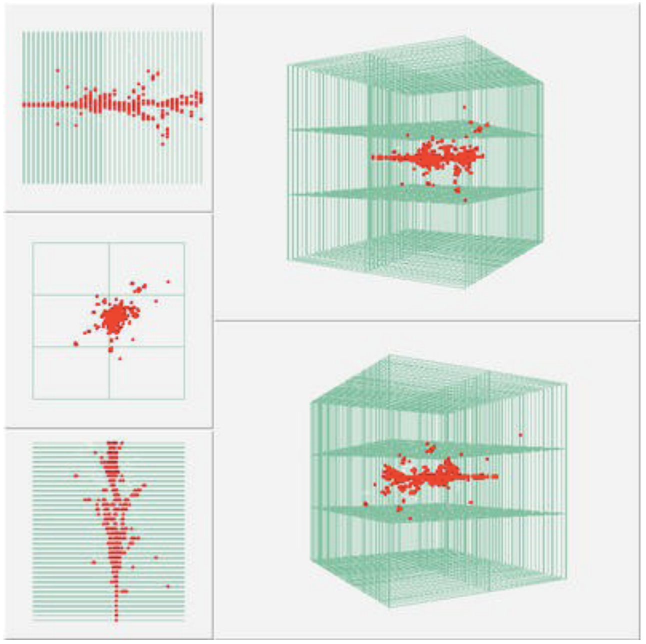


CMOS MediPix chip


COMPASS RICHs
CBM
STAR
HallA
PANDA
EMC Barrel
Central tracker
ToF Barrel
Forward Dirc
ALICE
Kloe
T2K
hep-ph/0402110
GAr
LAr
GLACIER
ILC TPC
SiD HCAL
TOTEM
COMPASS
Area (m2)
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
1.E-02
1995
2000
2005
2010
2015
2020
2025
2030
Year
total area produced
size of the single GEM/μM foil
foster industrial large scale production


COMPASS
RICHs
CBM
STAR
HallA
EMC Barrel
PANDA
Central
tracker
ToF Barrel
Forward
Dirc
ALICE
Kloe
T2K
Area (m2)
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
1.E-02
1995
2000
2005
2010
2015
2020
2025
2030
Year
total area
produced
hep-ph/0402110
GAr
LAr
GLACIER
ILC
TPC
SiD
HCAL
TOTEM
COMPASS
foster industrial
large scale production
10

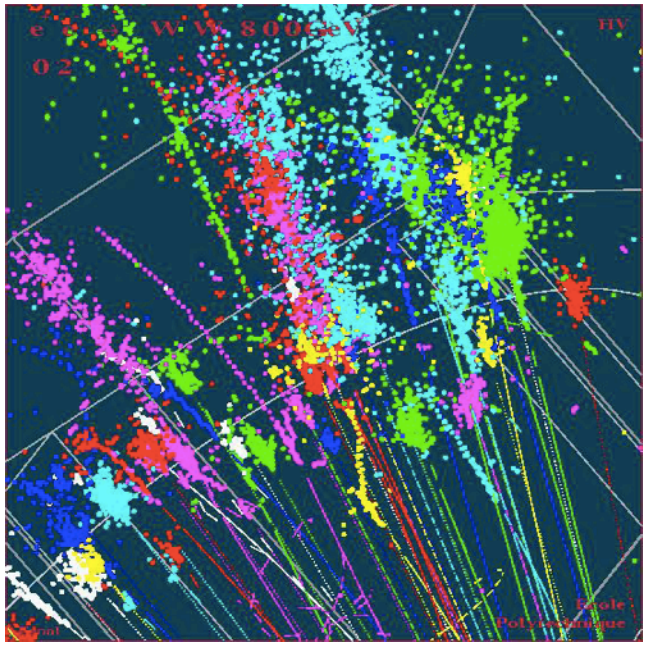
Calorimetry



- Particle Flow Algorithm - main thing from ILC/ CLIC CDRs
  - High jet energy resolution
  - Possible sub-jet information

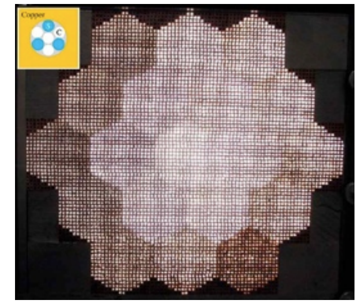
  - Large area tracking
  - Radiation hardness

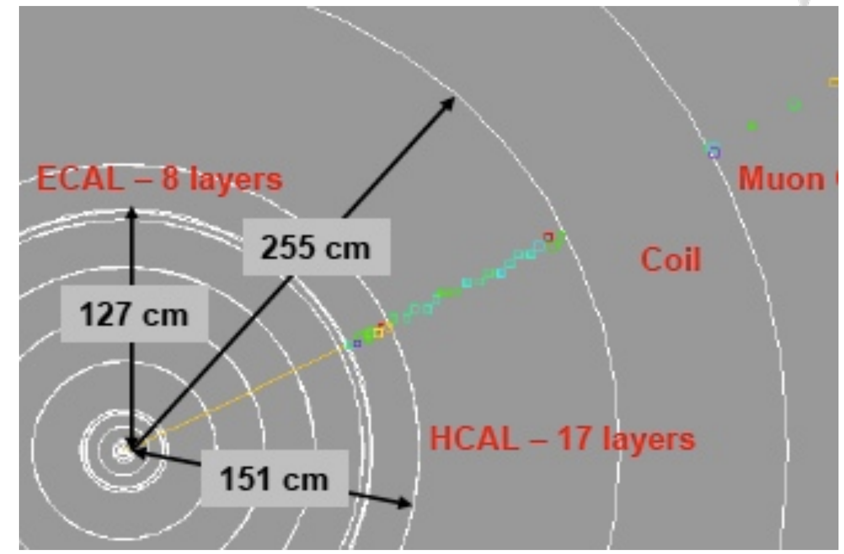
- DREAM - Dual-REAdout Method
  - Hadronic and electromagnetic separation
  - Scintillation light from EM + Hadronic
  - Cerenkov radiation from EM component
  - Crystals and glasses
  - Can do PFA as well



DREAM

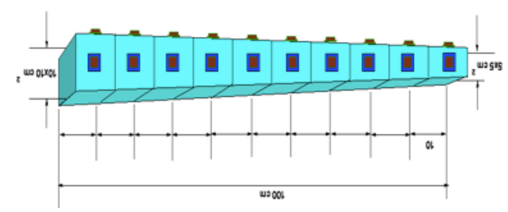
measure the Cerenkov (C) and scintillation light (S)along the shower

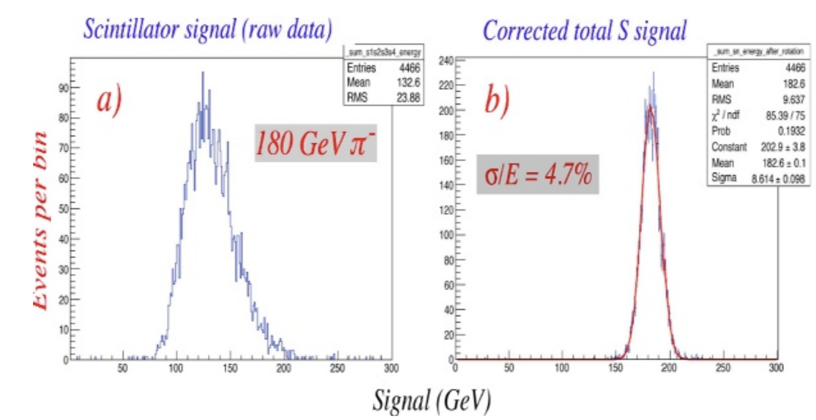




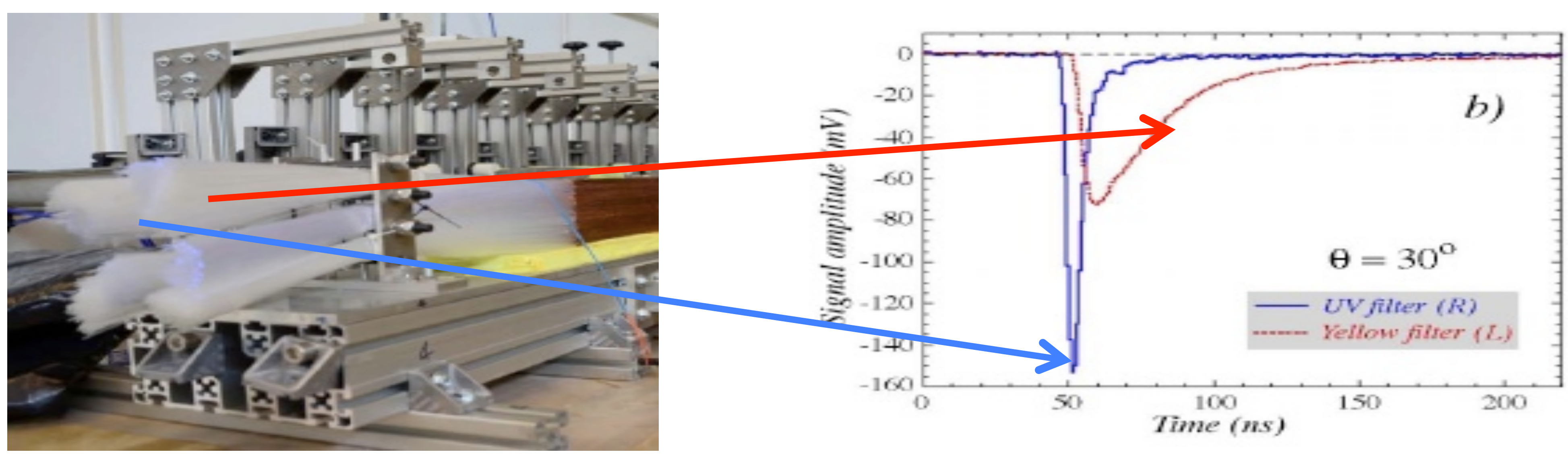
Total absorption Dual read out applied to glasses & crystals GOOD! a fresh momentum to R&D on crystals

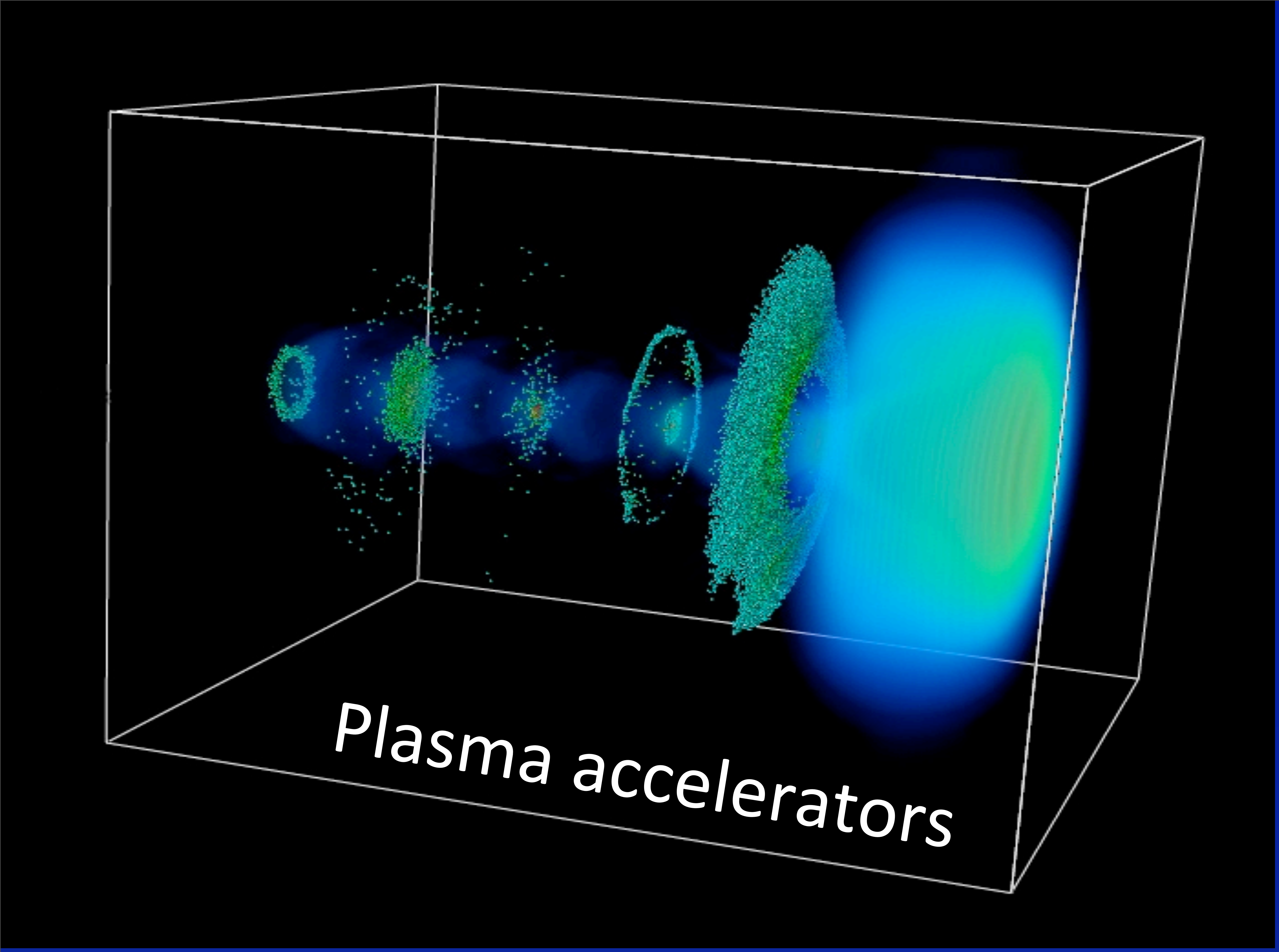
→ FWD calorimetry





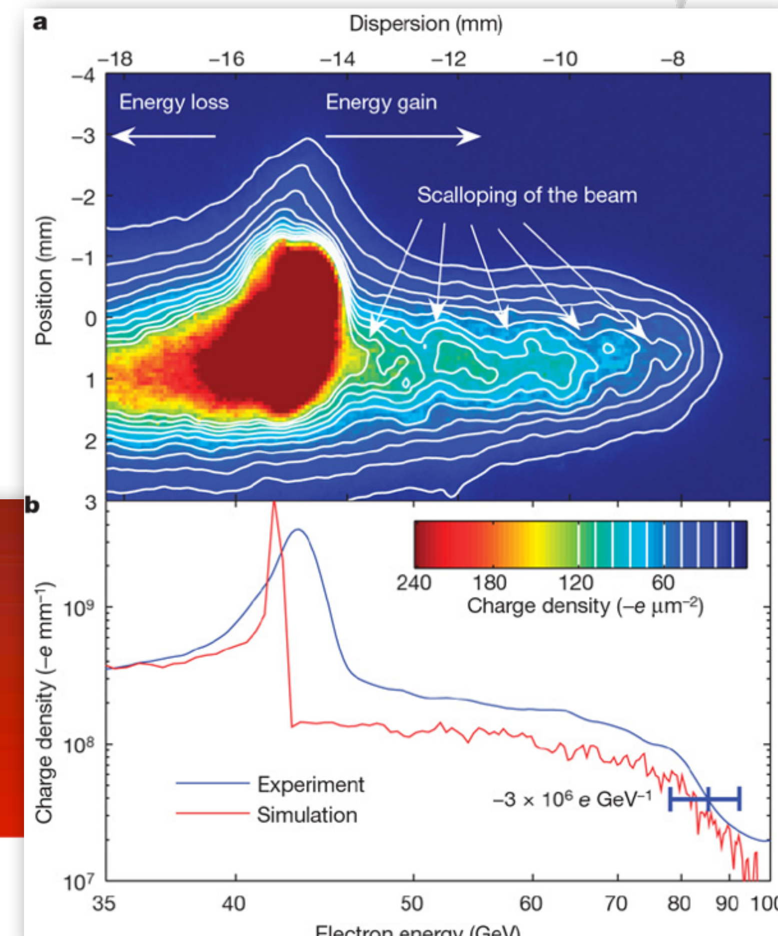
ECAL+HCAL with homogeneous crystal
crystals are segments to perform PFA




Plasma accelerators

centre for particle physics Discovery

Disruptive technology



nature International weekly journal of science

Journal home > Archive > Letter > Abstract

Journal content
+ Journal home
+ Advance online publication
+ Current issue
+ Nature News
+ Archive
+ Supplements
+ Web focuses

Letter

Nature **445**, 741-744 (15 February 2007) | doi:10.1038/nature05538; Received 21 July 2006; Accepted 13 December 2006

Energy doubling of 42 GeV electrons in a metre-scale plasma wakefield accelerator

Ian Blumenfeld[1], Christopher E. Clayton[2], Franz-Josef Decker[1], Mark J. Hogan[1], Chengkun Huang[2], Rasmus Ischebeck[1], Richard Iverson[1], Chandrashekhar Joshi[2], Thomas Katsouleas[3], Neil Kirby[1], Wei Lu[2], Kenneth A. Marsh[2], Warren B. Mori[2], Patric Muggli[3], Erdem Oz[3], Robert H. Siemann[1], Dieter Walz[1] & Miaomiao Zhou[2]

ABSTRACT
+ Previous | Next +
+ Table of contents
Full text
Download PDF

centre for particle physics Discovery

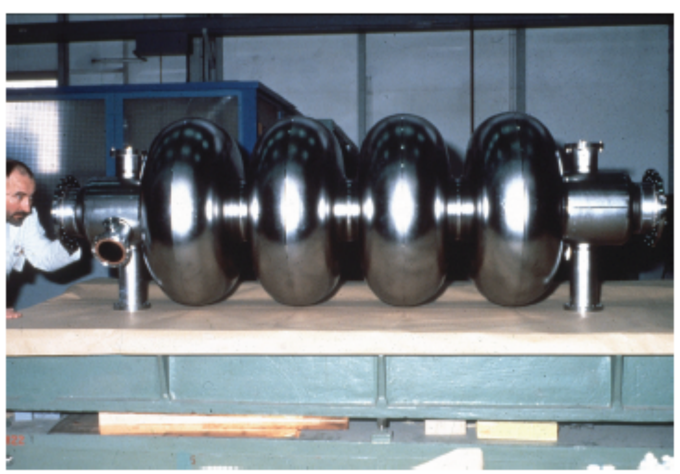
Plasma accelerators

Plasma accelerators Transform transverse fields into longitudinal fields

- Laser driven
- e- driven
- p driven
- dielectric wakefields

Demonstrated accelerating Gradients up to 3 orders of magnitudes beyond presently used RF technologies.

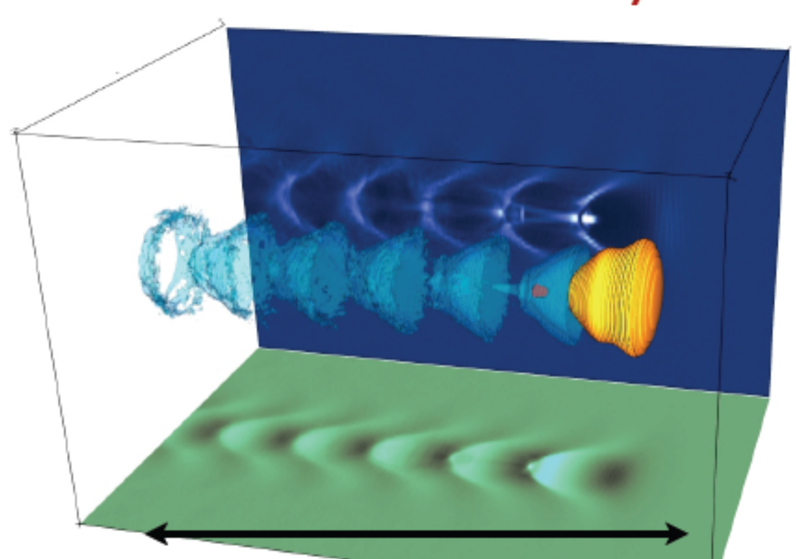
RF Cavity



I m => 100 MeV Gain

Electric field < 100 MV/m

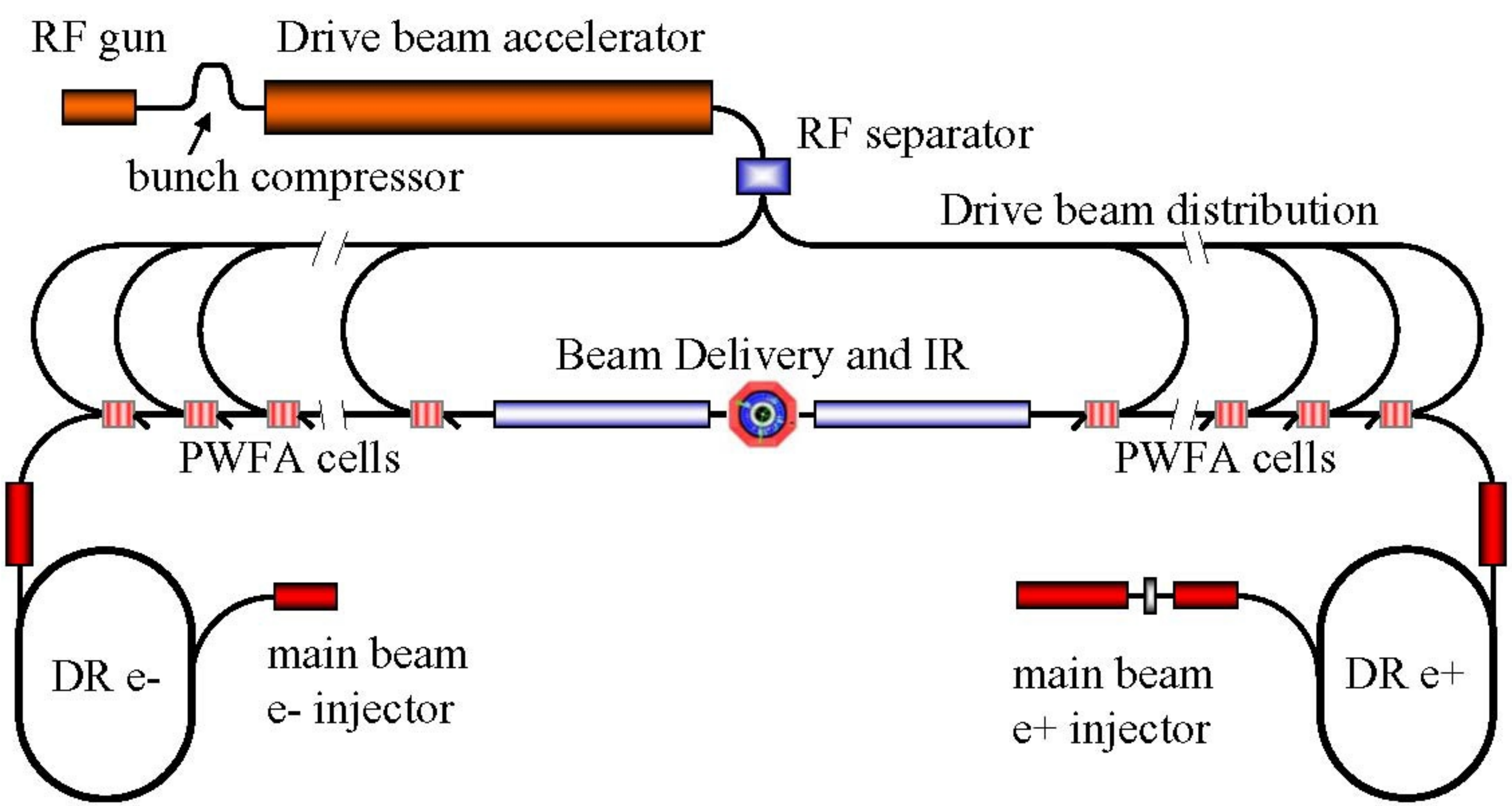
Plasma Cavity



1mm => 100 MeV

Electric field > 100 GV/m

Strawman proposals for LC Based on plasma acceleration



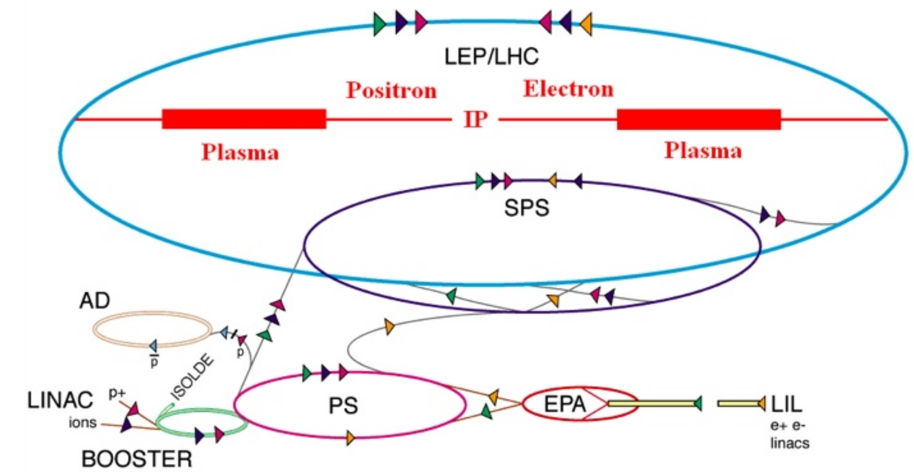
Laser driven benefits from laser science advances …hundreds of lasers
E beam driven from short pulses, low emittance
Proton beam driven very high energy efficiency very early stage .. Few stages for TeV colliders
HEP should invest, example polarised beams
Investments: 1 Billion euros for 10 years

R&D, tests, trials,…. Before being ready for a LC. Not for the next 20 years
In the meantime

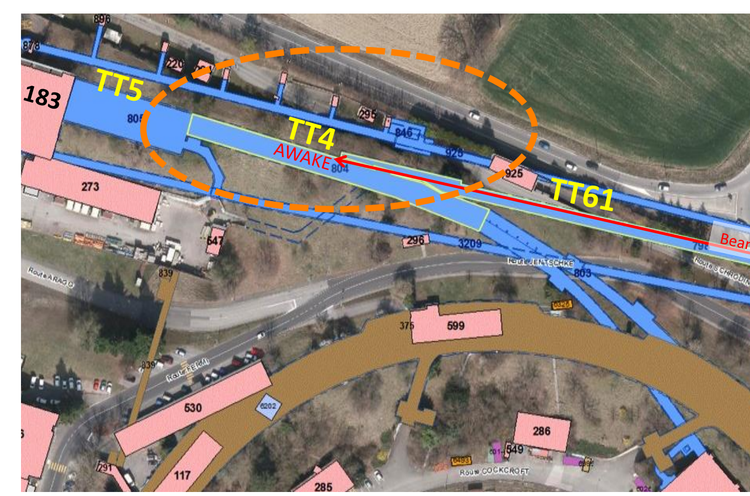
proton driven plasma wakefield acceleration

Simulations and proposal for CERN experiment
Need of 1 TeV p beam, high current to produce 600 GeV e- in 450 m plasma..

- HIGH Energy transfer: 10-100 GV m^{-1}
- "one-shot" transfer - no plasma cell staging
- Letter of intent sent last year
- CDR in preparation (~jan 2013)



- Dec 2013
  - Demonstrate at least one technology for a plasma length 5m with 1015 cm-3 , uniformity better than 2%, define baseline choice(s)
    - Demonstrate seeding in experimental tests, define baseline
- Dec 2014 – Demonstrate 1% uniformity and complete operational plasma cell(s)
- Aug 2015– Beam to plasma-cell in experimental facility



Dreams of high gradient acceleration

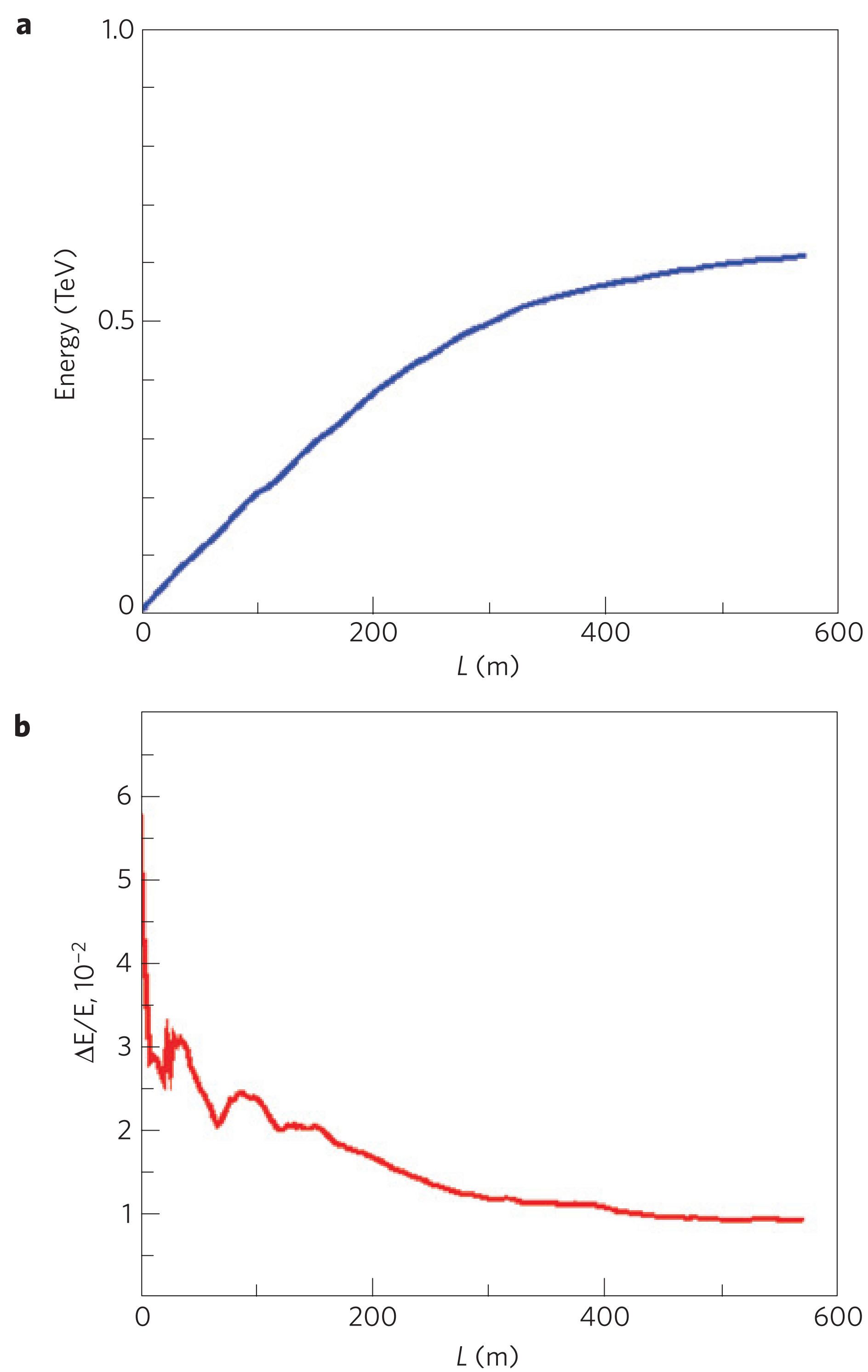
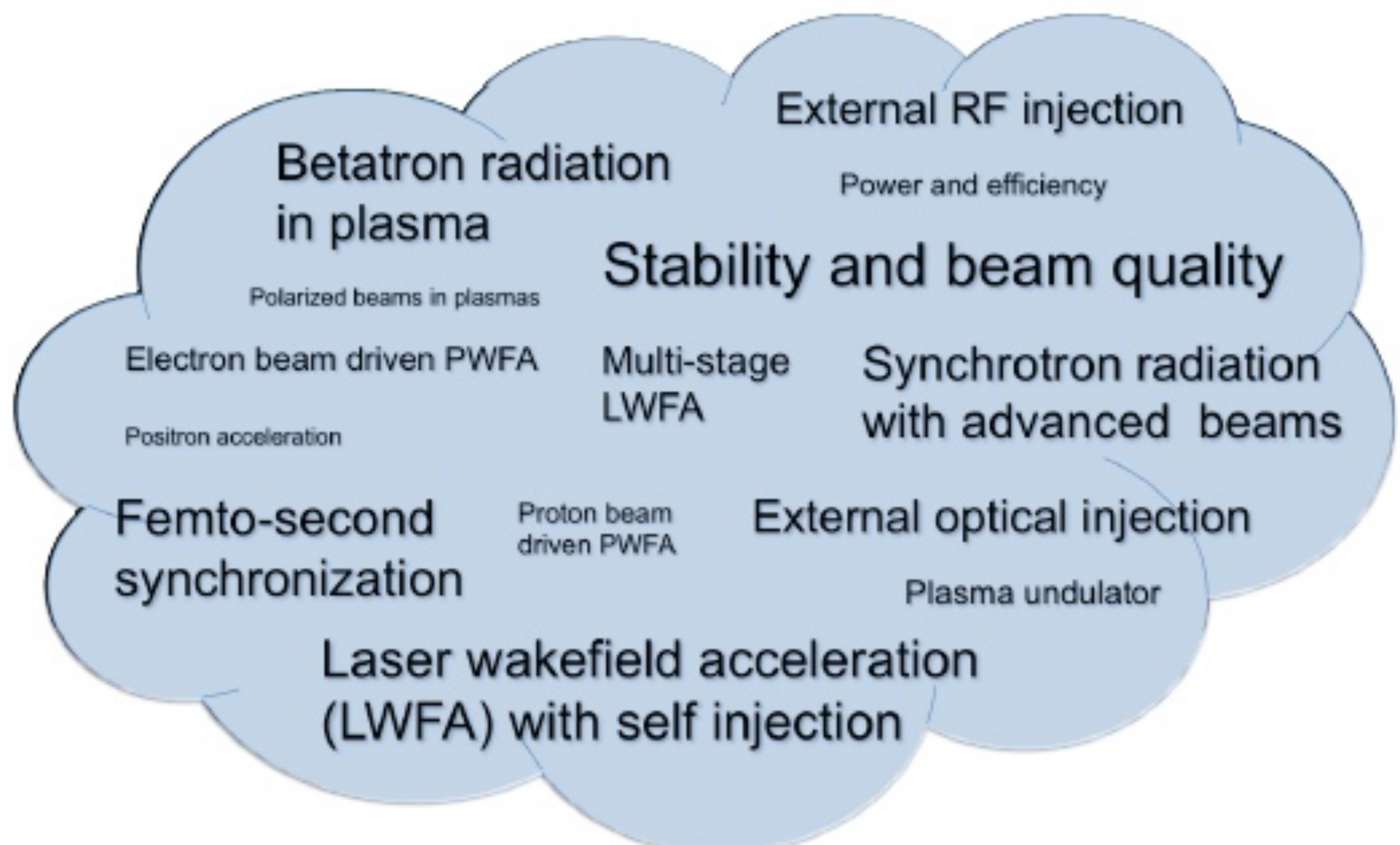


Figure 4 | Electron energy versus distance. a,**b**, The mean electron en in TeV (**a**) and the r.m.s. variation of the energy in the bunch as a percentage (**b**) as a function of the distance travelled in the plasma.

EURONACC: most important Technical Goals

1. External Optical injection
2. External RF injection
3. LWFA with self injection
4. Multi-stage LWFA
5. Synchrotron radiation with advanced beams
6. Electron beam driven PWFA
7. Proton beam driven PWFA
8. Betatron radiation in plasma
9. Plasma undulator
10. Stability and beam quality
11. Polarized beams in plasmas
12. Positron acceleration
13. Femto-second synchronization
14. Power and efficiency

Investments :
1 billlion Euro over 10 year horizon
EuroNNAc : 52 institutes



Applications
FELs, Photons, p acceleration (hadron therapy)

compact accelerators for scientific, commercial and medical

..here we demonstrate that laser-driven collisionless shocks can accelerate proton beams to ~20 MeV with extremely narrow energy spreads of about 1% and low emittances

Accelerators point of view :

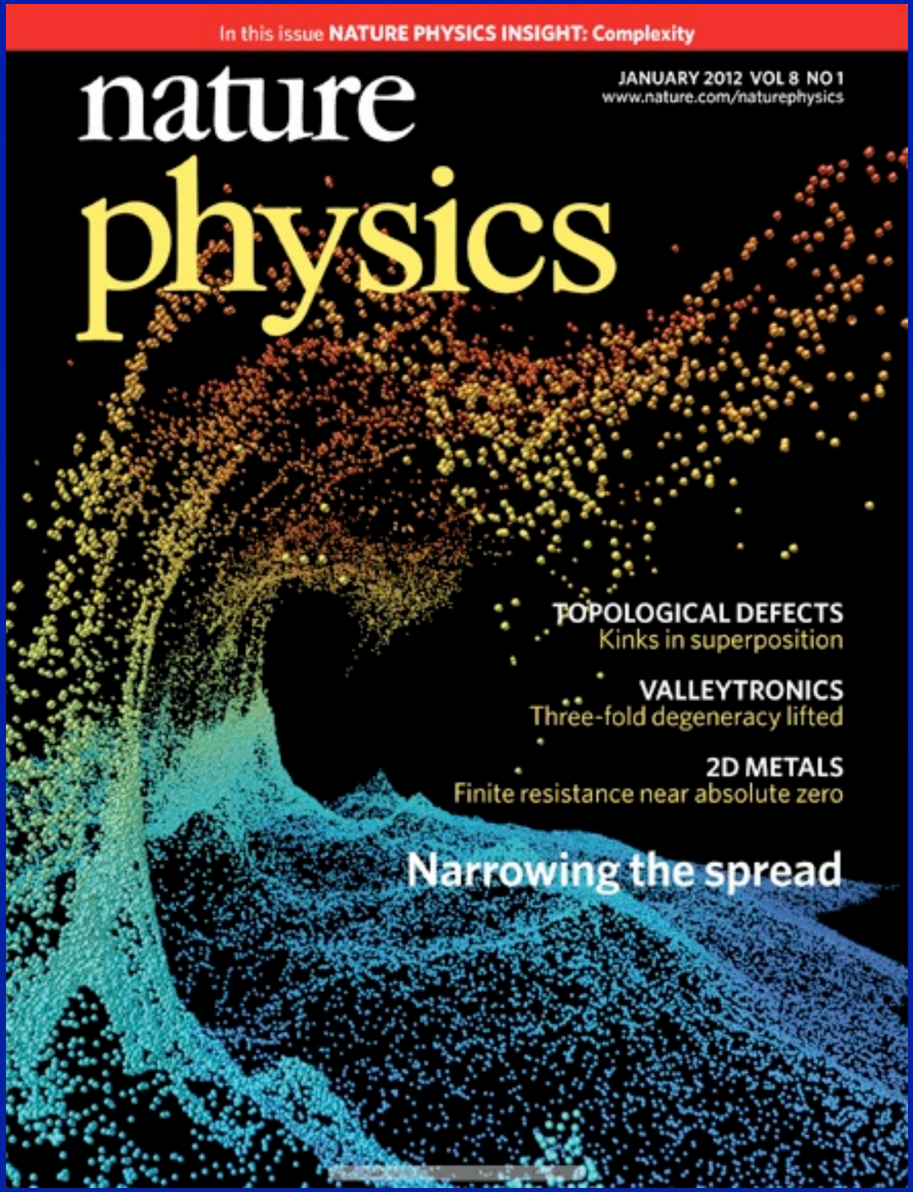
Good beam quality & Monoenergetic dE/E down to 1 %	√
Beam is very stable	√
Energy is tunable: up to 400 MeV	√
Charge is tunable: 1 to tens of pC	√
Energy spread is tunable: 1 to 10 %	√
Peak energy at 1.4 GeV	√
Ultra short e-bunch : 1,5 fs rms	√
Low divergence : 2 mrad	√
Low emittance[1-3] : π.mm.mrad	√

S. Fritzler *et al.*, Phys. Rev. Lett. **92**, 165006 (2004), [2]C. M. S. Sears *et al.*, PRSTAB **13**, 092803 (2010)
[3]E. Brunetti *et al.*, Phys. Rev. Lett. **105**, 215007 (2010)

Applications
FELs, Photons, p acceleration (hadron therapy)

compact accelerators for scientific, commercial and medical

..here we demonstrate that laser-driven collisionless shocks can accelerate proton beams to ~20 MeV with extremely narrow energy spreads of about 1% and low emittances



Accelerators point of view :

- Good beam quality & Monoenergetic dE/E down to 1 % √
- Beam is very stable √
- Energy is tunable: up to 400 MeV √
- Charge is tunable: 1 to tens of pC √
- Energy spread is tunable: 1 to 10 % √
- Peak energy at 1.4 GeV √
- Ultra short e-bunch : 1,5 fs rms √
- Low divergence : 2 mrad √
- Low emittance[1-3] : π.mm.mrad √

S. Fritzler *et al.*, Phys. Rev. Lett. **92**, 165006 (2004), [2]C. M. S. Sears *et al.*, PRSTAB **13**, 092803 (2010)
[3]E. Brunetti *et al.*, Phys. Rev. Lett. **105**, 215007 (2010)

References

http://indico.cern.ch/conferenceDisplay.py?confId=182232

Detector information grabbed from:

Ariella Cattai (CERN)

http://indico.cern.ch/getFile.py/access?contribId=30&sessionId=6&resId=1&materialId=slides&confId=182232

Accelerator info:

Caterina Biscari (INFN)

http://indico.cern.ch/getFile.py/access?contribId=27&sessionId=5&resId=1&materialId=slides&confId=182232