# 2008 NSS Program

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|---|---|---|---|---|---|---|
| **Mo** | 08:30 - 10:00 | **Plenary Session ( #1000)** ITER, FAIR and XFEL | | | | |
| | 10:30 - 12:30 | | | | | |
| | | NSS Luncheon | | | | |
| | 14:00 - 16:00 | **Poster session** | | | | |
| | 16:30 - 18:30 | N05-Nuclear Power | N03-Gas Detector I | N06-DAQ I | N04-New Solid State Det. I | N07-Instr. Rad. Medecine I |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Tu** | 08:00 - 10:00 | N12-Photon Detectors I | N08-Gas Detector II | N09-Instr. Rad. Medecine II | N11-Analog&Digital Circuits I | N10-Astrophsics & Space I |
| | 10:30 - 12:30 | N16-Software I | NSS/MIC/RTSD | N13-Synchrotron & FEL | N15-Radiation Damage I | N14-Nuclear Physics Instr. I |
| | 13:30 - 15:30 | N20-Software II | NSS/MIC | N17-DAQ II | N19-Radiation Damage II | N18-Nuclear Physics Instr. II |
| | 16:00 - 18:00 | N24-Photon Detectors II | NSS/MIC | N22-Nucl.Meas. & Monitor I | N23-Analog&Digital Circuits II | N21-Astrophsics & Space II |

MIC (PET)

| | | | | | | |
|---|---|---|---|---|---|---|
| **We** | 08:00 - 10:00 | N29-Software III | N27-HEP Trackers I | N26-Neutr. Instrument. I | N28-Astrophsics & Space III | N25-Trigger I |
| | 10:30 - 12:30 | **Poster session** | | | | |
| | 13:30 - 15:30 | N35-Scintillat. Detectors I | N33-HEP Calorimeters I | N32-Software IV | N34-New Solid State Det. II | N31-Gas Detectors III |
| | 16:00 - 18:00 | N40-Scintillat. Detectors II | N38-HEP Muons I | N37-Software V | Round Table (16:00-19:00) | N36-Trigger II |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Th** | 08:00 - 10:00 | N45-Scintillat. Detectors III | N43-HEP Trackers II | N42-Neutr. Instrument. II | N44-Analog&Digital Circuits III | N41-Software VI |
| | 10:30 - 12:30 | N50-Photon Detectors III | N48-HEP Beam Monitors I | N47-Nucl.Meas. & Monitor II | N49-Radiation Damage III | N46-Software VII |
| | 13:30 - 15:30 | N55-Scintillat. Detectors IV | N53-HEP Muons II | N52-DAQ III | N54-Semiconductor Tracker I | N51-Software VIII |
| | 16:00 - 18:00 | N60-Astrophsics & Space IV | N58-HEP Beam Monitors II | N57-ATCA (16:00-19:00) | N59-Homeland Security II | N56-Photon Detectors IV |

MIC (PET)

| | | | | | | |
|---|---|---|---|---|---|---|
| **Fr** | 08:00 - 10:00 | N65-Photon Detectors V | N63-HEP Calorimeters II | N62-Gas Detector IV | N64-Analog&Digital Circuits IV | N61-Homeland Security II |
| | 10:30 - 12:30 | **Closing Session ( #1000)** LHC and ILC | | | | |
| | 13:30 - 15:30 | N69-Scintillat. Detectors V | N67-Software IX | N70-DAQ IV | N68-Semiconductor Tracker II | |
| | 16:00 - 18:00 | | | | | |

| | | |
|---|---|---|
| Hall 1 & 2 & 3 | Conference 1 (190) | Conference 4 (102) |
| Hall 2 & 3 | Conference 2 (102) | Conference 4 & 5 (200) |
| Hall 2 | Conference 3 (102) | Conference 5 (102) |
| Hall 3 | Conference 6 (270) | Conference 7 & 8 (70) |

# Design and Performance of Liquid Xenon Detectors for PET

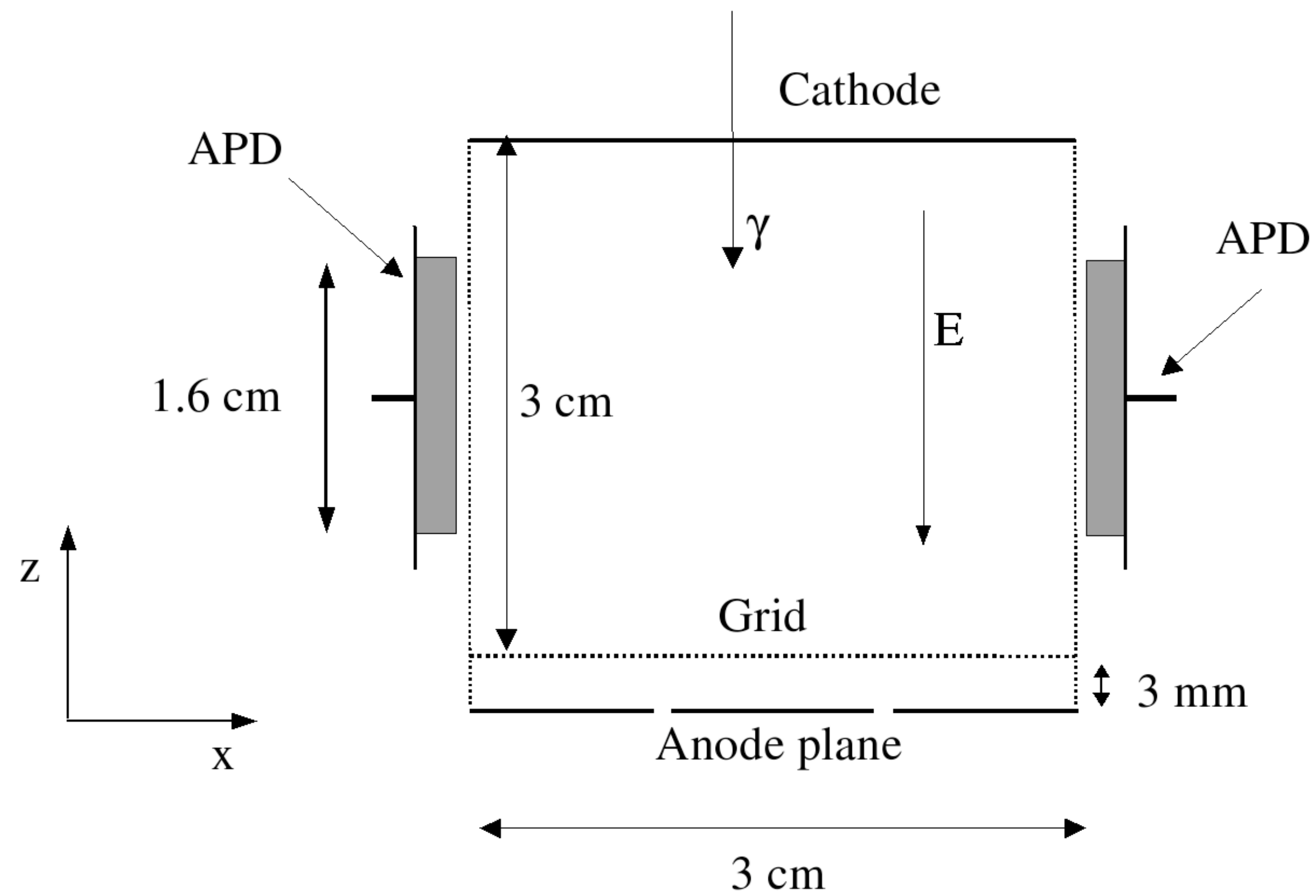
P. Amaudruz[1] D. Bryman[2] L. Kurchaninov[1] P. Lu[2] C. Marshall[1] J. P. Martin[3] A. Muennich[1] F. Retiere[1] A. Sher[1] V. Sossi[2]

[1]TRIUMF, Vancouver, Canada
[2]The University of British Columbia, Vancouver, Canada
[3]The University of Montreal, Montreal, Canada

2008 IEEE Nuclear Science Symposium and Medical Imaging Conference

# Small Prototype: Time Projection Chamber (TPC)

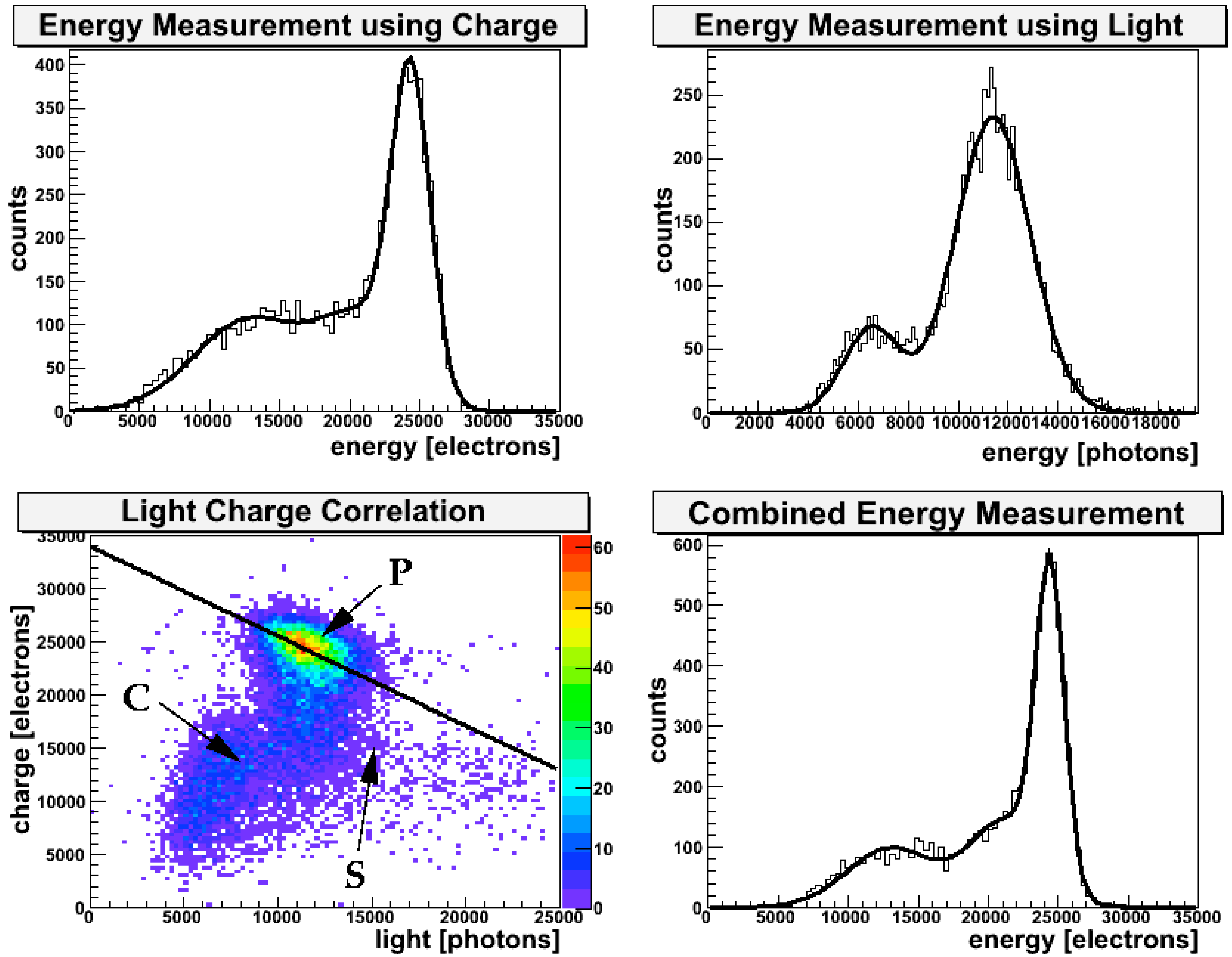
- TPC volume 3x3x3 $cm^3$
- typical: $E$=1 kV/cm, $v_d$ =2 mm/$\mu$s
- 2 APDS; solid angle $\approx$ 12%




Results for 511 keV photons from $^{22}$Na:

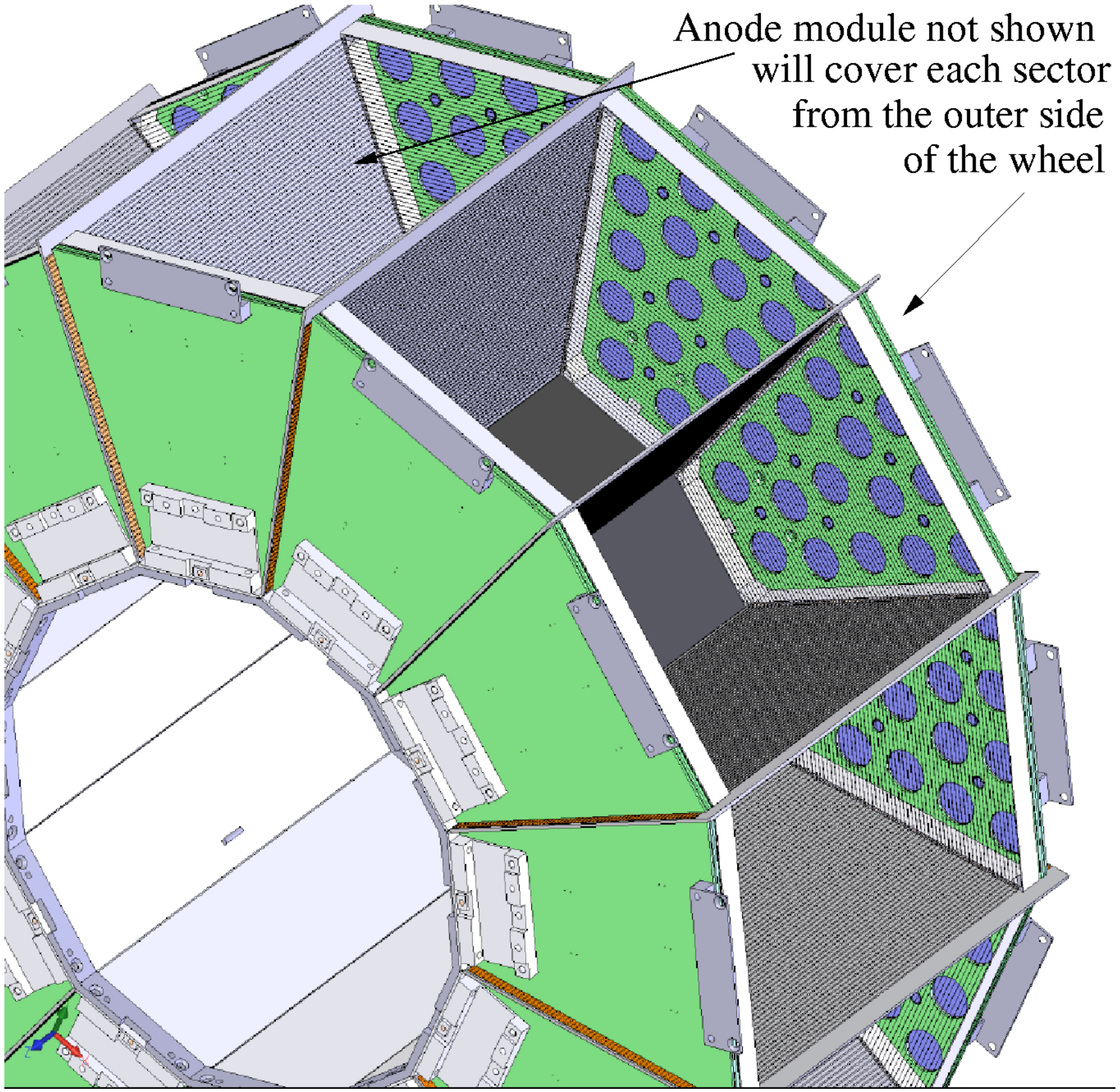
- Light resolution: 11.4% (rms)
- Charge resolution: 5.6% (rms)
- Combined energy resolution: 3.9% (rms)

# Combining Light and Charge Measurement with 511 keV Photons




P: Photoelectric, C: Compton, S: Scattered outside

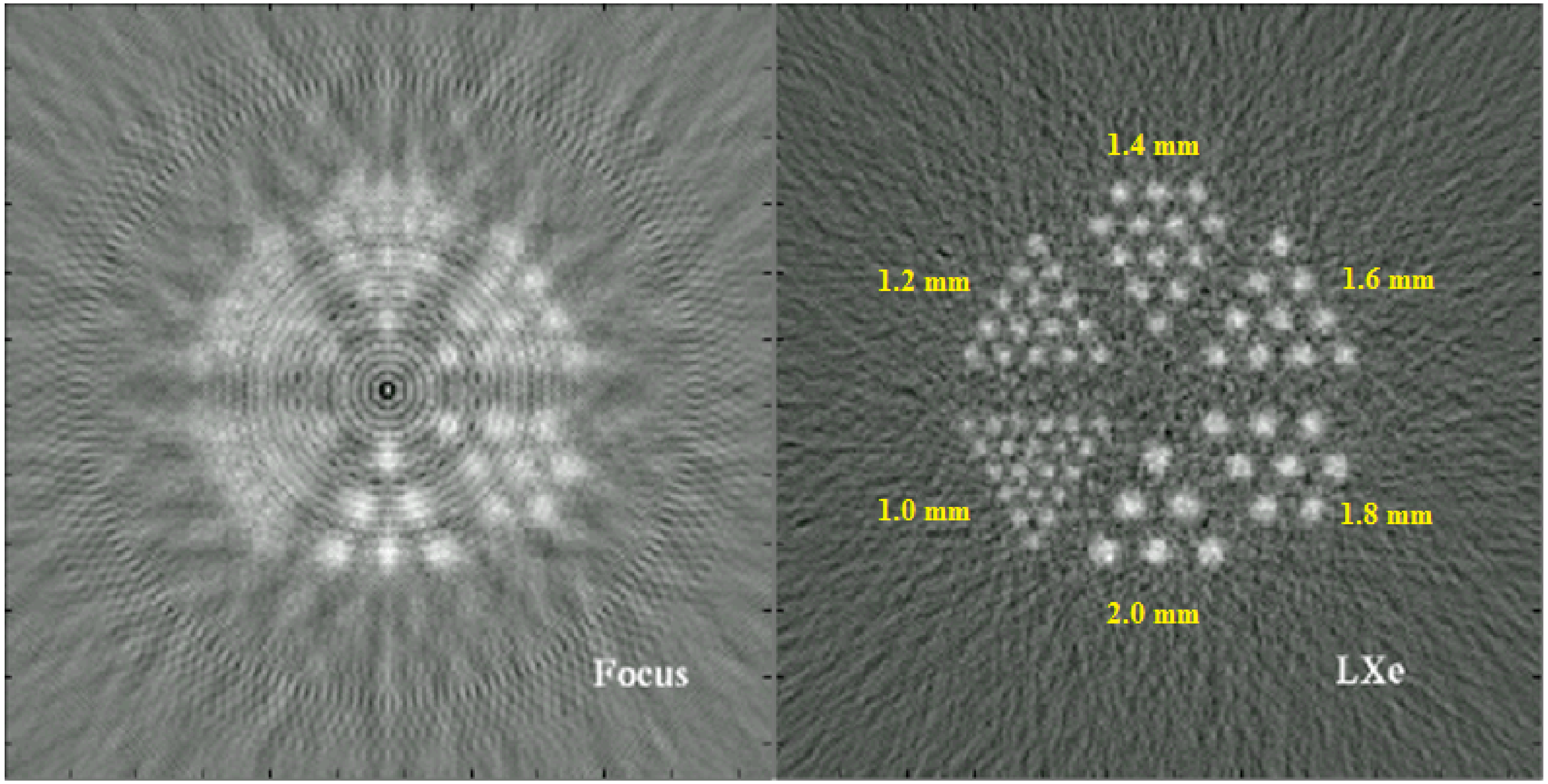
# Micro-PET Design




- 12 sectors, 32 APDs per sector, 96 anode wires, 96 anode induction wires
- Radial depth 12 cm
- Minimal dead space between sectors to increase active volume

## Image Reconstruction from Simulations

Same simple reconstruction method (Filter-Back Projection) used for both (emphasis on resolution not image quality):




In the simulation, the limitations of the LXe system are primarily due to physics effects such as the positron range.

## Conclusion and Outlook

- A small liquid xenon TPC has been shown to give excellent energy resolution ($<$10% FWHM) by combining ionization charge and scintillation light signals observed with avalanche photodiodes.
- We are presently designing and building a prototype of one sector for a Micro-PET scanner
- Design of full Micro-PET system in progress

Next steps:

- Operate and test the first sector prototype
- Build a second sector and operate in coincidence for PET measurments within a cryostat designed for a full PET ring

# Optimization of LSO for Time-of-Flight PET

W. W. Moses[1], M. Janecek[1], M. A. Spurrier[2], P. Szupryczynski[2,3] , W.-S. Choong[1], C. L. Melcher[2], and M. Andreaco[3]

[1]Lawrence Berkeley National Laboratory
[2]University of Tennessee, Knoxville
[3]Siemens Medical Solutions

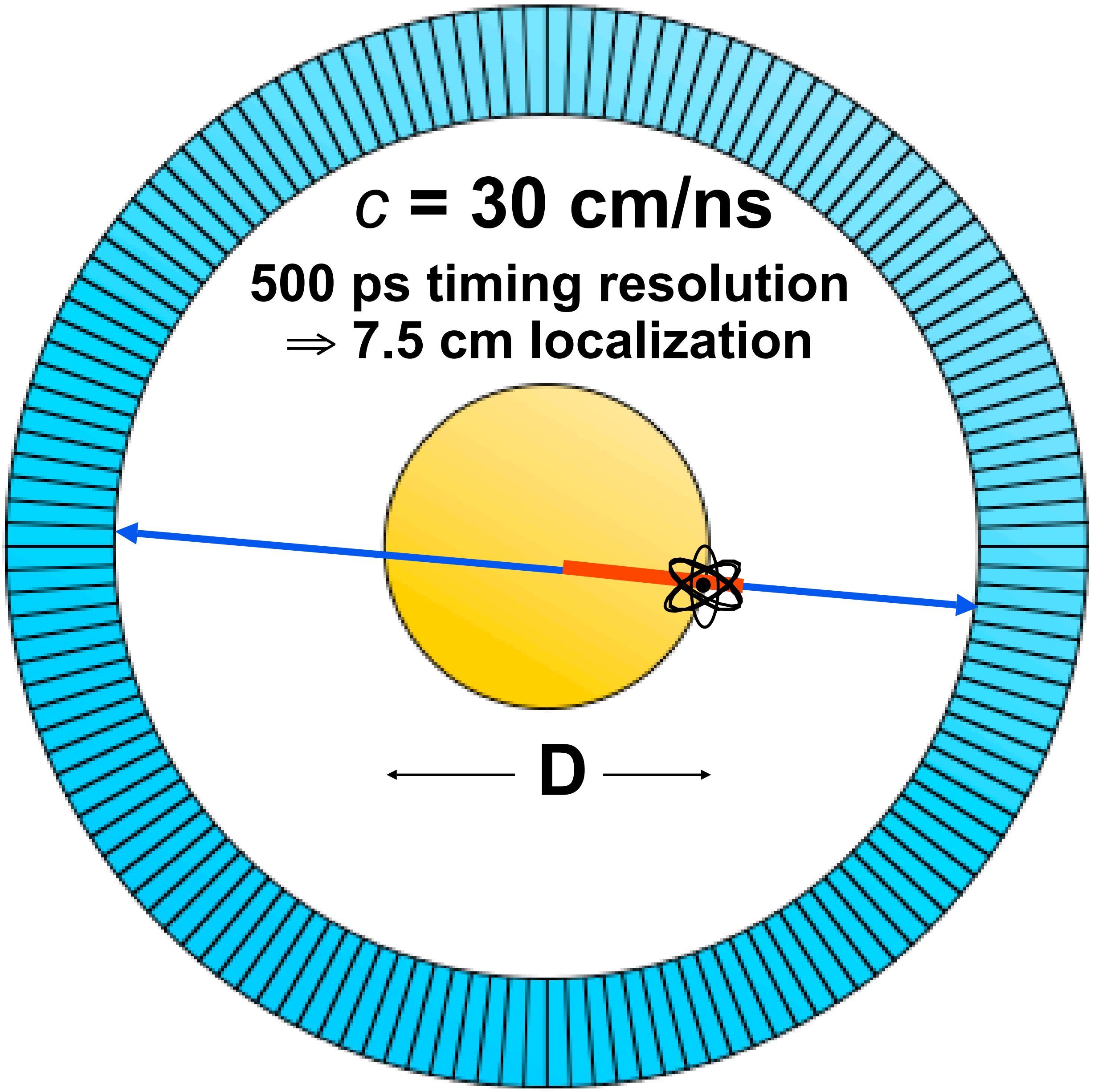
October 21, 2008

## Outline:

- Motivation
- Reflector Optimization
- LSO Optimization
- PMT Optimization

This work was supported by the NIH (NIBIB grant No. R01-EB006085).

# Time-of-Flight in PET




- Can localize source along line of flight.
- Time of flight information reduces noise in images.
- Variance reduction given by $2D/c\Delta t$.
- 500 ps timing resolution
  ⇒ 5x reduction in variance!

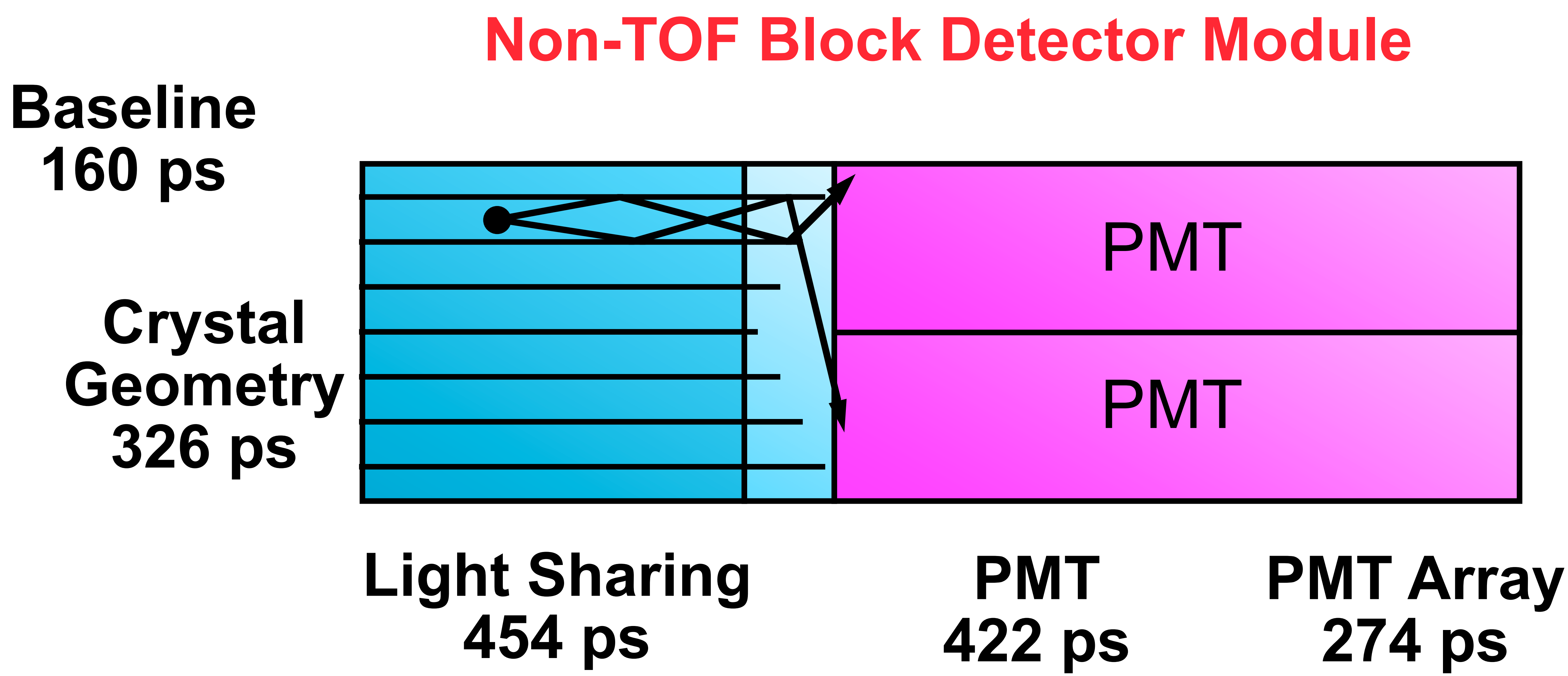
- Time of Flight Provides a *Huge* Performance Increase!
- Largest Improvement in Large Patients

# Our Goal:
# "Demonstration" TOF PET Camera

- **With better timing resolution ($\Delta t$),** ***huge*** **gains predicted (23x variance reduction for 100 ps timing)**
- *Measure* **image improvement vs. timing resolution**
- **Use LSO scintillator**
  - **Don't change other factors that influence SNR (efficiency, scatter fraction, etc.)**

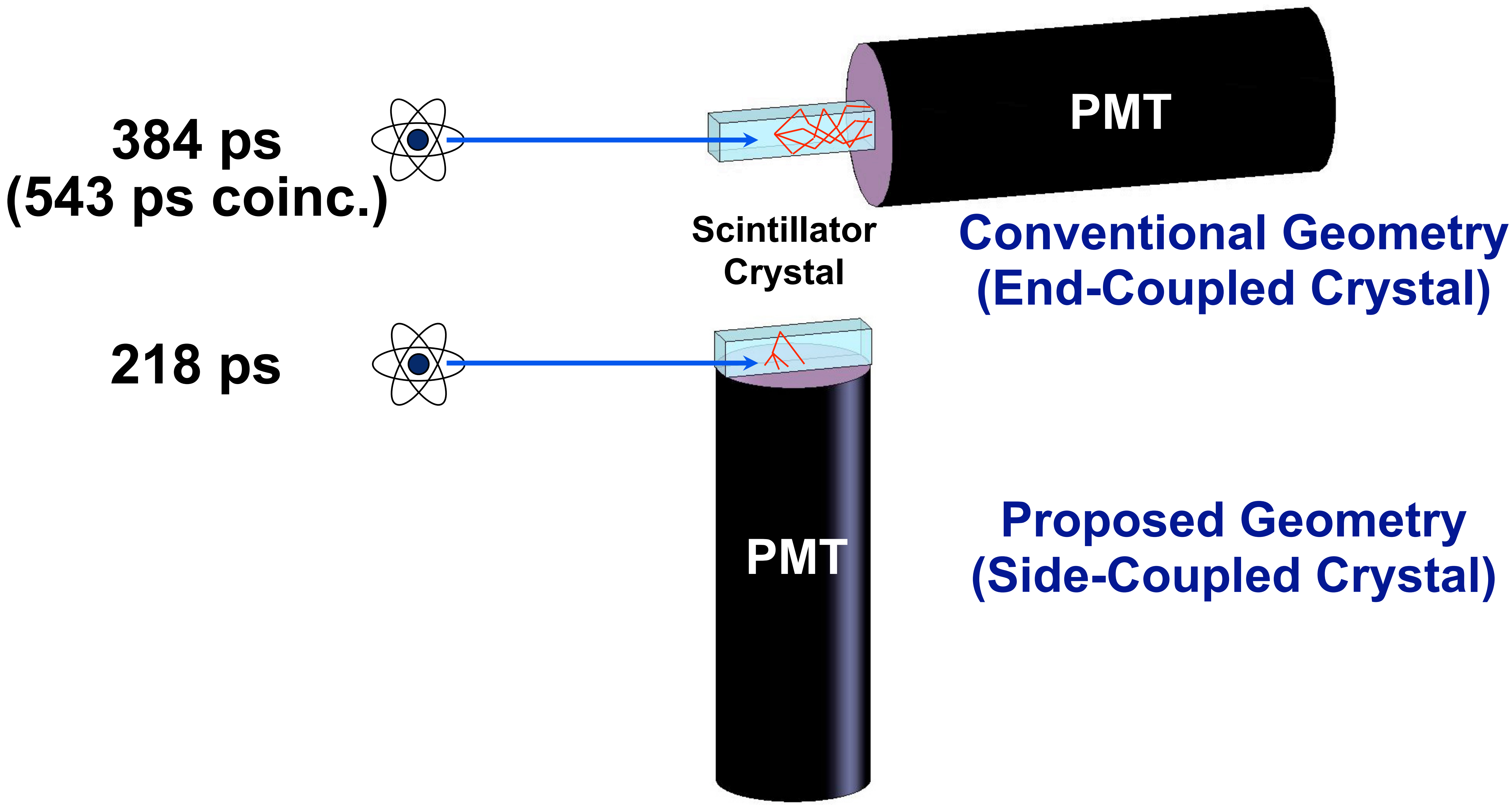
**Achieve the *Best* Timing Possible w/ LSO**

# What Limits Timing Resolution?



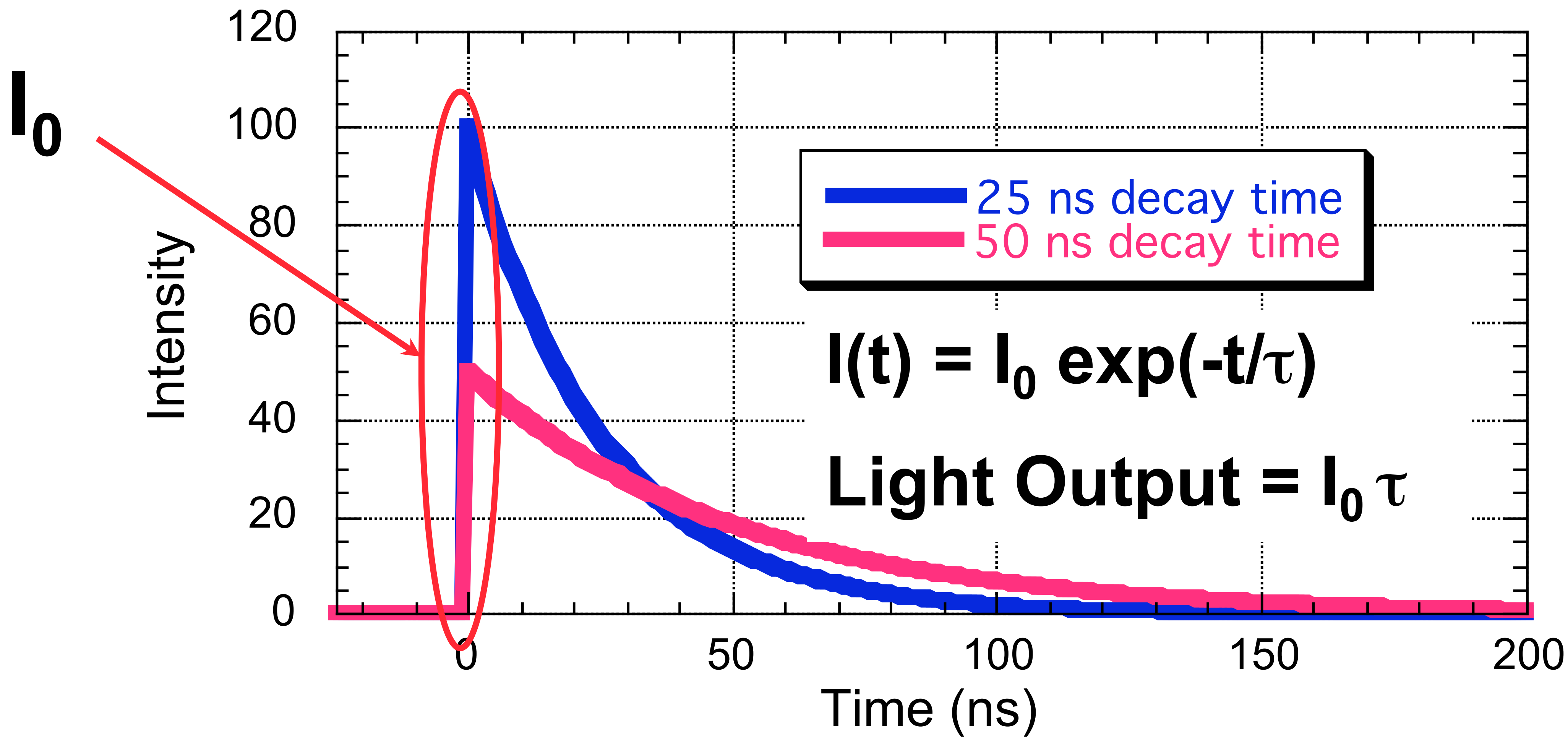

- Many Factors
- “Optical Geometry” Particularly Important

# Proposed Side-Coupled Design




**Shorter Optical Path Length & Fewer Reflections**

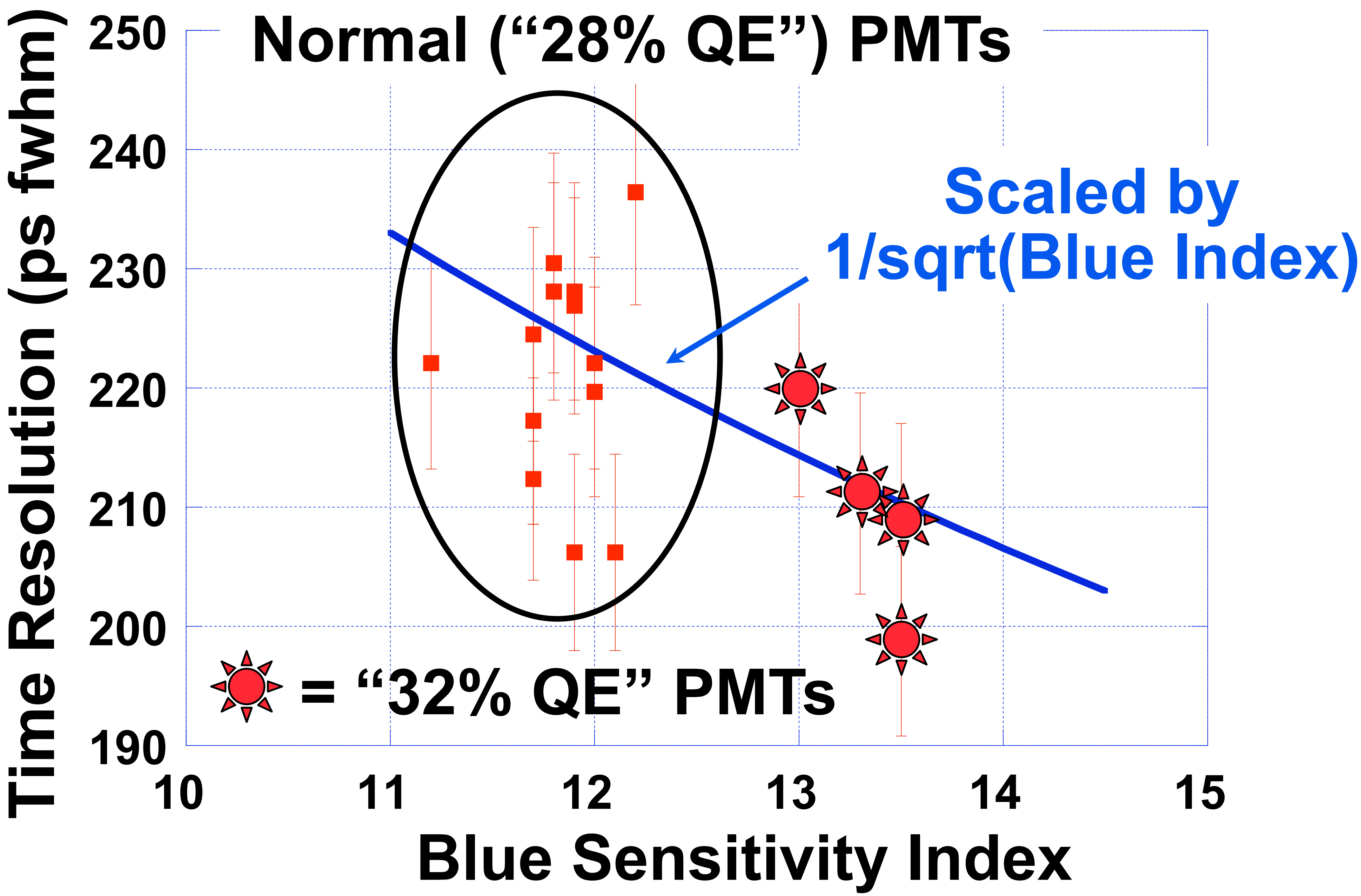
# Optimization: LSO Composition




- **Both Scintillators Have Same Light Output (photons/MeV)**
- **Red Decay Time is 2x Longer Than Blue Decay Time**

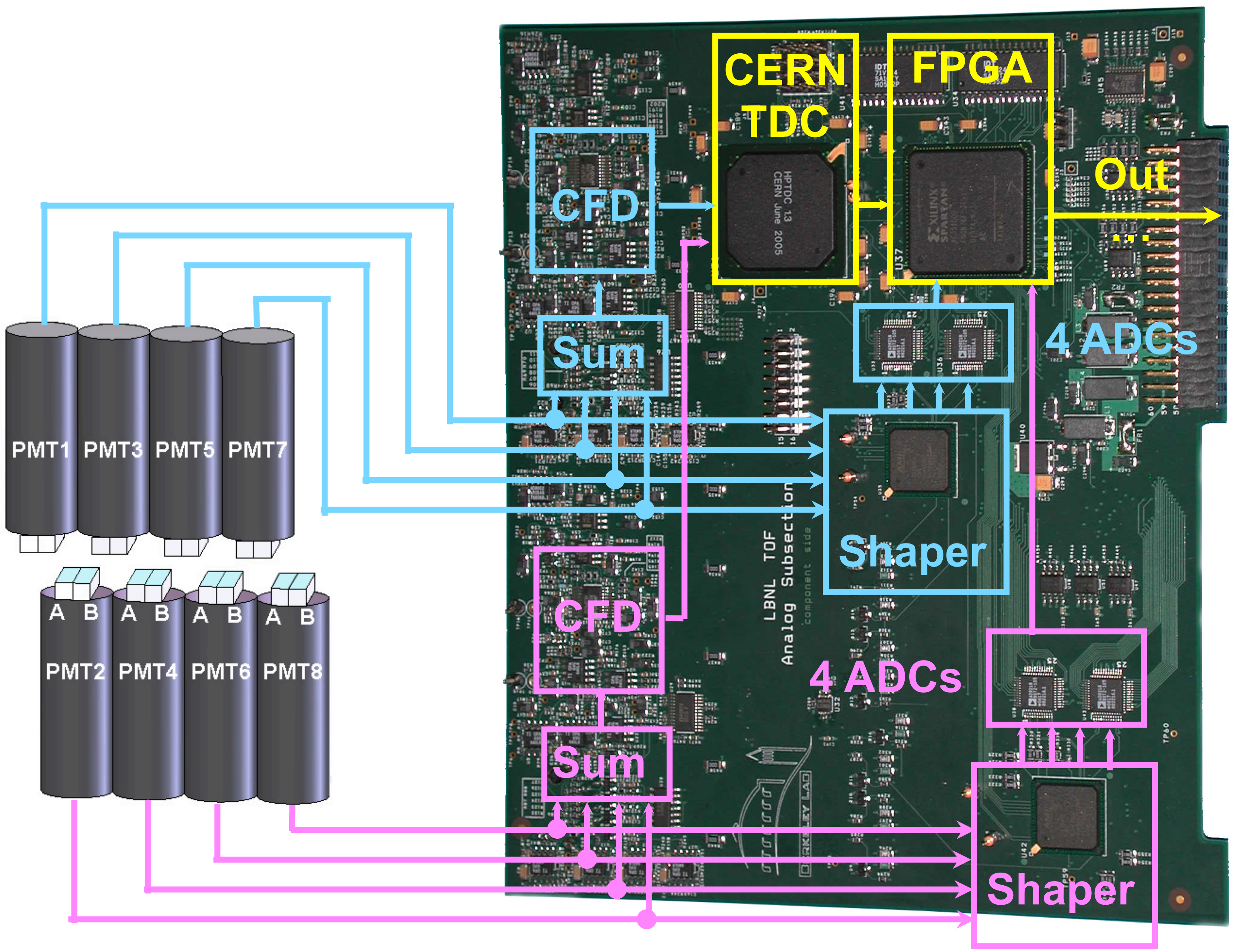
- **Predicted Timing Resolution $\propto 1/\mathrm{sqrt}(I_0)$**
- **Want High Total Light Output & Short Decay Time**
- **Possible By Co-Doping LSO With Calcium**

# Measured Results: High QE PMTs




- Increased QE Improves Timing Resolution by 7%
- Expect 10% Improvement with 35% SBA PMT

# Electronics




Based on Siemens “Cardinal” electronics.

CFD triggers if any of 4 adjacent modules fire.

CERN HPTDC digitizes arrival time w/ 24 ps LSB.

Pulse height from all 8 modules read out on every trigger.

FPGA uses pulse heights to identify interaction crystal.

FPGA also does calibration, event formatting, etc.

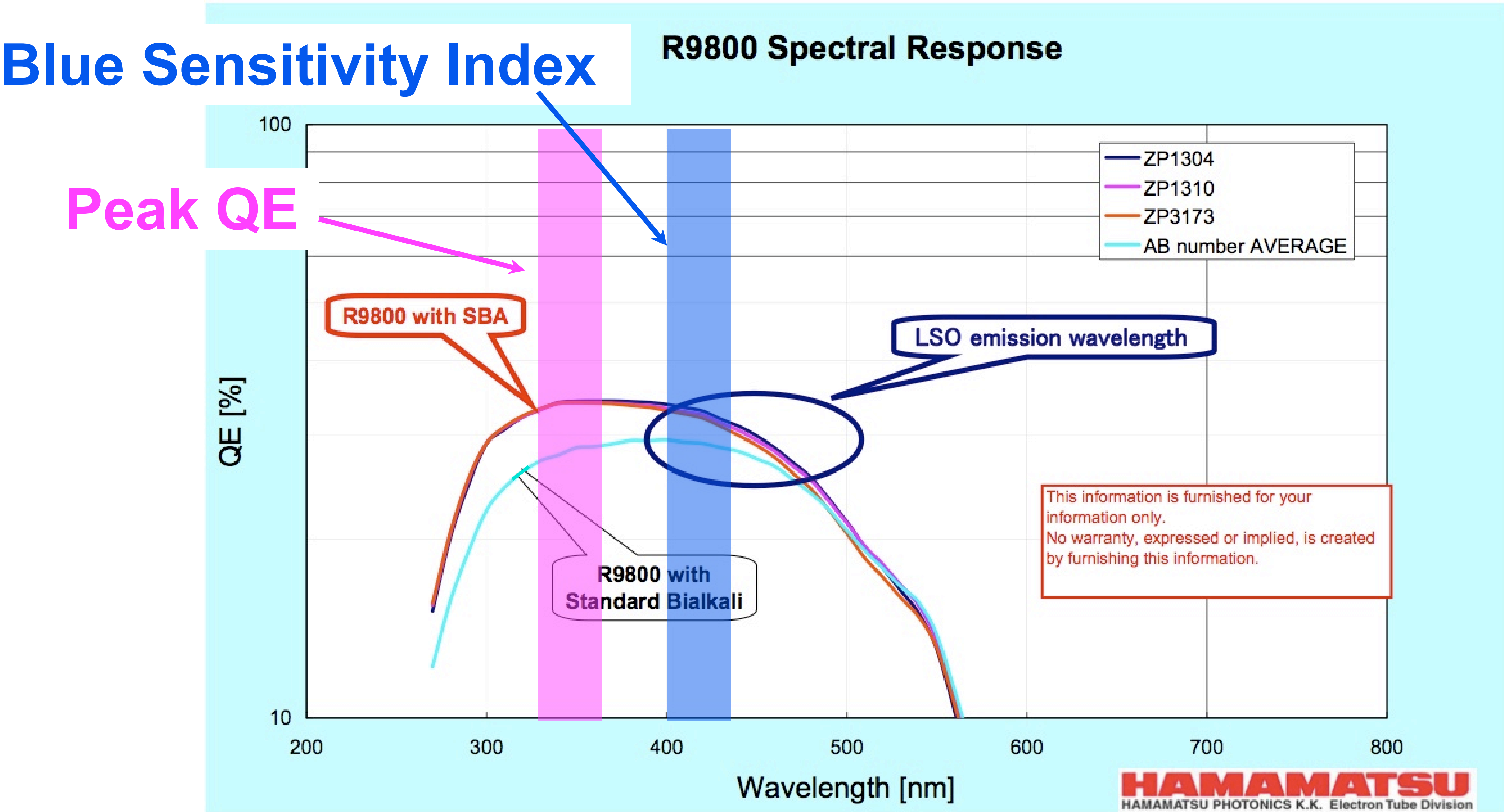
- Intrinsic Timing Resolution is 63 ps fwhm
- With Detectors, Same Timing as NIM Electronics

# Summary

| Hardware | Single (ps fwhm) | Coinc. (ps fwhm) | TOF Gain |
|---|---|---|---|
| End-Coupled Crystal | 384 | 544 | 4.3 |
| Side-Coupled Crystal | 218 | 309 | 7.6 |
| Etched, Reflector Paint | 227 | 321 | 7.3 |
| Co-Doped LSO | 182 | 258 | 9.1 |
| 32% QE PMT | 155 | 219 | 10.6 |
| 35% QE “SBA” PMT | 148 | 209 | 11.1 |

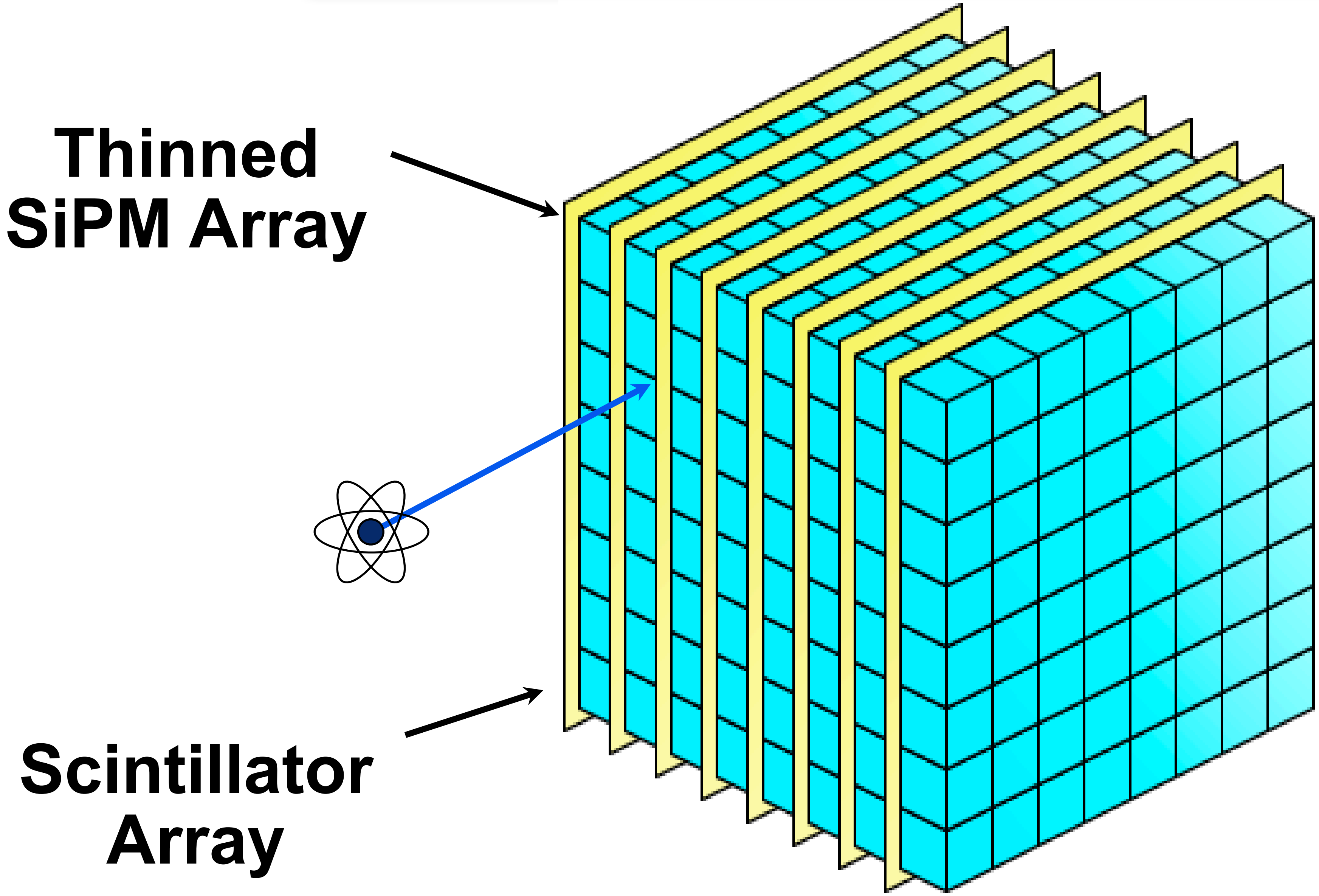
- **TOF PET with *Significantly* Better Timing is Possible**
- **To Achieve, We Must “Think Outside the Block Detector”**

# Optimization: Photomultiplier Tube




- Predicted Timing Resolution ∝ 1/sqrt(QE)
- Want High Quantum Efficiency Version of PMT

# Future TOF PET Design?




- Depth of Interaction & 150 ps Timing Resolution
- 11x Reduction in Variance in Practical Geometry

NSS-MIC October 2008

# Silicon Photomultiplier as an Alternative for APD in PET/MRI Applications

**Antoni Nassalski, M. Moszyński, A. Syntfeld-Każuch, Ł. Świderski, T. Szczęśniak, D. Wolski, T. Batsch, J. Baszak[*)]**

*The Sołtan Institute for Nuclear Studies, PL 05-400 Otwock-Świerk, Poland*

[*)] *Hamamatsu Photonics Deutschland GmbH, Polish Office*

# Experimental Details

## Hamamatsu MPPC parameters [2]

| Type | S10362-33-025C | S10362-33-050C |
|---|---|---|
| Active area | 3×3 mm$^2$ | 3×3 mm$^2$ |
| Number of pixels | 14400 | 3600 |
| Pixel size | 25x25 μm | 50x50 μm |
| Fill factor | 30.8 % | 61.5 % |
| Gain | 2.75 x $10^5$ | 7.5 x $10^5$ |
| Spectral resp. range | 270 - 900 nm | |
| Q.E. | 70% at 400 nm | |
| Operating voltage | 70 ± 10 V | |
| Dark counts | 5 Mcps | |
| Capacitance | 320 pF | |

## Properties of the LSO crystal [5]

| | |
|---|---|
| Light output [ph/MeV] | 31000 |
| Peak emission [nm] | 420 |
| Decay time [ns] | 40 – 47 |
| Refr. Index | 1.82 |
| Density [g/cm$^3$] | 7.4 |
| Manufacturer | CTI |

The MPPC were illuminated by a red laser diode type HL6501MG, Opnext, Japan.

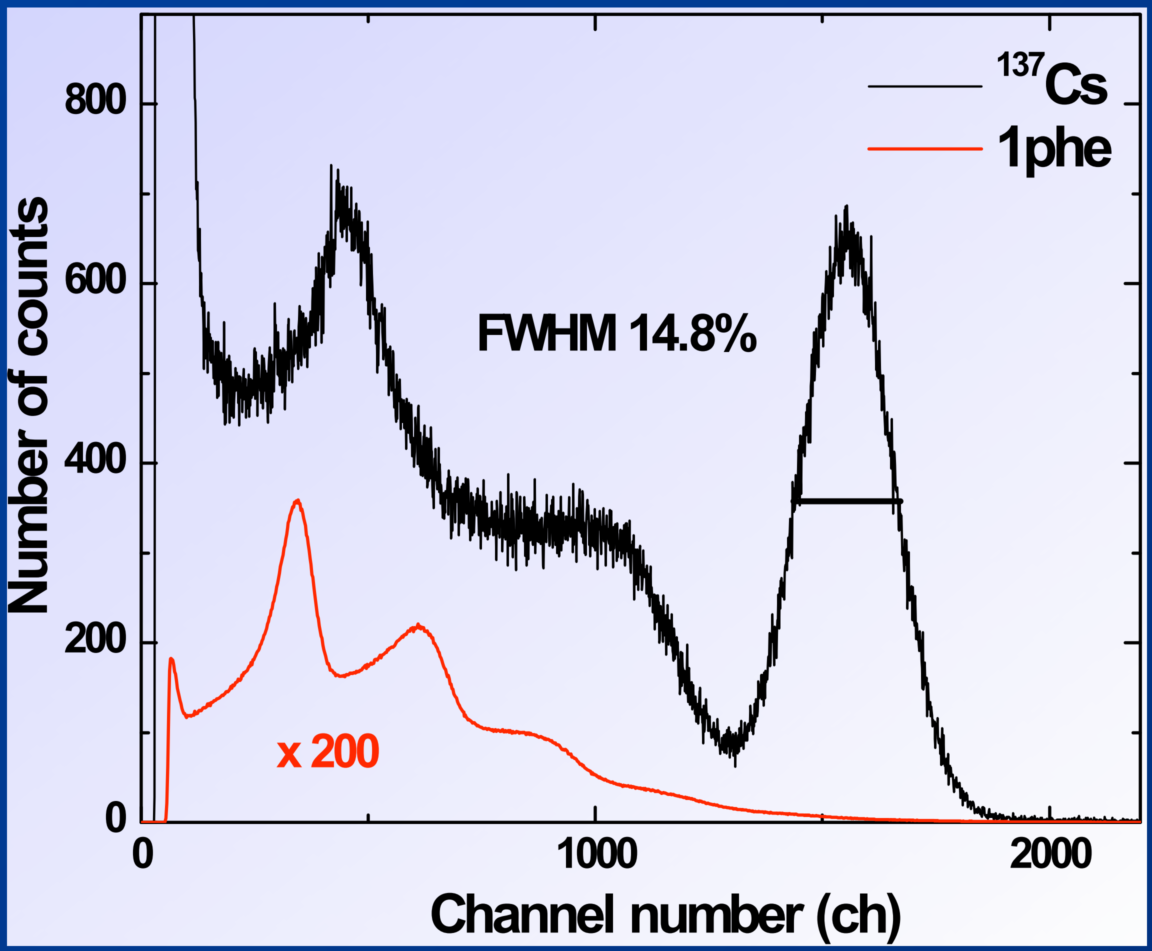
The signal was sent to the:

Charge sensitive preamplifier, Ortec 460 Delay Line Amplifier, Multichannel analyzer Tukan 8K [exhibition Booth 42].

# Gamma-ray Spectrometry

| Photodetector | Number of pixels | $N_{phe}$ [a)] | ΔE/E [%] | QE (PMT) PDE (MPPC) | Light output [ph/MeV] |
|---|---|---|---|---|---|
| MPPC 025C | 14400 | 1550±80 | 14.8±0.6 | 8.6±1% | 18000±1800 |
| MPPC 050C | 3600 | 1700±90 | 14.0±0.6 | 9.2±1% | 18000±1800 |
| PMT XP2020Q | - | 3950±200 | 11.3±0.5 | 21.9% | 18000±1800 |
| APD S8550 [e)] | - | 7010±350 | 12.8±0.6 | - | - |

[a)] Number of photoelectrons, phe/MeV, $^{137}$Cs (662keV),
[e)] 2x2x15 mm$^3$ LSO crystal coupled to Hamamatsu S8550 APD array [7],




The energy spectra of single photoelectron and $^{137}$Cs, measured for LSO crystal with 14400 pixels Hamamatsu MPPC.

**The light output of the LSO measured with the XP2020Q PMT, allows estimate the PDE of the tested MPPC.**

P.D.E. (Photon Detection Efficiency)

**The estimated PDE is much lower than expected (based on the QE and fill factor) 43 % for 14400 and 22 % for 3600 pixels devices.**

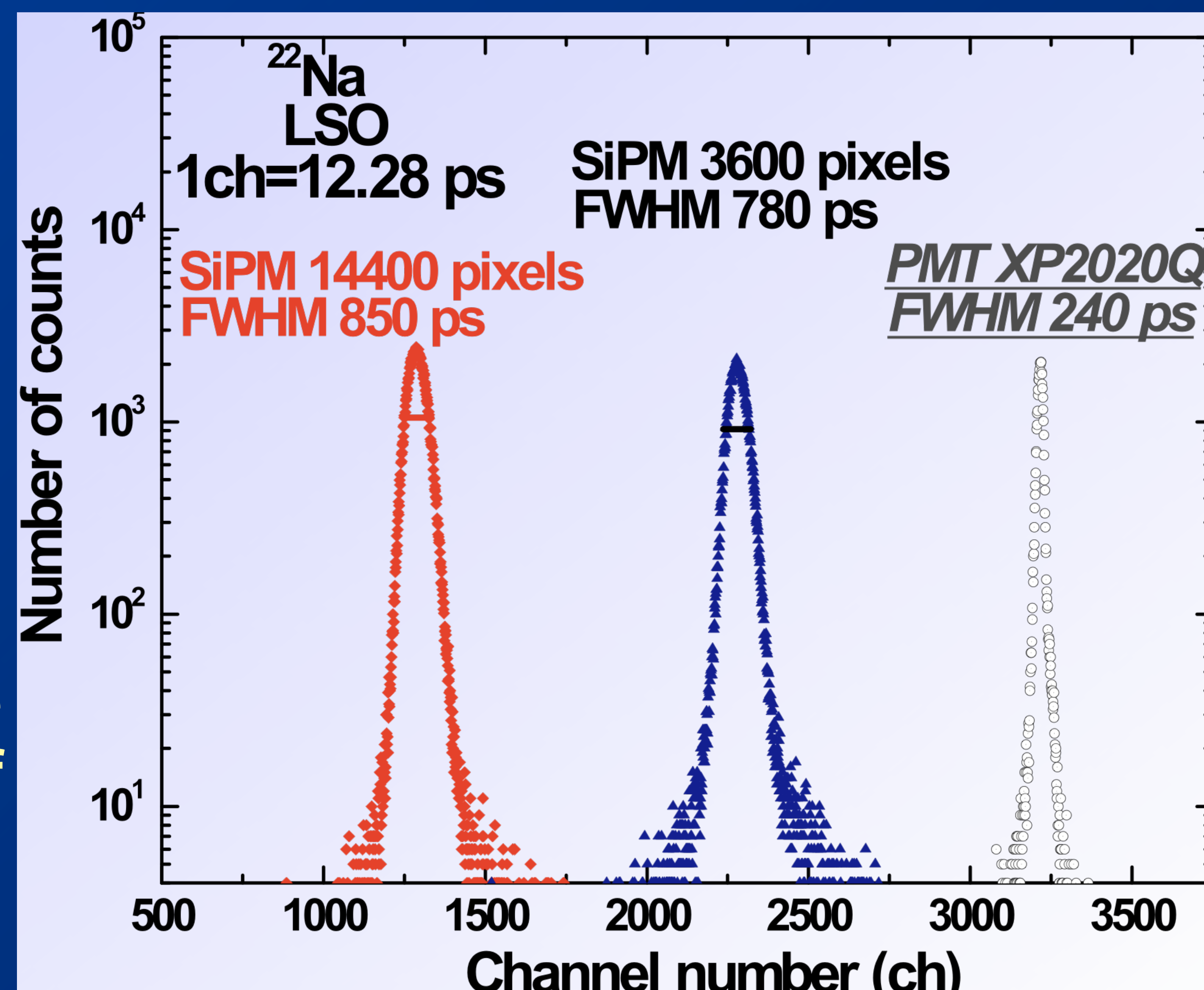
# Time Resolution Study

| Photodetector | Number of pixels | $N_{phe}$ a) | δt [ps] | $\delta t * N^{1/2} \times 10^3$ |
|---|---|---|---|---|
| MPPC 025C | 14400 | 790±40 | 850±40 | 23.9±1.2 |
| MPPC 050C | 3600 | 870±40 | 780±40 | 23.0±1.2 |
| PMT XP2020Q | - | 2000±100 | 240±10 | 10.7±0.6 |
| APD S8550 b) | - | 3180±160 | 2150±110 | - |

The best time resolution was measured with the PMT, 3 times better than with the MPPCs and superior to the APD array due to its dark noise.

a) Number of photoelectrons for 511 keV,
b) 2x2x15 $mm^3$ LSO crystal coupled to Hamamatsu S8550 APD array [7].

The time resolution normalized to the number of photoelectrons reflects a better timing capabilities of the PMTs in comparison to the MPPCs.
This is the effect of a slow rise time and a large capacitance of the MPPCs.



# Metamaterials for novel X- or $\gamma$-ray detector designs

P. Lecoq, Member, IEEE

One of the limitations of currently available PET (Positron Emission Tomography) and SPECT (Single Photon Emission Tomography) cameras is a poor spatial resolution (5 to 6mm in whole body clinical cameras), which is partly related to the necessity to integrate on a sufficiently large detector pixel the primary Compton scattering interaction (70% of the cases in the currently used conversion materials such as Lutetium orthosilicate: LSO) and the final photoelectric interaction.

# HEAVY CRYSTAL FIBER TECHNOLOGY

Crystal Clear colaboration [1] (CERN, VUB Brussels, University Claude Bernard LPCML, company Fibercryst Lyon, company Cyberstar, Grenoble)

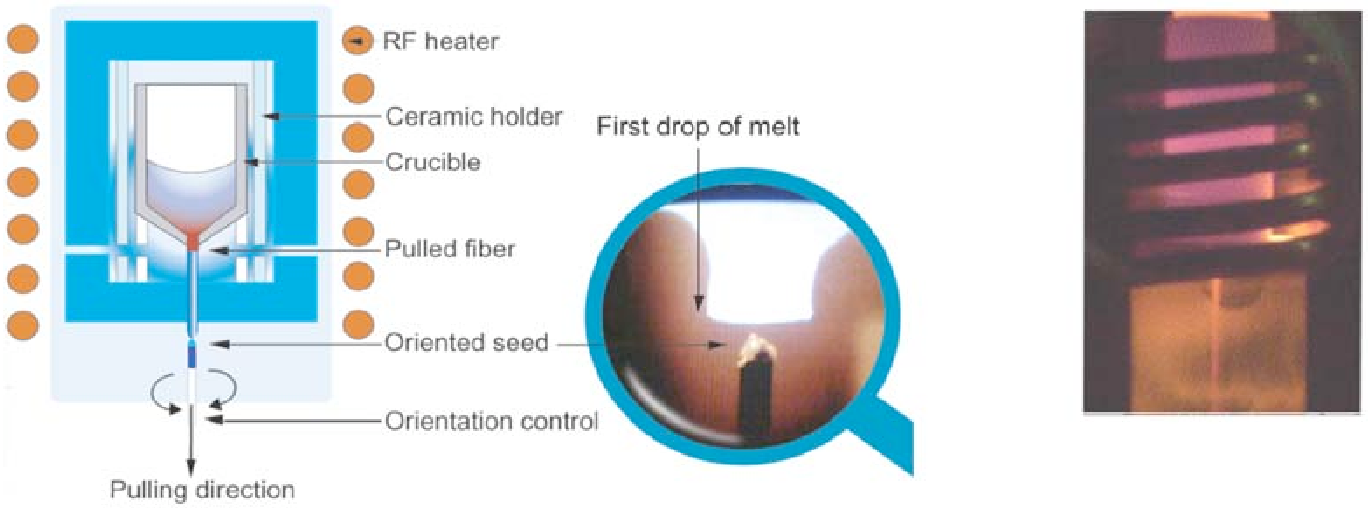
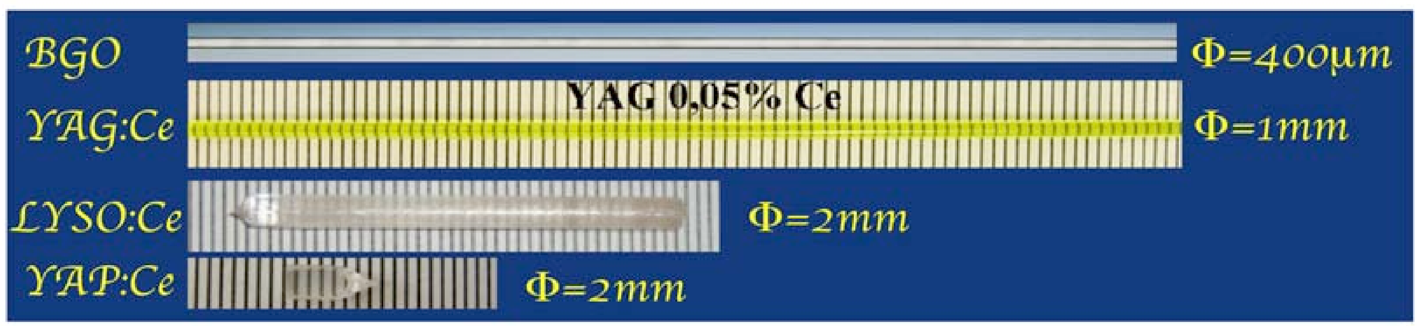


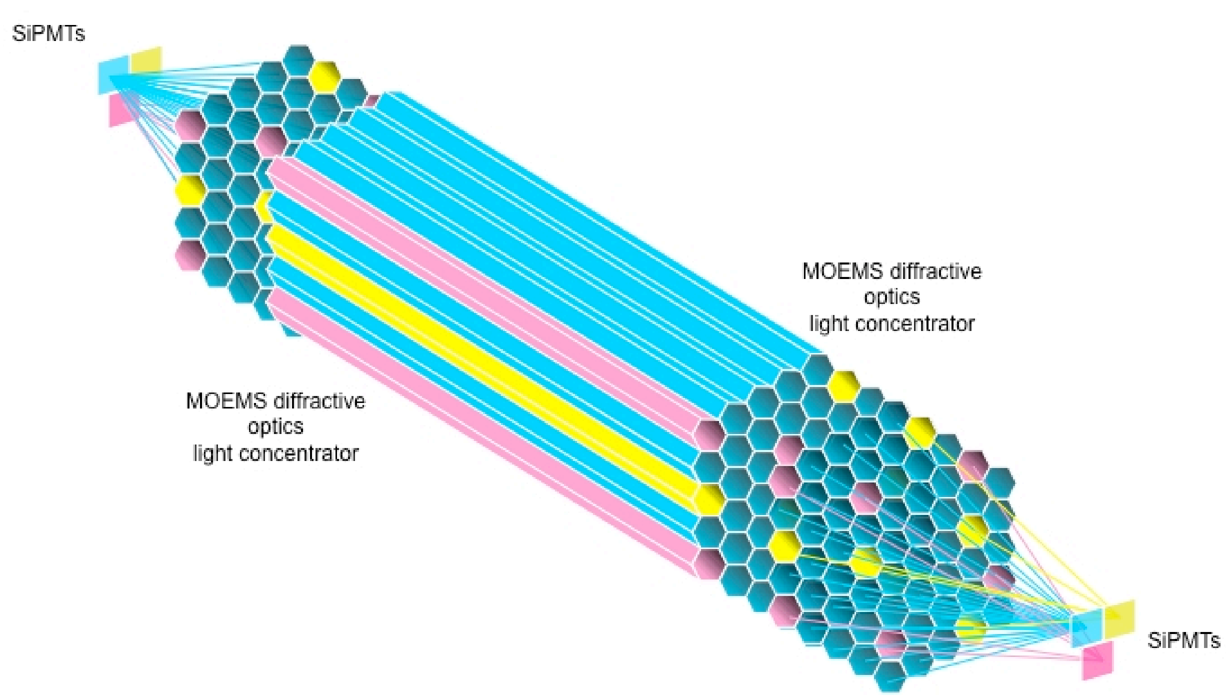

TABLE I
SOME PARAMETERS OF CRYSTALLINE FIBERS GROWN BY FIBERCRYST

| Crystal | Light Yield ph/Mev | Decay Time ns | Peak emission wavelength nm | Density g/cm$^3$ |
|---|---|---|---|---|
| BGO | 8000 | 300 | 480 | 7.13 |
| GSO:Ce | 14000 | 60 | 460 | 6.71 |
| YSO:Ce | 14000 | 37 and 82 | 420 | 4.45 |
| LYSO:Ce | 25000 | 40 | 420 | 7.40 |
| YAG:Ce | 20000 | 70 | 550 | 4.57 |
| LuAG:Ce | 20000 | 70 | 535 | 6.73 |
| LuAG:Pr | 20000 | 20 | 290-350 | 6.73 |

Micro-pulling down crystal growth technology




can grow fiber(rod) crystals with diameter 0.3 to 3.0mm, up to 2m length, 0.1-0.5mm/min




Concept of a metacable for calorimetry at future LCs

scintillating, Cerenkov and neutron sensitive fibers

# PHOTONIC CRYSTALS AND QUATUM DOTS

if the size of a semiconductor crystal becomes small enough that it approaches the size of the material's Exciton Bohr Radius, the electron energy levels become discrete through the effect of quantum confinement.

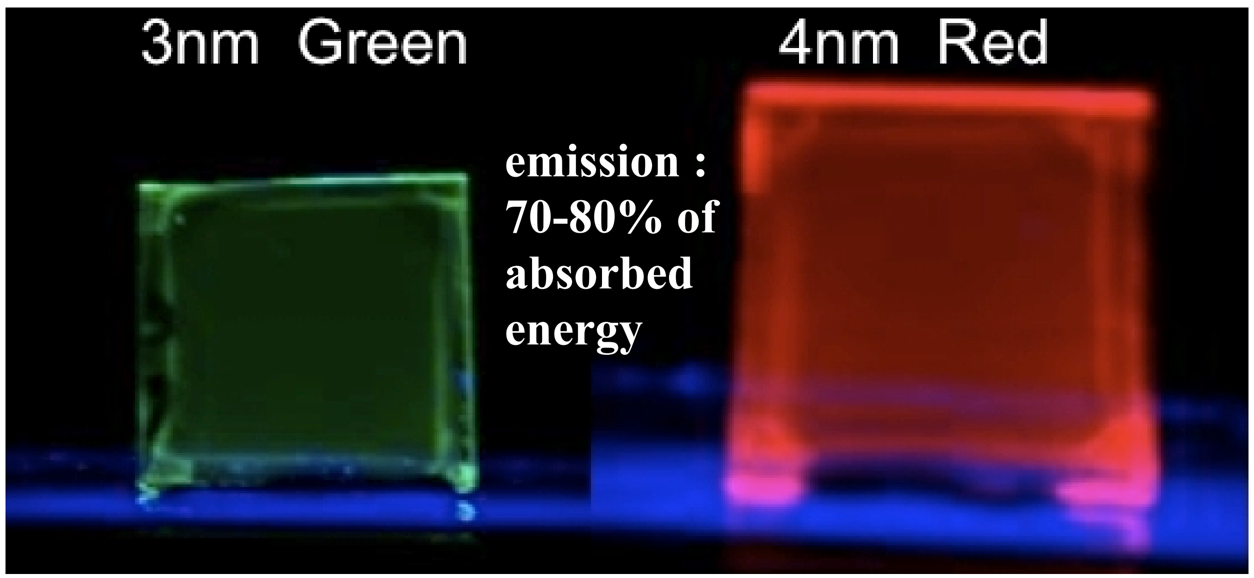



Fig. 2. Quantum dots of the same material but different size under UV illumination.

Photonic crystals are periodically structured electromagnetic media, generally possessing photonic band gaps: ranges of frequencies, in which light cannot propagate through the structure.

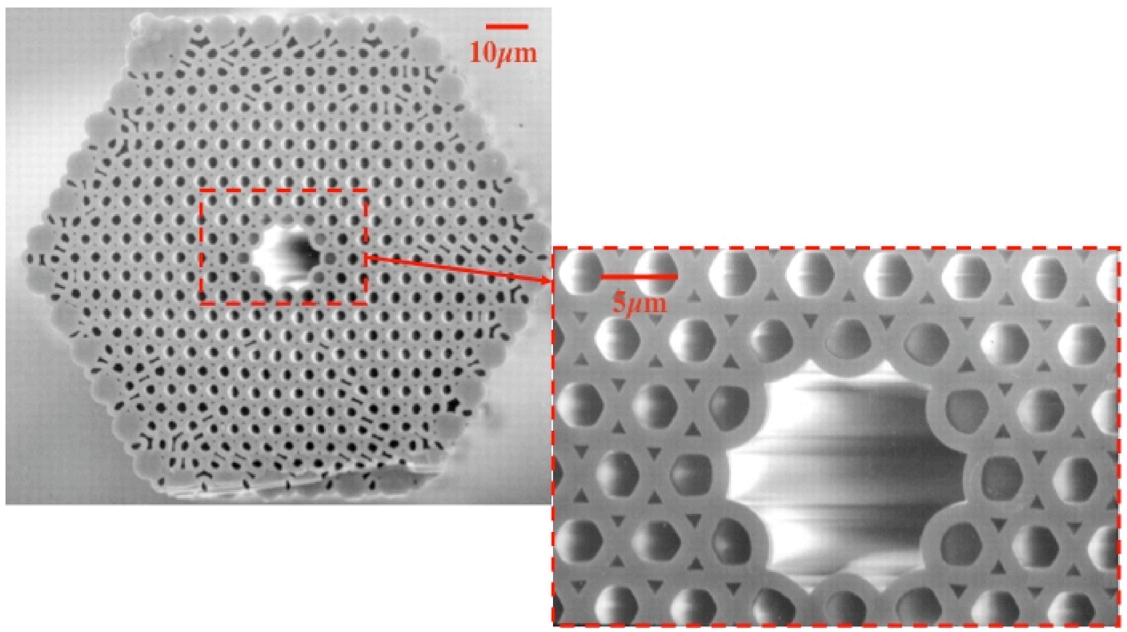
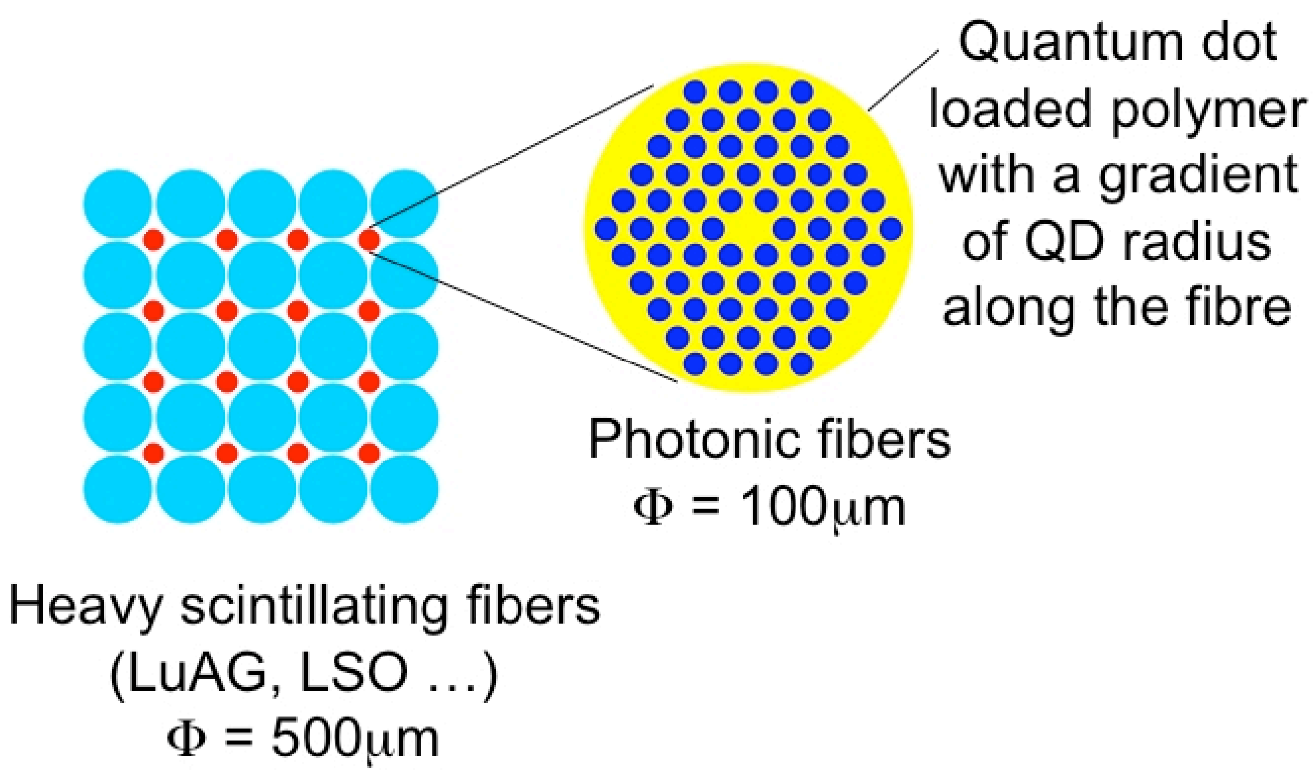



Fig. 3. Photonic crystal fiber




Concept of a metacable for low energy X and γ-rays

γ interaction in scintillating fibers
DOI by quantum dots, readout with photonic fibers

# Potentials for large axial field of view positron camera systems

L.Eriksson, D.W.Townsend,
M.Conti,C.L.Melcher,M.Eriksson,B.W.Jakoby,
H.Rothfuss,M.E.Casey, B.Bendriem

The extended FOV for PET systems based on Resistive Plate Chambers (RPCs) has been discussed by Couceiro et al. The timing characteristics of the RPC are excellent and for 511 keV gamma rays the time resolution has experimentally been found to be around 300 ps.

an intrinsic spatial resolution around 0.5 mm using filtered backprojection for the image reconstruction. The RPC technology does not provide energy information but is claimed to have a built in low energy discrimination.

TABLE 1.
SIMULATED RELATIVE EFFICIENCIES FOR LARGE AFOV RPC SYSTEMS FROM COUCEIRO ET AL [3]

| AFOV (cm) | RPC relative sensitivity | | RPC scatter fraction | |
|---|---|---|---|---|
| | 60 plates | 120 plates | 60 plates (%) | 120 plates (%) |
| 15 | 0.081 | 0.25 | 36.8 | 38.0 |
| 30 | 0.32 | 0.97 | 42.2 | 43.0 |
| 45 | 0.67 | 2.1 | 44.2 | 44.3 |
| 60 | 1.1 | 3.5 | 45.4 | 45.4 |
| 90 | 2.2 | 6.9 | 45.9 | 46.2 |
| 120 | 3.4 | 11 | 46.6 | 46.4 |
| 150 | 4.7 | 15 | 46.7 | 46.7 |
| 180 | 5.9 | 18 | 46.0 | 46.2 |
| 210 | 6.8 | 21 | 46.0 | 46.1 |
| 240 | 7.2 | 23 | 46.6 | 46.4 |

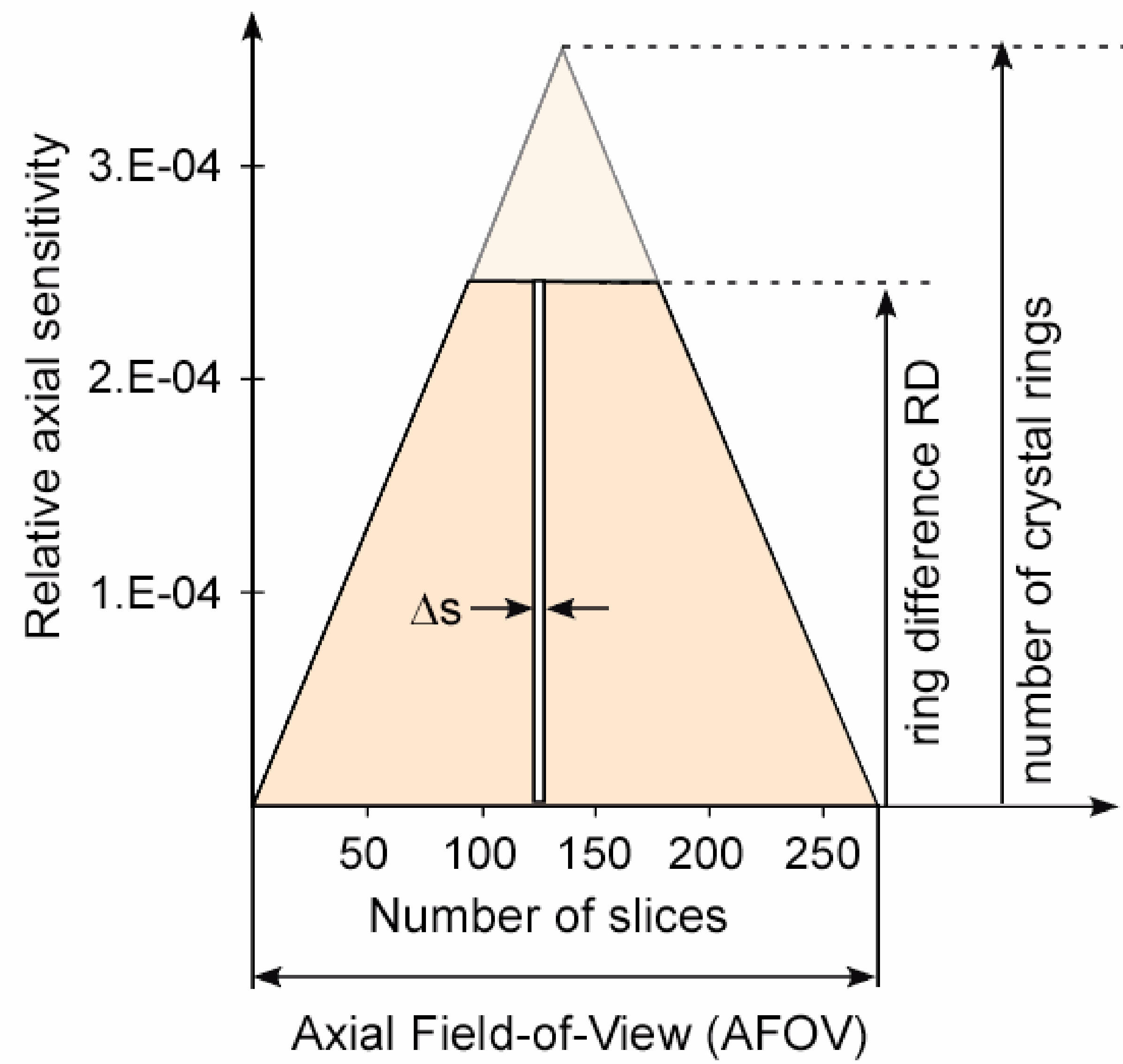



Fig. 1 The axial sensitivity of a PET system operated in 3D has a triangular shape. By limiting the axial acceptance angle, the sensitivity profile will have a trapezoidal shape. RD is the ring difference selected in such a way that the top triangle in the figure is ~ 10% of the full triangle implying a 10% sensitivity loss. The orange area is now related to the axial sensitivity ($\eta_{axial}$). If based on a common reference (70 cm line source) $\eta_{abs}$ = (AFOV/70)* $\eta_{axial}$. The planar sensitivity is then ~ [RD*Δs/(orange trapezoidal area)]* $\eta_{abs}$ (Δs is the slice thickness). The planar sensitivity is related to the time necessary to obtain acceptable image quality. The concept is especially useful when comparing different systems.

TABLE 2.
SUMMARY OF THE LSO SYSTEM PARAMETERS USED TO SIMULATE THE 196 CM RPC SYSTEMS. BLOCK SPECIFICATIONS USED IN THE SIMULATIONS: NUMBER OF PIXELS PER BLOCK = 13*13. PIXEL SIZE IS 4*4*4.3 $MM^3$. BLOCK FRONTAL AREA IS 5.6*5.6 $CM^2$

| System parameters | The 196 cm AFOV LSO system or "RPC" system |
|---|---|
| System diameter in cm | 85.5 |
| Axial extension (AFOV) in cm | 196 |
| Scintillator used to simulate RPC performance | LSO |
| Number of LSO blocks in a block ring | 48 |
| Number of LSO block-rings to give 196 cm axial FOV | 35 |
| Solid angle fraction (dΩ) out of 4π at center | 0.916 |
| Ideal crystal volume in $cm^3$ (ideal) | 22711 |
| Actual crystal volume of the simulated scanner in $cm^3$ (actual) | 19534 |
| Packing fraction (P) = ratio (actual/ideal) | 0.86 |
| Central point sensitivity $\eta max \sim (d\Omega)*(P)^2 (\eta_s)^2$ | 0.023 |
| Axial line source sensitivity $\eta_{axial}$ | 0.012 |
| Axial line source sensitivity with ring difference RD defined to give 90% of full efficiency ($\eta_{axial90}$) | 0.0108 |
| Absolute sensitivity as (AFOV/70)* $\eta_{axial90}$ | 0.029 |
| Planar sensitivity (assuming ~2 mm slice thickness) | 3.02E-05 |

TABLE 3.
COMPARISON BETWEEN THE SIEMENS TRUEPOINT TRUEV SYSTEM AND THE 196 CM AFOV "RPC" SYSTEM

| System parameters | Truepoint TrueV | The 196 cm AFOV LSO system or "RPC" system |
|---|---|---|
| System diameter in cm | 85.5 | 85.5 |
| Axial extension (AFOV) in cm | 22 | 196 |
| LSO block definition | 13*13 pixels 4*4*20 $mm^3$ forming a 5.6*5.6 $cm^2$ block | 13*13 pixels 4*4*4.3 $mm^3$ forming a 5.6*5.6 $cm^2$ block |
| Number of blocks /block-ring | 48 | 48 |
| Number of block-rings | 4 | 35 |
| Solid angle fraction at center | 0.249 | 0.916 |
| Absolute sensitivity | 0.0083 | 0.029 |
| Planar sensitivity | 1.165E-04 | 3.02E-05 |
| Time/bed to achieve same image quality (min) | 1min 30 sec | 5min 48 sec |
| Number of bed steps for a 70 cm axial FOV | 5 | 1 |
| Total scan time in minutes | 7min 30 sec | 5min 48 sec |

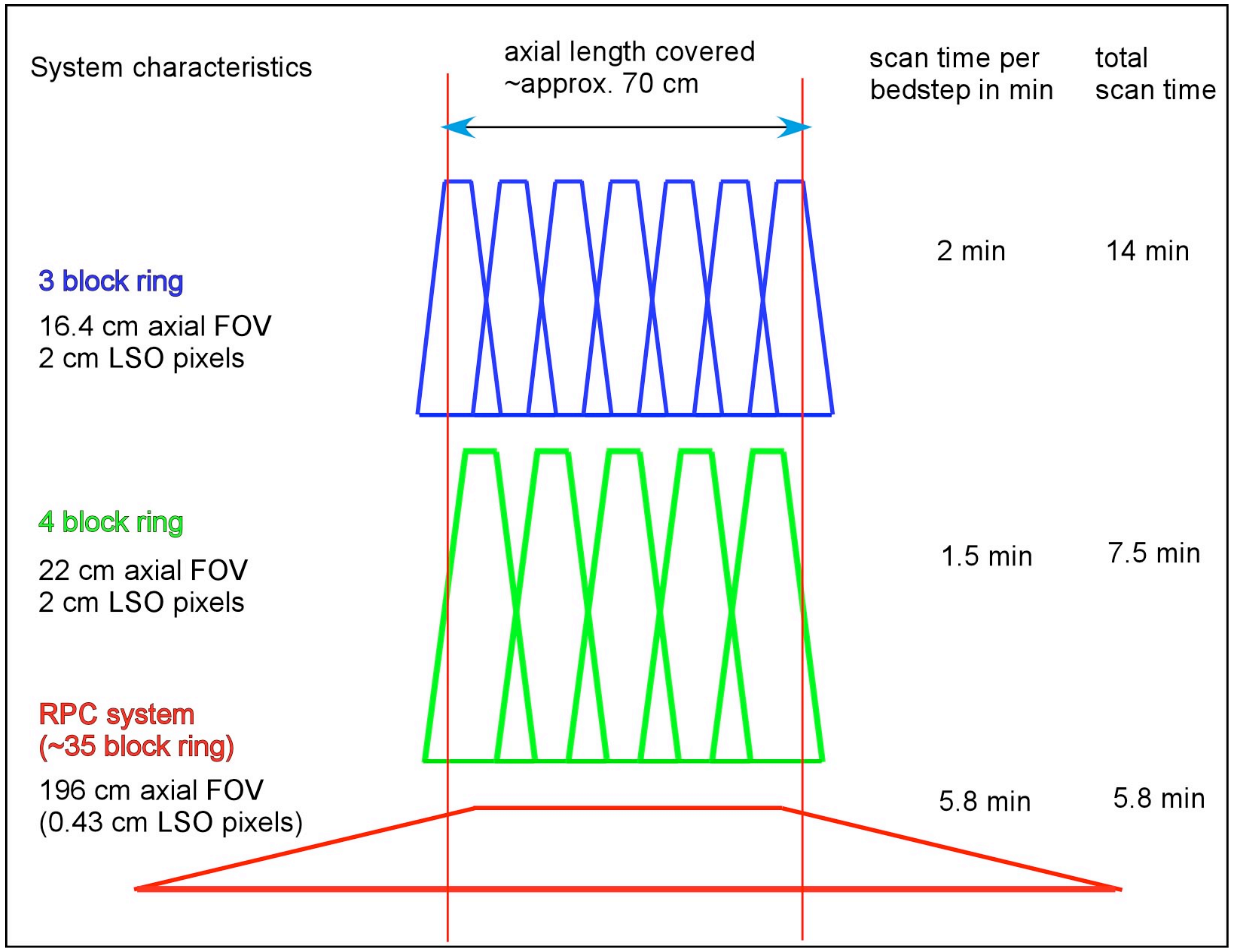



Fig. 2 Axial sensitivity profiles for the Truepoint 3 and 4 block ring system compared to the count rate simulated RPC system. Based on the planar sensitivities, the scan time per position is calculated. The Truepoint 3 ring planar sensitivity is almost 3 times higher than the planar sensitivity of the simulated RPC system. Due to the limited axial FOV extensions, 7 bed positions are needed for the 3 block ring system and 5 positions for the 4 block ring system to cover an approximate body area of 70 cm extension. Only one position is needed for the 2 meter RPC system. In this case the RPC based system is more effective than the Truepoint systems even if the four block ring system is quite close in time.

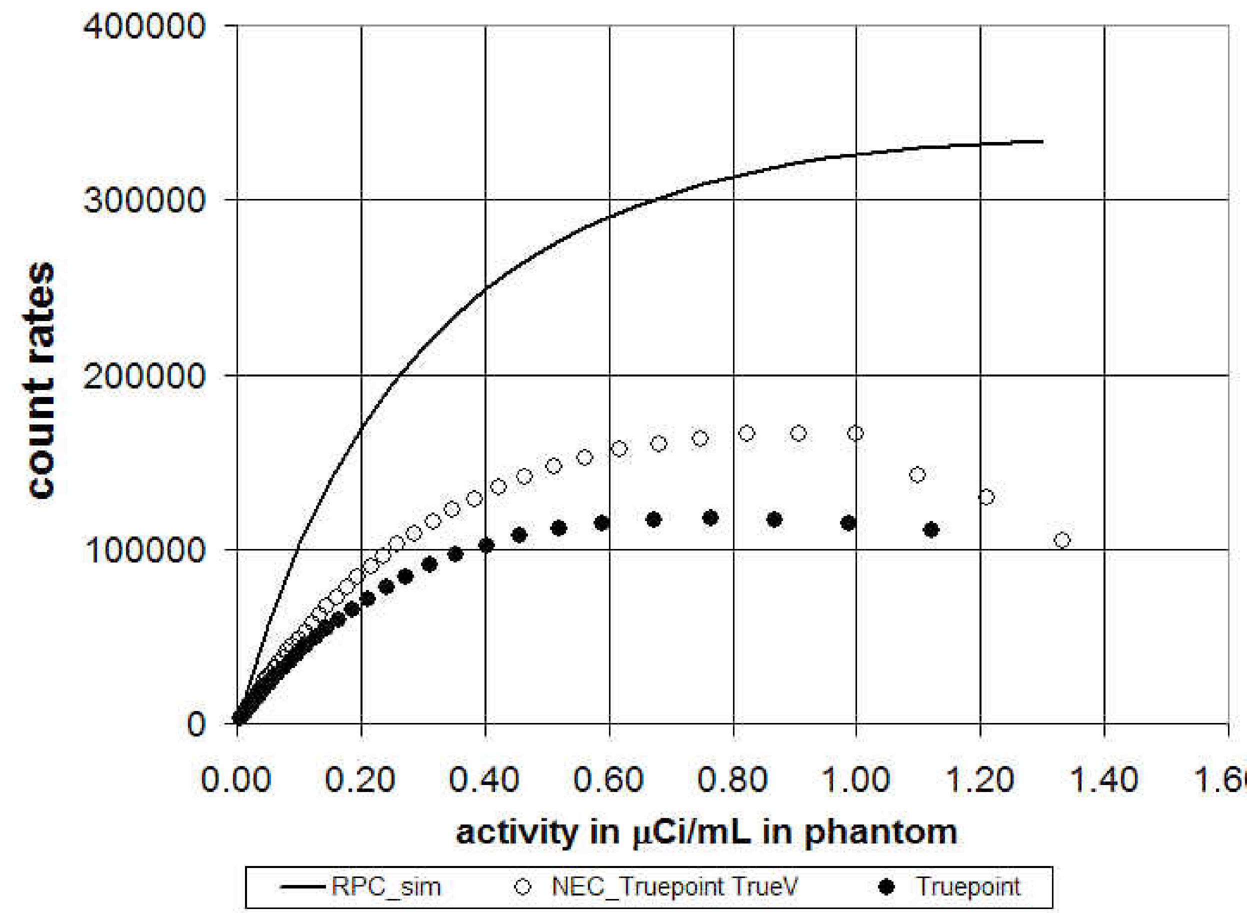
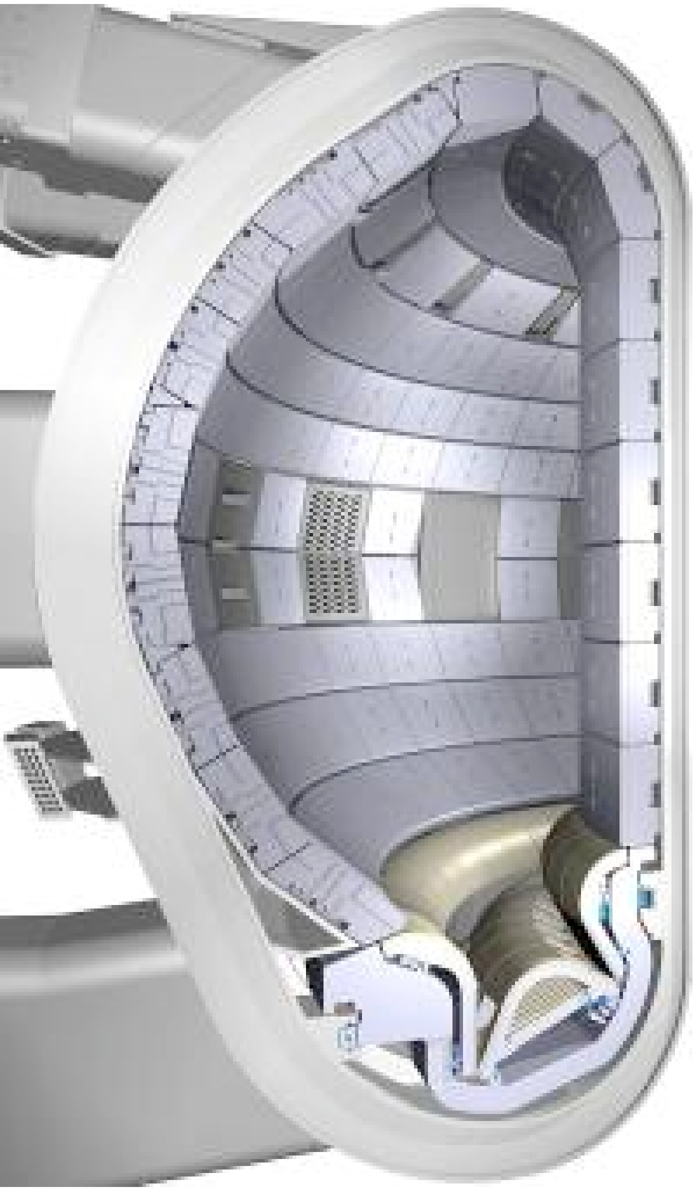


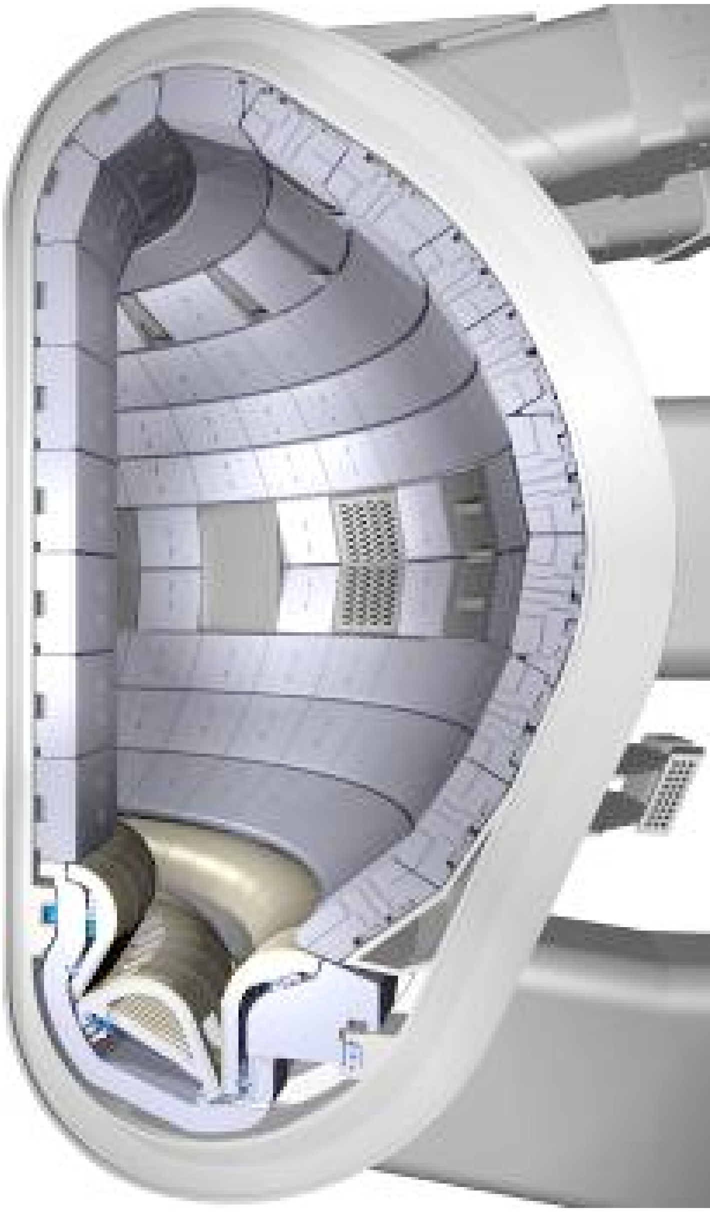

Fig 3. NEC calculations of the simulated RPC system compared to the Siemens Truepoint and Truepoint TrueV LSO block ring system.



# Status of the ITER Project

**Carlos Alejaldre**

**ITER Deputy Director General**



## NSS 2008
## Dresden

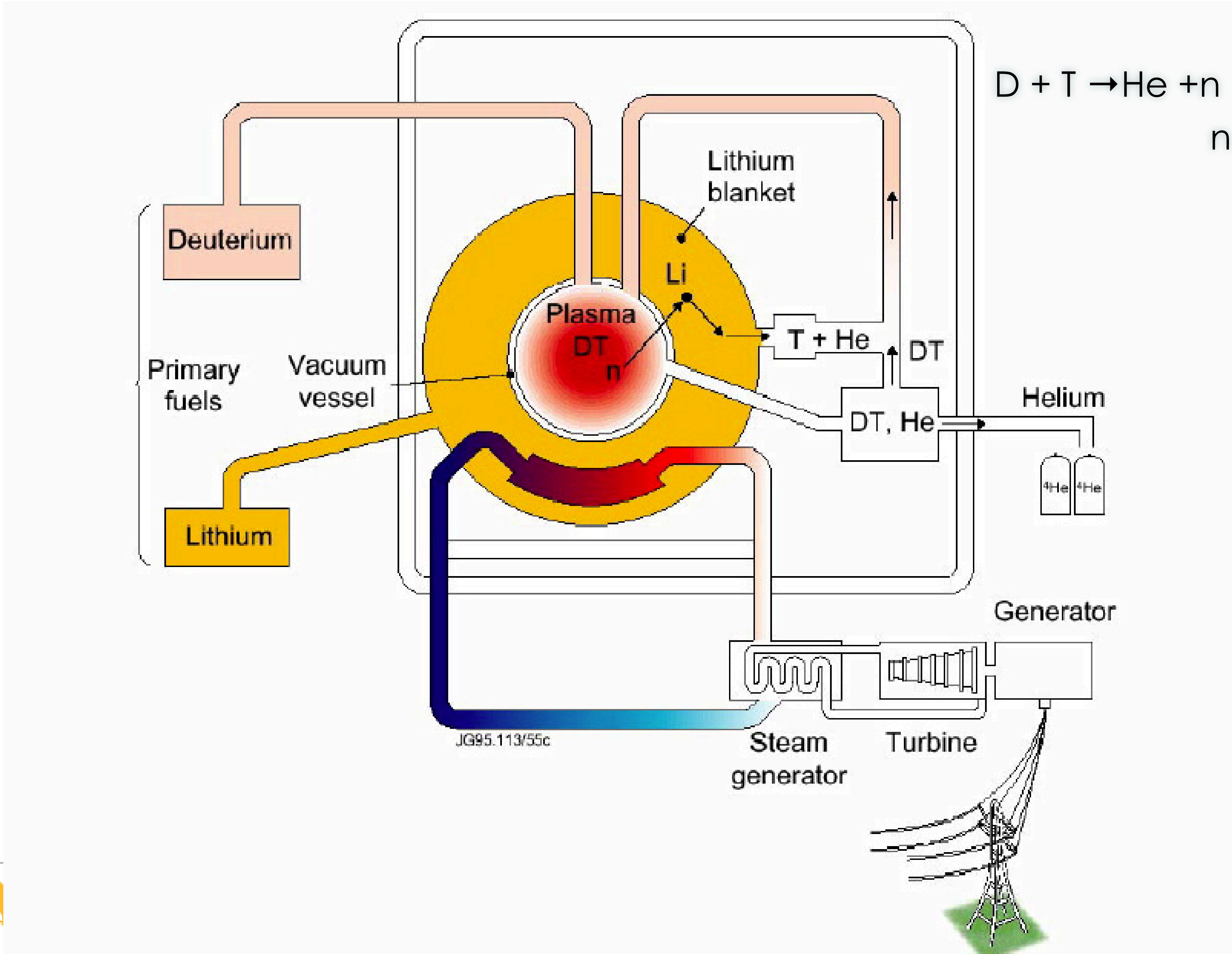
# ITER – Key facts

- Designed to produce 500 MW of fusion power (tenfold the energy input) for an extended period of time
- Will bring together most key technologies needed for future fusion power plants
- 10 years construction,
  20 years operation
  5 years deactivation
- Cost: 5 billion Euros for construction, and 5 billion for operation and decommissioning


Cadarache Site

The current ITER building

# Power Reactor




D + T →He +n

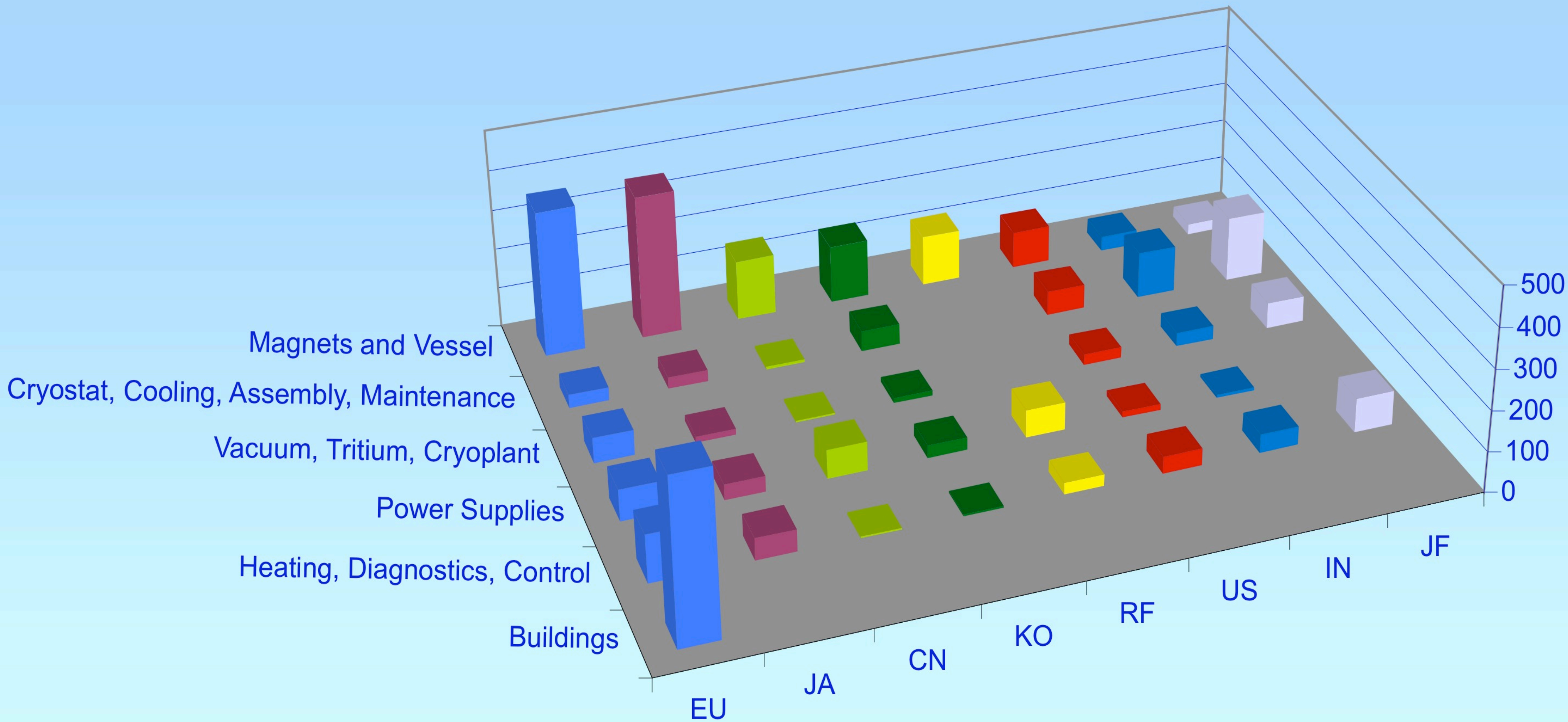
n + Li →T

# Procurement Sharing

How the overall costs are shared:

EU 5/11, other six parties 1/11 each. Overall contingency of 10% of total. Total amount: 3577 kIUA (5.365 Mil € / 2008)

A unique feature of ITER is that almost all of the machine will be constructed through *in kind* procurement from the Parties



# The Way to Fusion Power – The ITER History

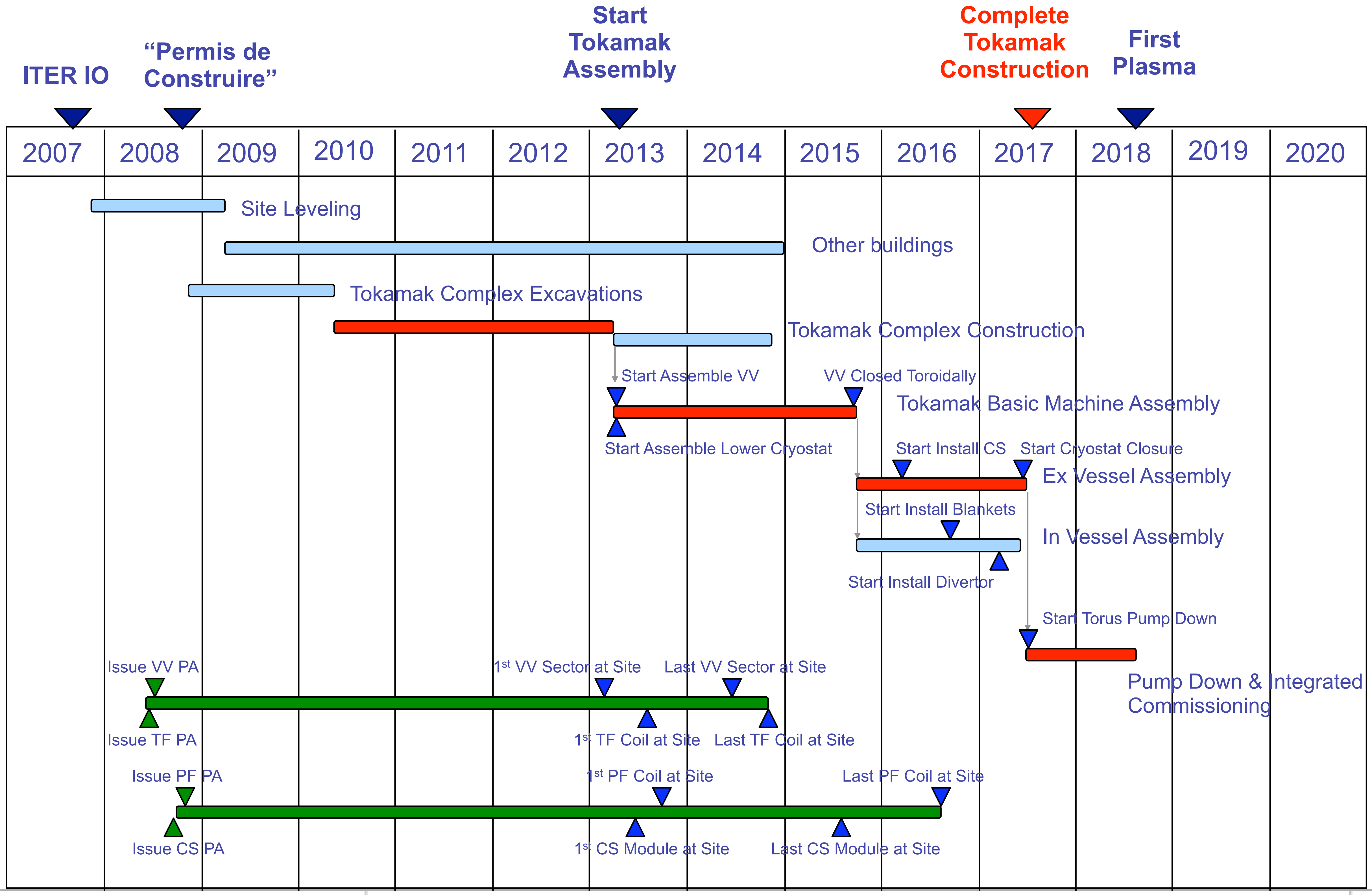
*“For the benefit of mankind ”*

The idea for ITER originated from the Geneva Superpower Summit in 1985 where Presidents Gorbachev and Reagan proposed international effort to develop fusion energy…

…“*as an inexhaustible source of energy for the benefit of mankind*”.

China, Europe, India, Japan, Korea, Russian Federation and the United States of America sign the ITER Agreement on 21 November 2006 in the Elysee Palace, Paris

# The Schedule



# The site - artist's view

# Fusion in Tokamak Plasma

**Deuterium + Tritium = Helium (3.5 MeV) + neutron (14MeV)**

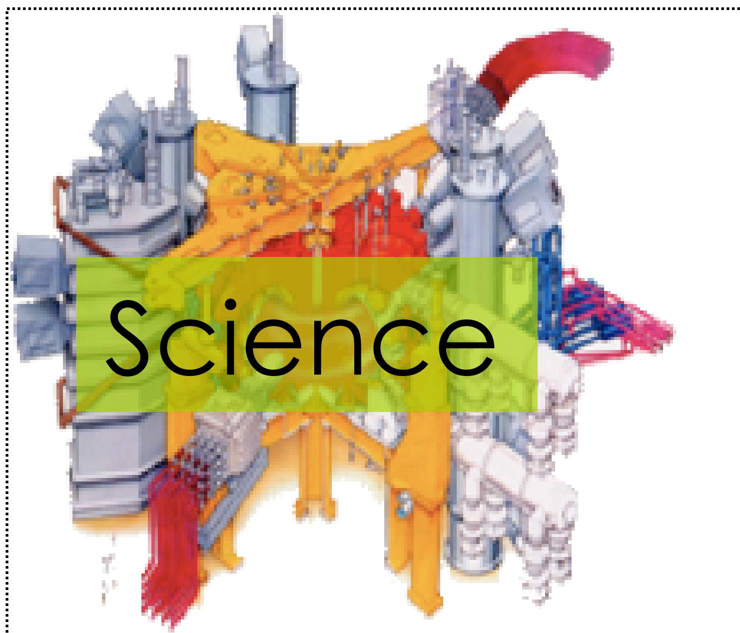
**( Deuterium from water, Tritium produced from Lithium with neutron collision)**

**Energy: 1 g of fusion fuel = 8 tonnes of oil**

**JET(EU),**

**JT-60(Japan)**

**Plasma research**




**Plasma Volume** ~ 100m³

**Fusion Power** ~ 16 Mega Watt (JET)

**Temperature** ~ 520 Million C (JT60)

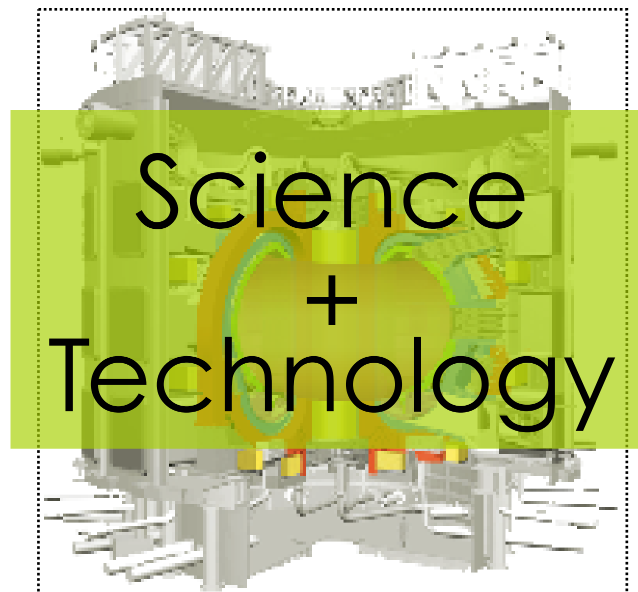
**Pulse length** ~ a few seconds

**Cu magnets**

**ITER**

**Long burn, Integration of fusion tech.,**

**Test of tritium production**




**850 m³**

**500 MW**

**200 - 300 M°C**

**400s -> steady state**

**SC magnets**

**Electricity - generating power plant including tritium production**


**similar size**

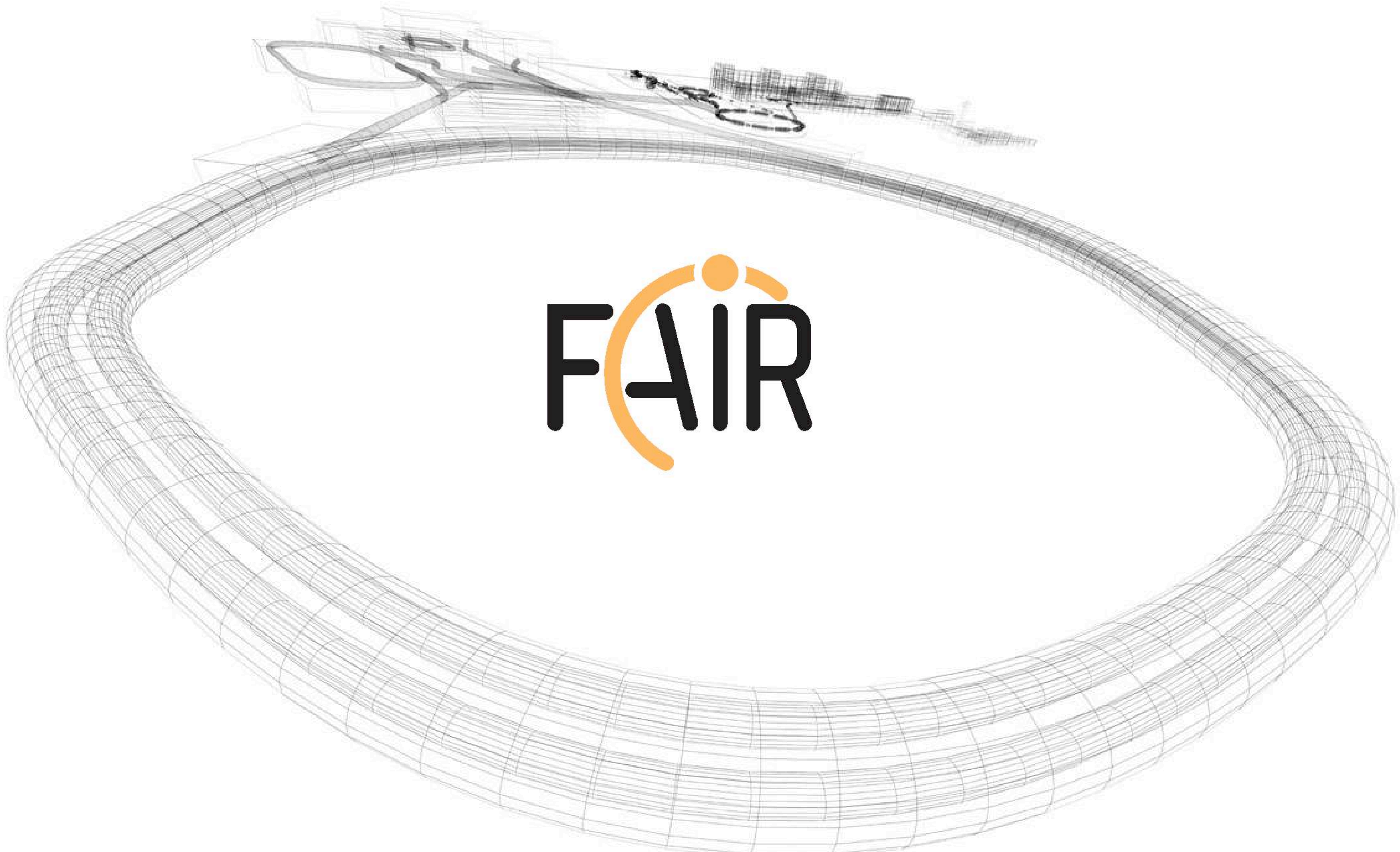
**3000 MW**

**200 - 300 M°C**

**steady state**

# FAIR – Facility for Antiproton and Ion Research

## Facility, Physics Overview
## Focus on Strong Interactions



GSI Helmholtz Centre for Ion Research — HELMHOLTZ GEMEINSCHAFT

Peter Braun-Munzinger, GSI/TU Darmstadt & FIAS

# FAIR Characteristics

## Gain Factors

- Beam intensities by factors of 100 - 10000
- Beam energies by a factor 20
- Production of antimatter beams
- Factor 10000 in beam brilliance via cooling
- Efficient parallel operation of programs

## Construction Period, Cost, Users

- Construction in three phases until 2016
- Total cost 1.2 B€
- Scientific users: 2500 - 3000 per year

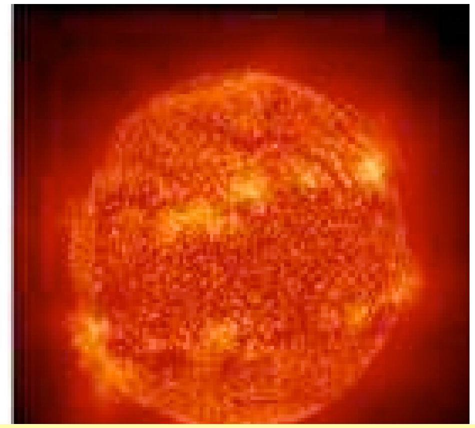
## Financing

- 65 % Federal Government of Germany
- 10 % State of Hessen
- 25 % Partner Countries

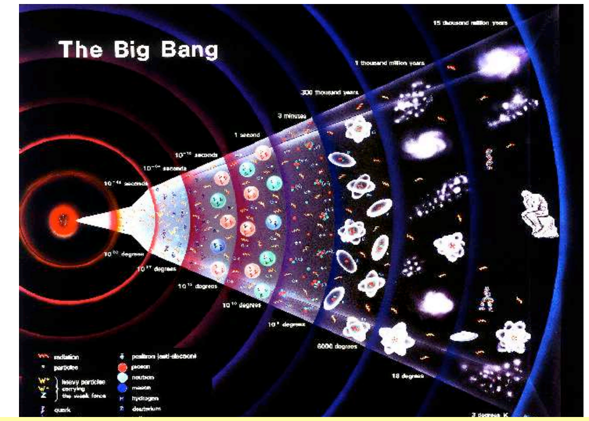
→ FAIR GmbH with International Shareholders

# FAIR physics areas and users

nucl. astrophysics
atomic physics
in the cosmos



plasma physics




QCD, QGP, mass generation
novel states

Hadron Structure, QCD & Medium
Cooled antiprotons < 15 GeV, **500 users**

QCD-Phase Diagram: CBM
HI beams 2 to 45 AGeV; **400 users**

Warm Dense Plasmas
Bunch-compression & **Petawatt- Laser 250 users**

Nuclear Astrophys. NUSTAR
**RI beam- fragmentation**; **600 users**

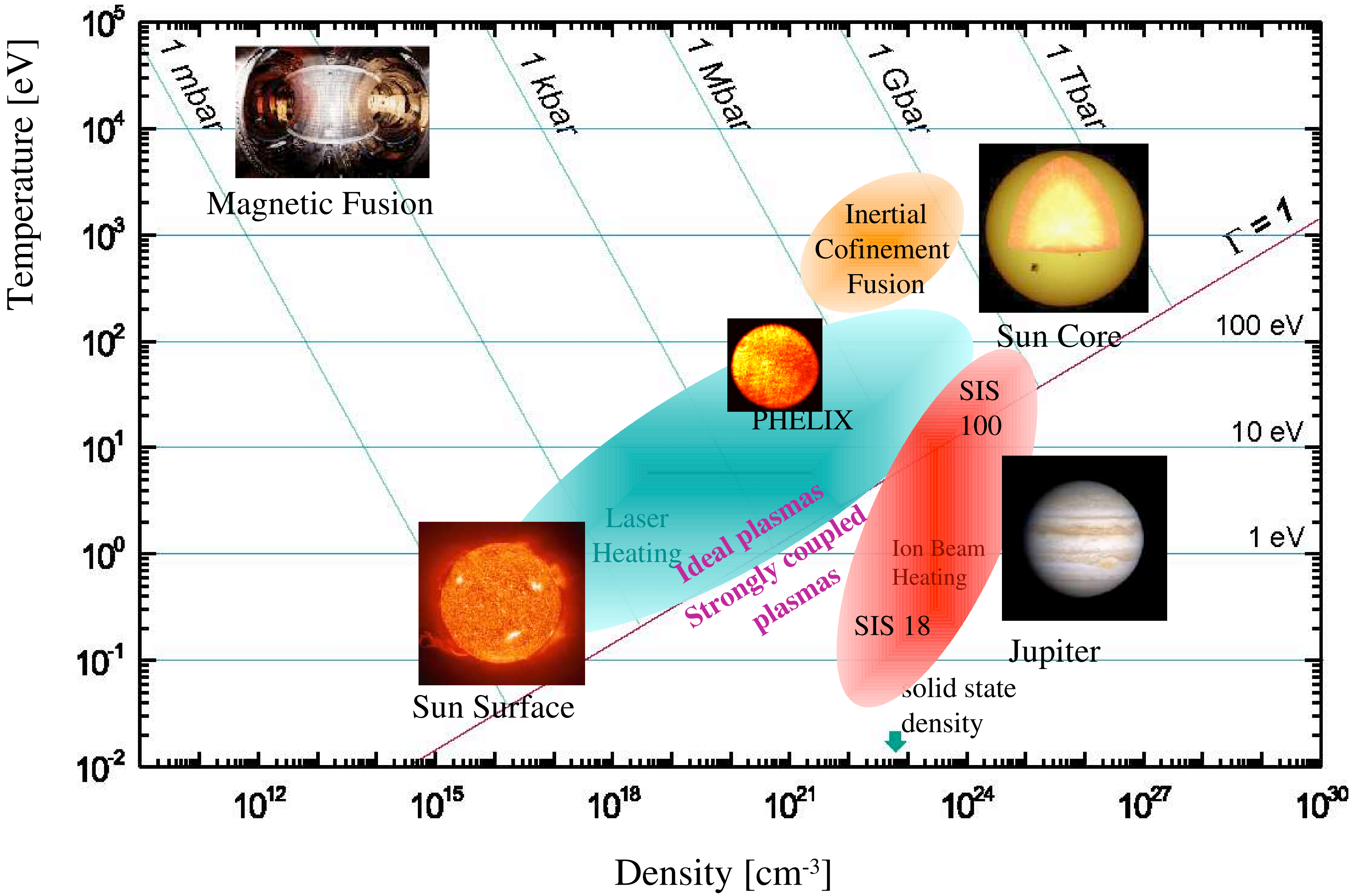
Materials Science,
Space- and Radiation Biology
(Ion- & antiproton- beams; **350 users**

Fundamental Symmetries
Ultra-High EM Fields SPARC;
FLAIR
**Antiprotons, Hi-Z ions**; **250 users**

Accelerator Physics:
**Eight** Rings & **two** Linacs, ultra-high intensities

# Hot EM-Plasmas produced with high intensity ion bunches and probed with petawatt laser pulses from PHELIX

## Matter at high energy densities



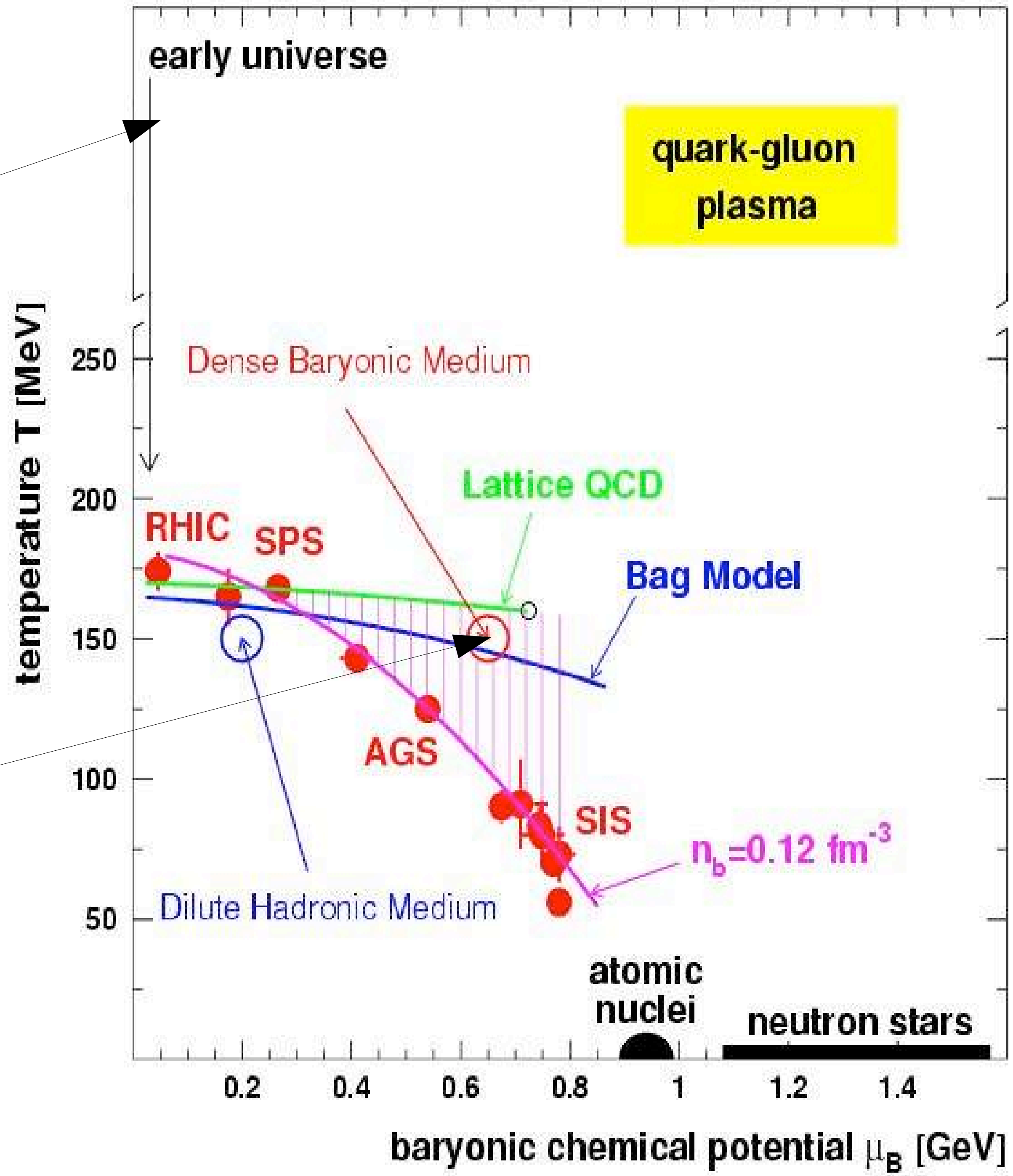

**Physics of Fast Ignition (another way to clean energy production)**

**Equation of state of planetary and stellar matter**

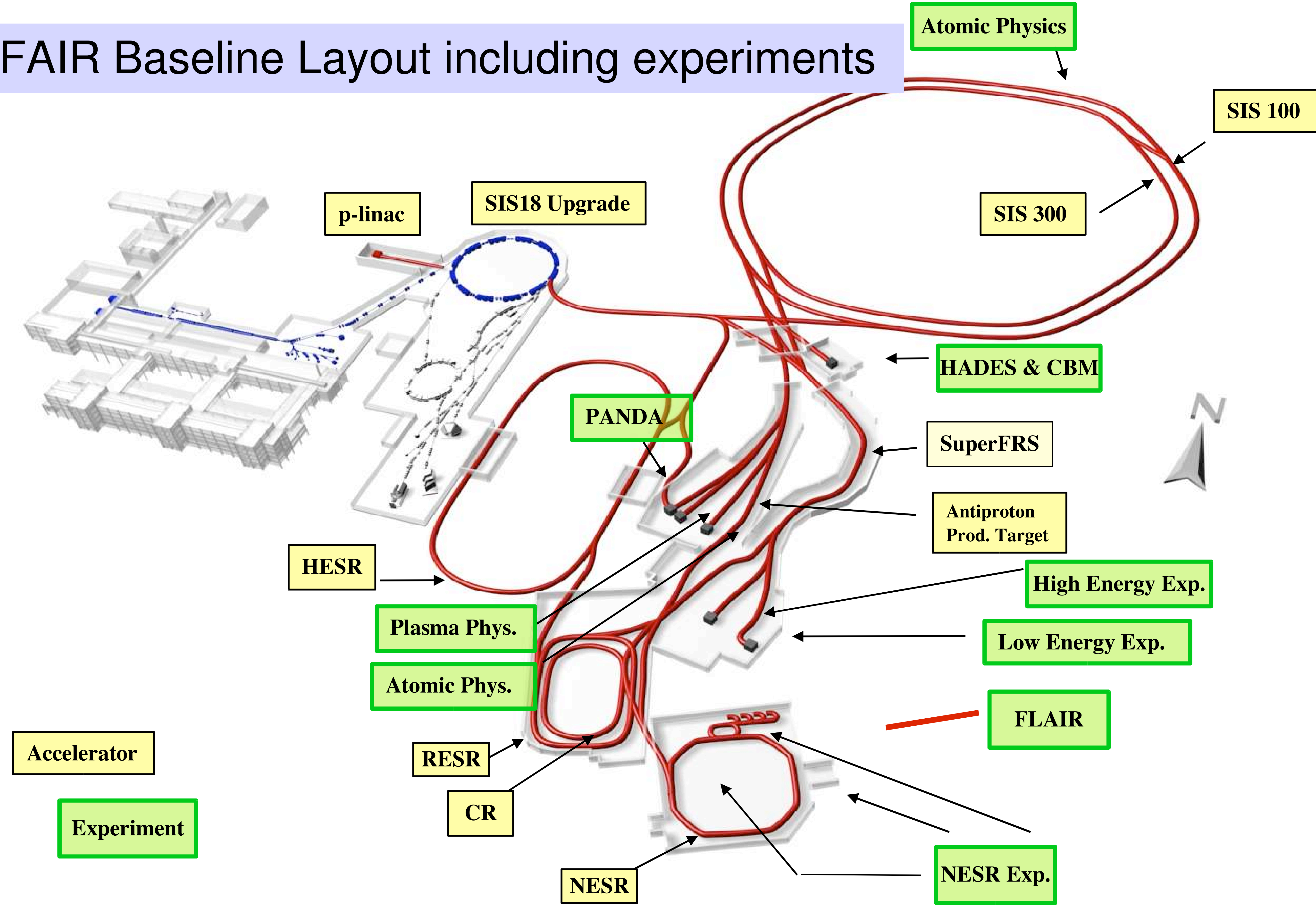
# Further directions to explore the phases of QCD

High temperature regime:
ALICE@ LHC

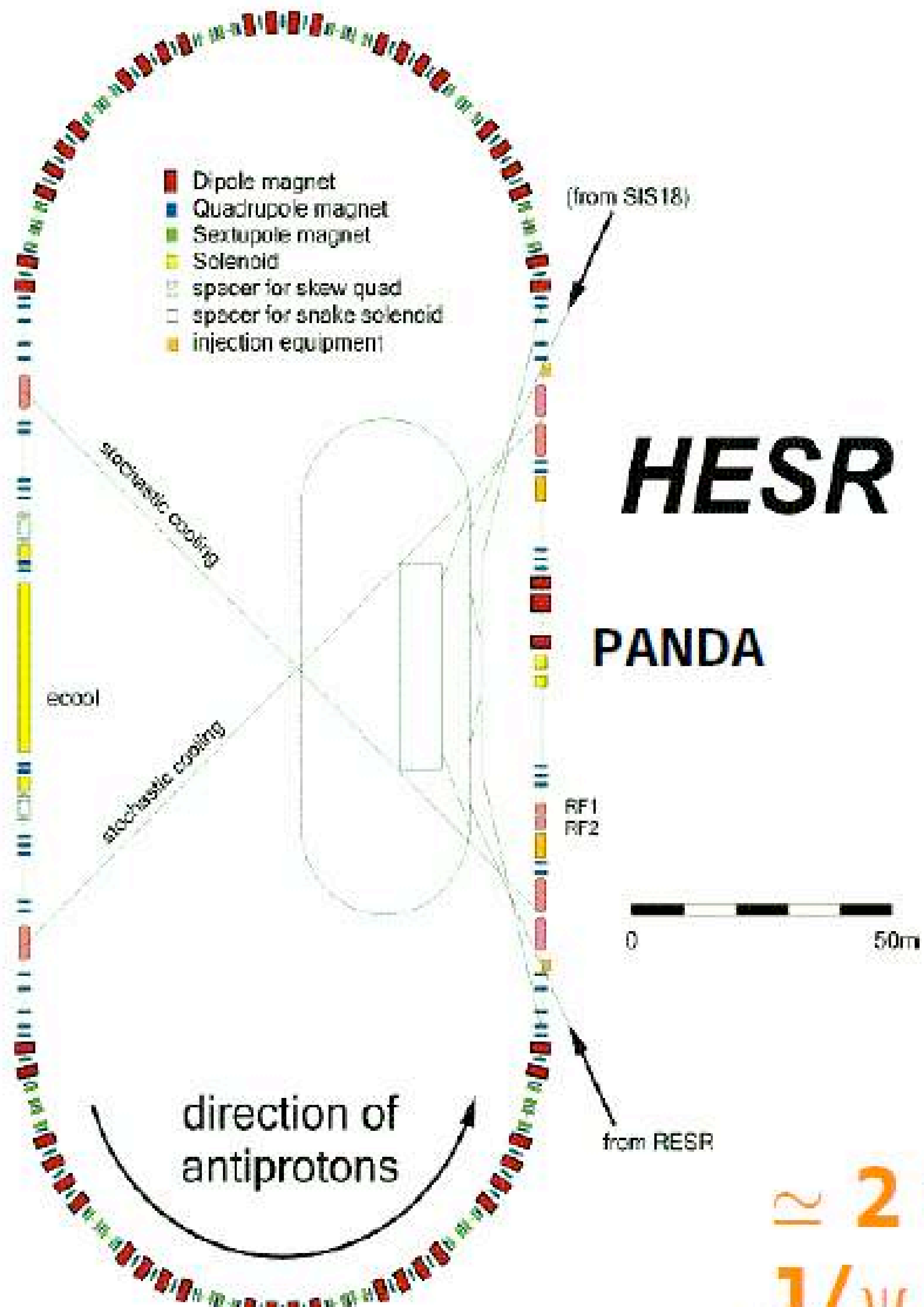
High density – moderate temperature regime
CBM@ FAIR-GSI



# FAIR Baseline Layout including experiments



# HESR (High Energy Storage Ring)




## For Anti-Protons

High intensity mode

- $10^{11}\ \bar{p}$
- $\delta p/p \approx 10^{-4}$ (stochastic cooling)

High resolution mode

- $10^{10}\ \bar{p}$
- $\delta p/p \approx 10^{-5}$ ($e^-$ cooling)

Internal targets

- $\mathcal{L} = 2 \cdot 10^{32}\,cm^{-2}s^{-1}$
- Pellets
- Cluster jet
- Nuclei: Be, C, Si, Al

$\simeq$ **2 x 10⁹** → **$\simeq 2 \times 10^9$ $J/\psi$ per year**

# FAIR Key-Components – Technical Challenges

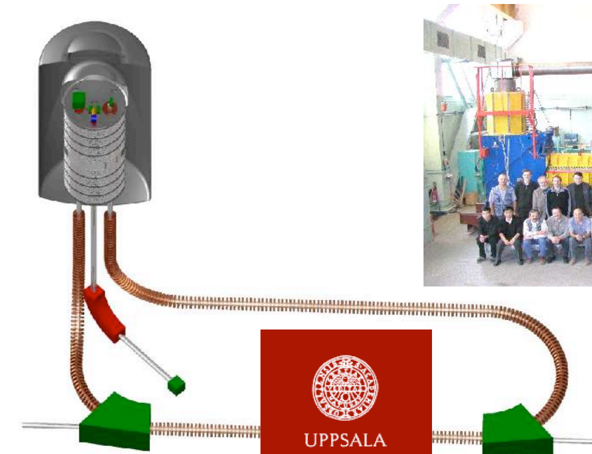
R&D by GSI & Partner Institutes (2001 – 2008)

INFN Istituto Nazionale di Fisica Nucleare

BROOKHAVEN NATIONAL LABORATORY

**Precision beams:**

**Electron & Stochastic Cooling**

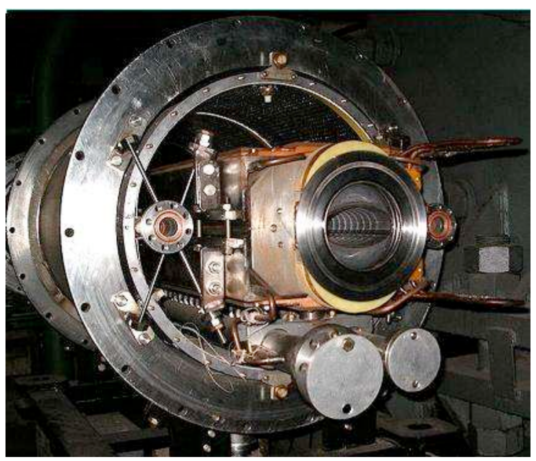


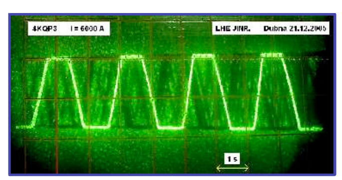
UPPSALA UNIVERSITET

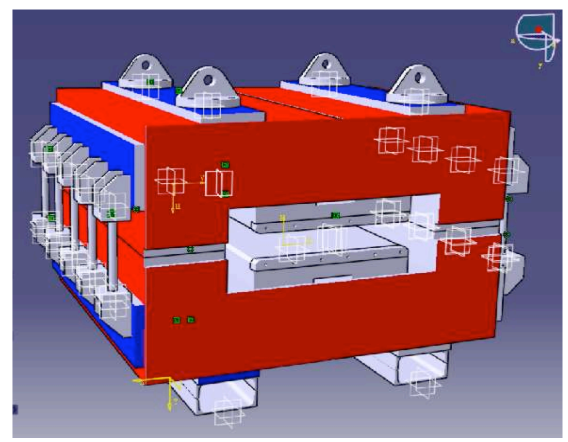
Forschungszentrum Jülich
*in der Helmholtz-Gemeinschaft*

**Compact & cost effective accelerators:**

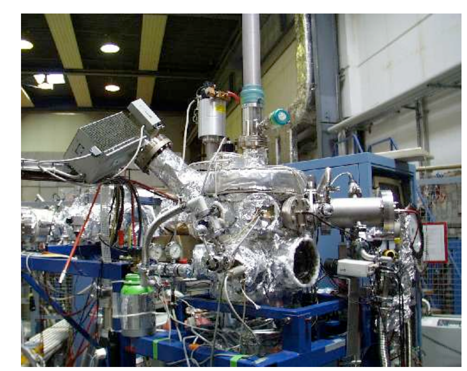
**Rapid cycling superconducting magnets: dB/dt ~ 4T/s**







GSI



CERN

ASTeC

**Fast acceleration:**

**High gradient variable frequency Ferrite & MA loaded cavities**

Hochschule Fulda
University of Applied Sciences

IHF

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

UPPSALA UNIVERSITET

Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft

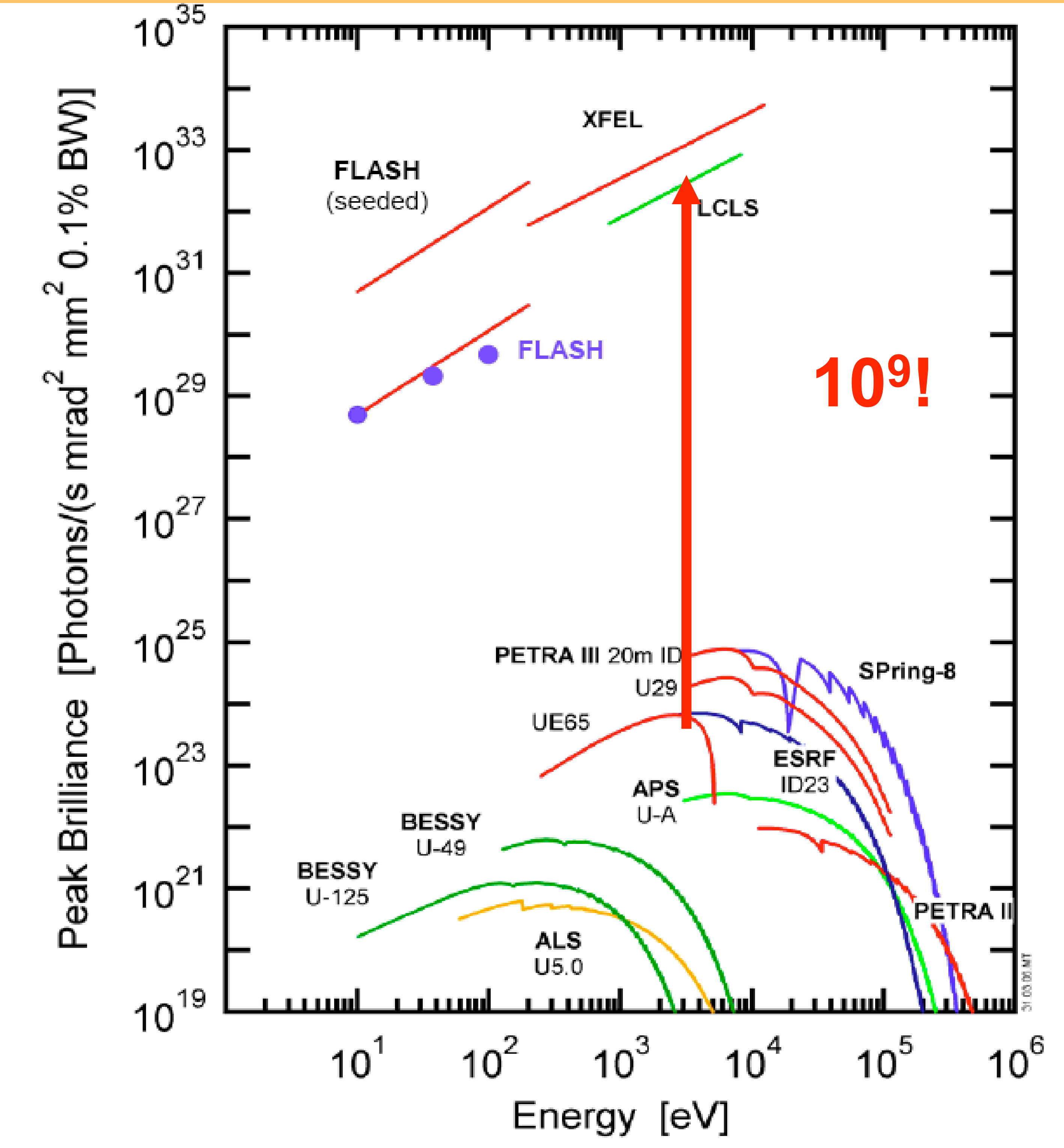
**XHV at high beam intensities:**

**Extremely High Vacuum ~$10^{-12}$ mbar**

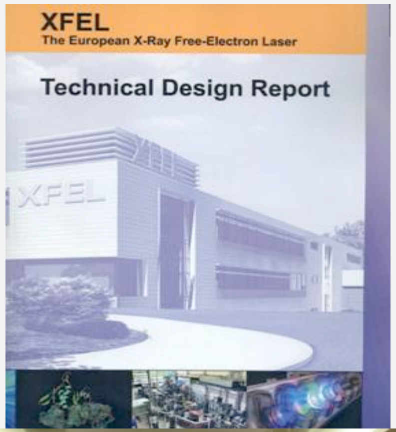
# Highlights from the European XFEL
# and
# Summary of the DESY Workshop

**Heinz Graafsma**
**Photon Science Detector Group - DESY**
**Workpackage Detectors – European XFEL**

# Why build an XFEL ?



# The European XFEL Introduction

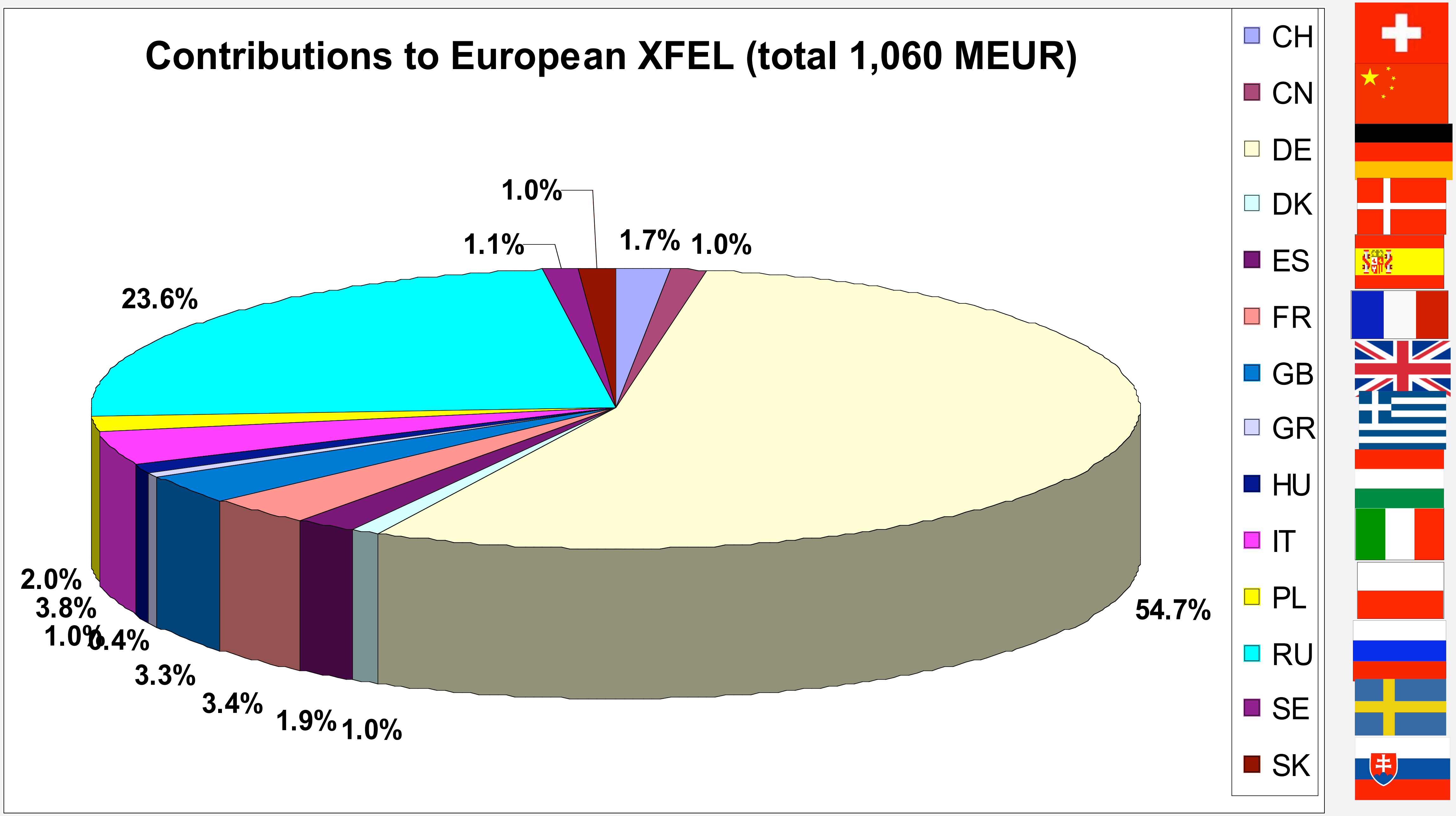

**Oct 2002** : XFEL supplement to TESLA TDR → Feb 2003 approval by German government to realize the XFEL as European project with at least 40% funding contributions from partners → *intense preparation work on technical design, industrialization of components, evaluation of cost/schedule, international project organization*

**July 2006**: completion of XFEL TDR, submitted to and approved by International Steering Committee → *986M€/ y2005 construction cost (+preparation & commissioning cost), negotiations of funding contributions continuing*

**June 5, 2007**: Official project start announced on basis of initially de-scoped start version at 850M€/y2005 construction cost → *launch tender process for civil construction, finalization of legal documents & prep of XFEL GmbH foundation, negotiations of in-kind contributions*

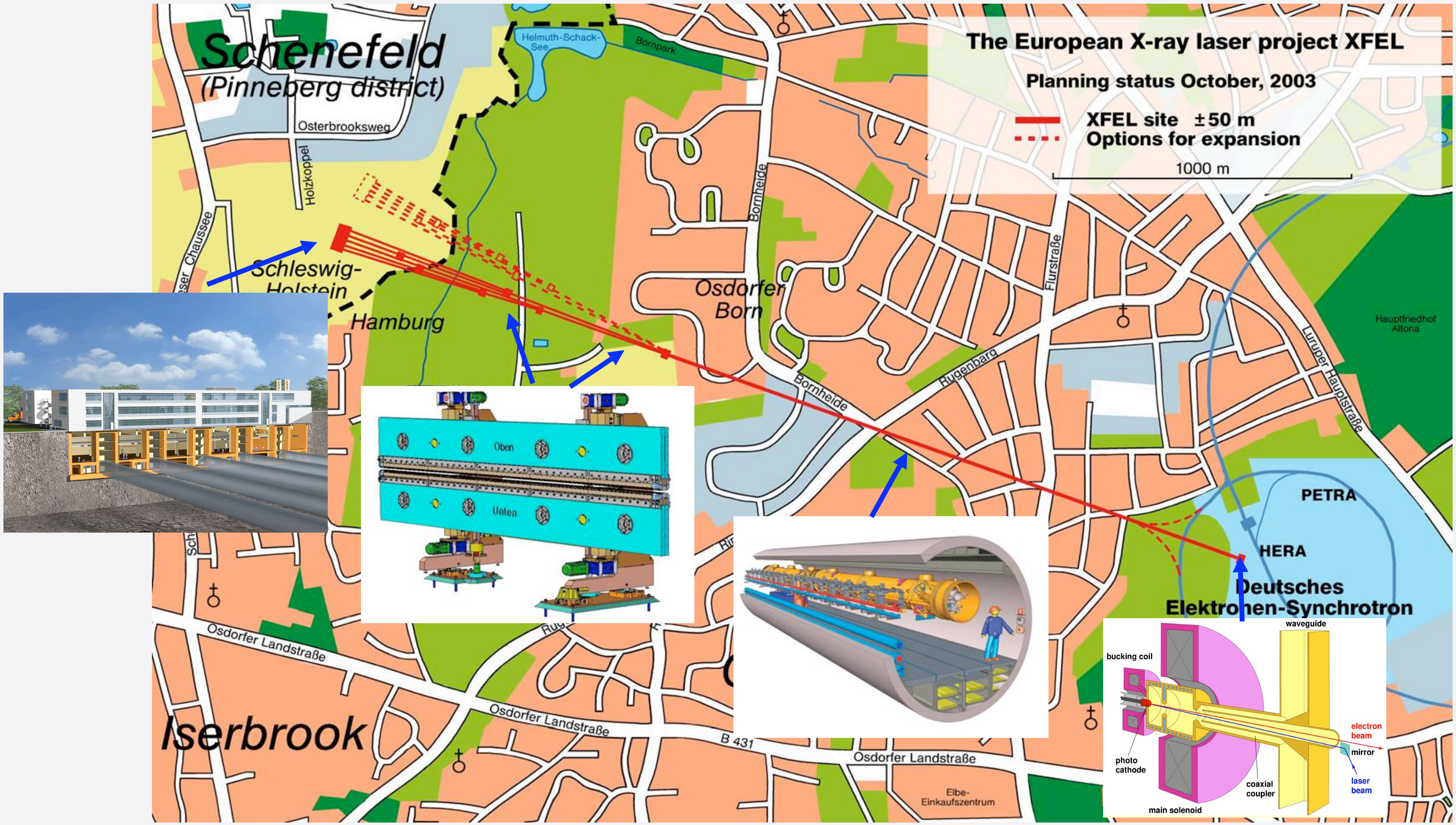
# Status of financial commitments to European XFEL projec

Includes ~90 M€ project preparation phase & commissioning costs

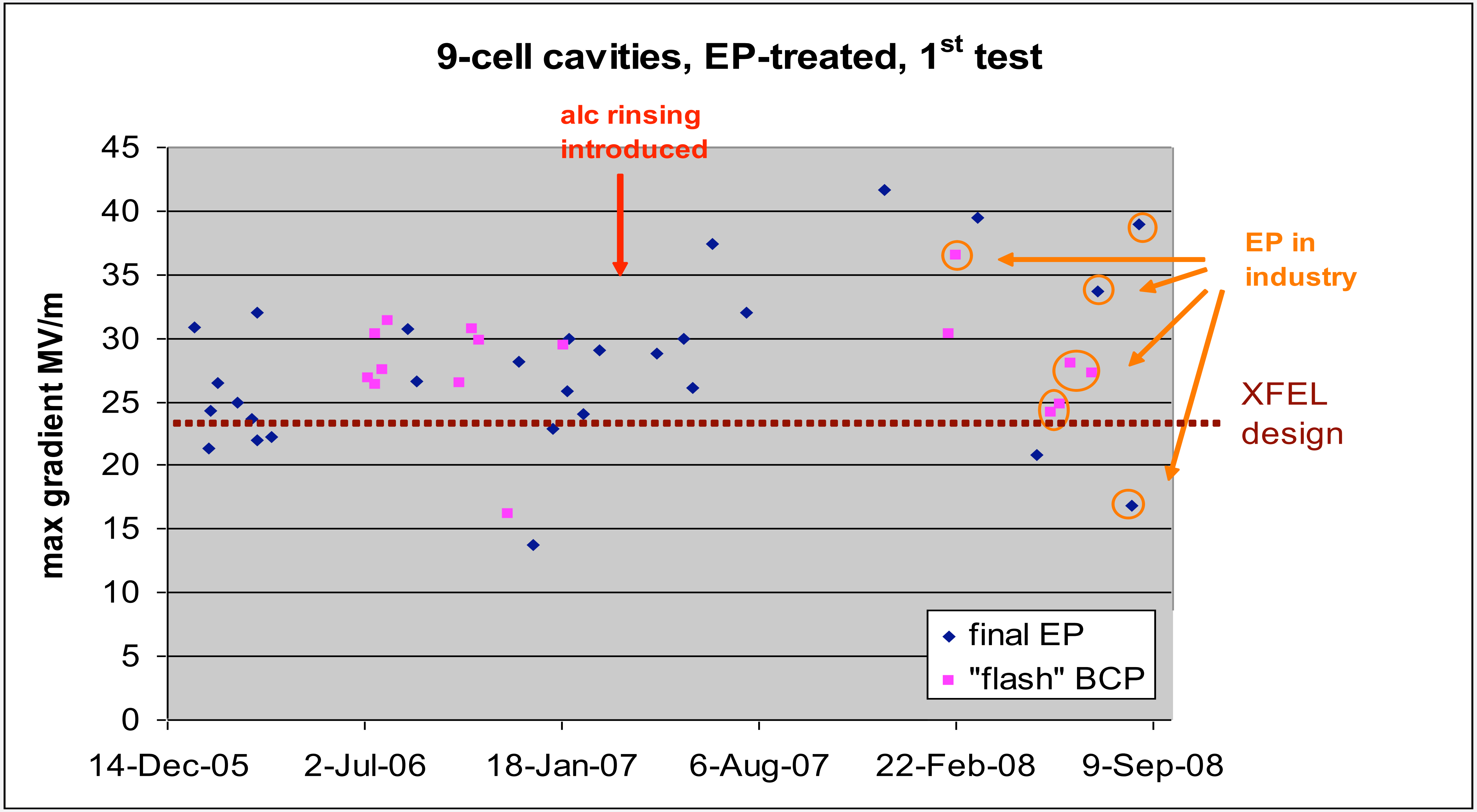


# Overall layout of the European XFEL

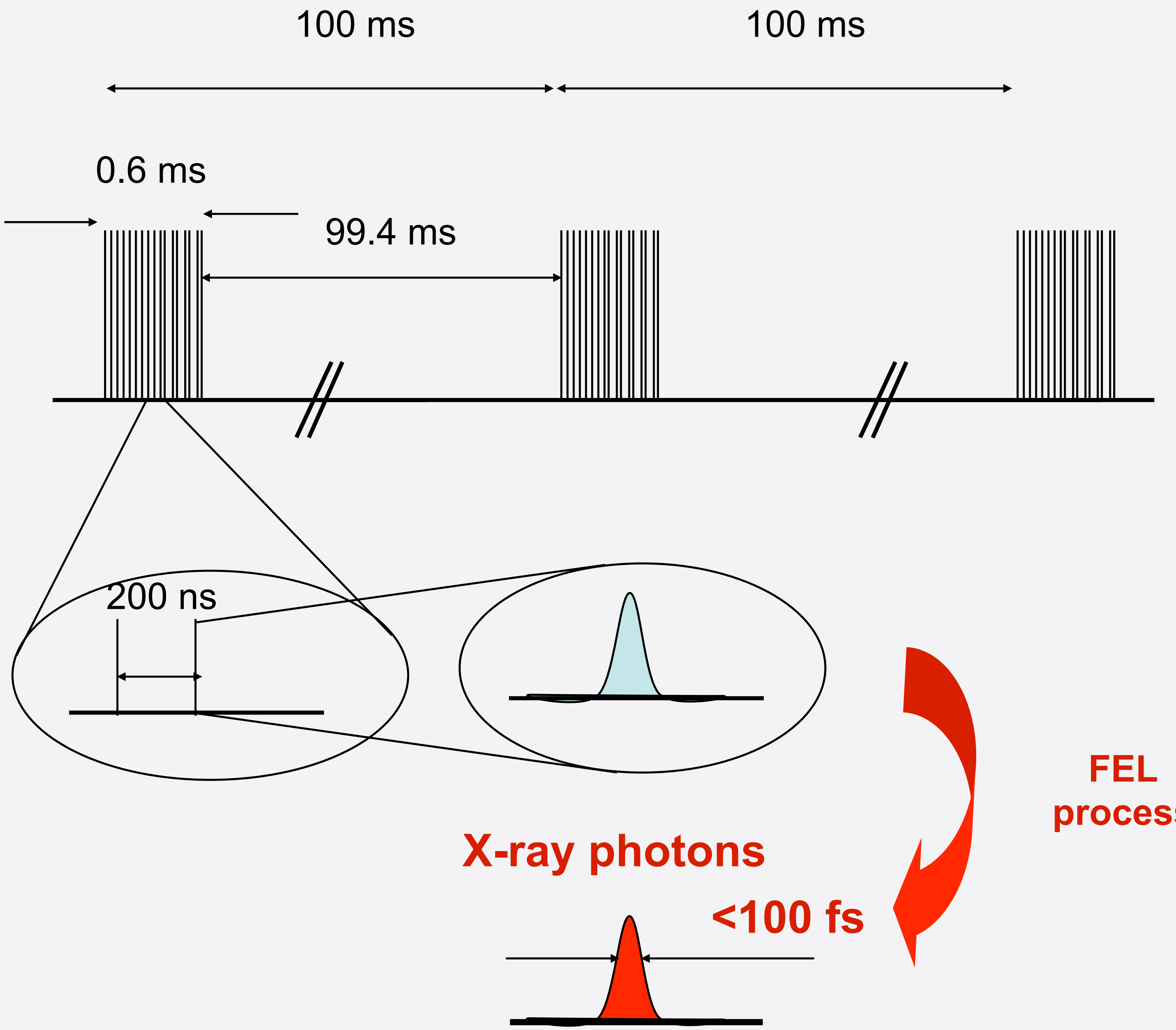
3.4km



# Cavities since Jan 2006, 1st test



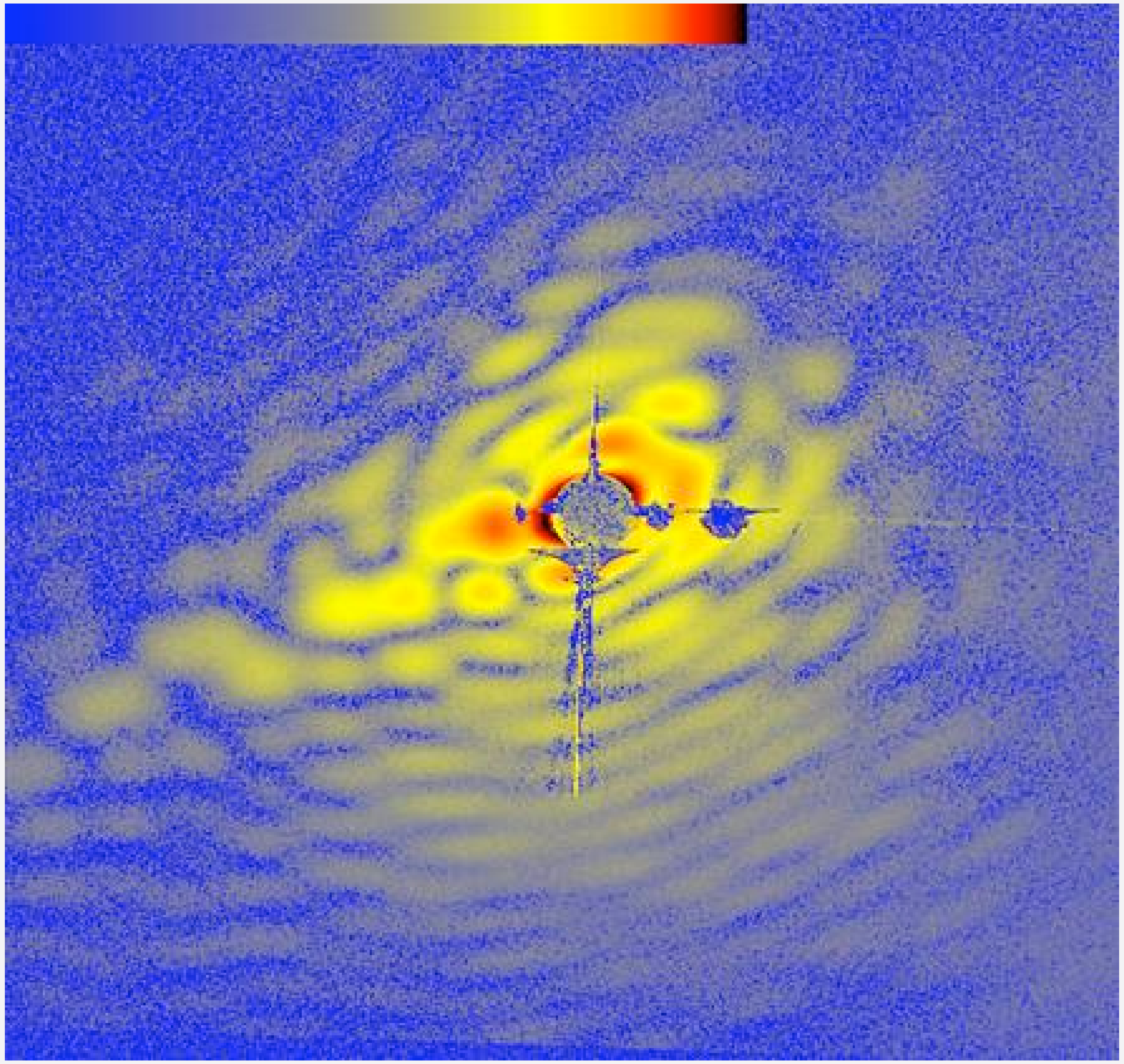
# Where is the detector challenge?




**Challenges:**

- up to 30,000 bunches per second
- very high intensities (up to $10^{12}\gamma$/bunch)
- „instantaneous“ energy deposition
- very high repetition rates (up to 5 MHz)
- large variability
    - pulse patterns
    - pulse to pulse variations

# Some Requirements and Specifications



Requirements:
- 1k x 1k (4k x 4k) pixels
- "no noise"
- $10^4$ ph/pixel/pulse
- Few 100 images/train
- …

Consequences:
- Integration detectors
- Low noise
- In-pixel frame storage
- Multiple gains or
- Non-linear gain


- **1 1/2 days**
- **74 registered participants**
- **50/50 HEP-PS**
- **11 invited talks (45’ + 15’)**
- **Round table at the end**

# Joint workshop program

**Opening and Science Session:**

Opening Remarks and Purpose of the Meeting: **Rolf-Dieter Heuer,** DESY
Present and Future of Photon Science Experimentation: **Edgar Weckert,** DESY
Present and Future of High Energy Particle Experimentation: **Harry Weerts,** ANL

**Sensor Session:**

Technologies: **Kenichi Sato,** Hamamatsu
HEP applications: **Marc Winter,** IPHC-Strasbourg
PS applications: **Veljko Radeka,** Brookhaven National Lab

**Frontend Electronics Session:**

Technologies: **Paul O'Connor,** Brookhaven National Lab
PS applications: **Michael Campbell,** CERN
HEP applications: **Christophe de la Taille,** LAL Orsay

**Interconnection Technology Session:**

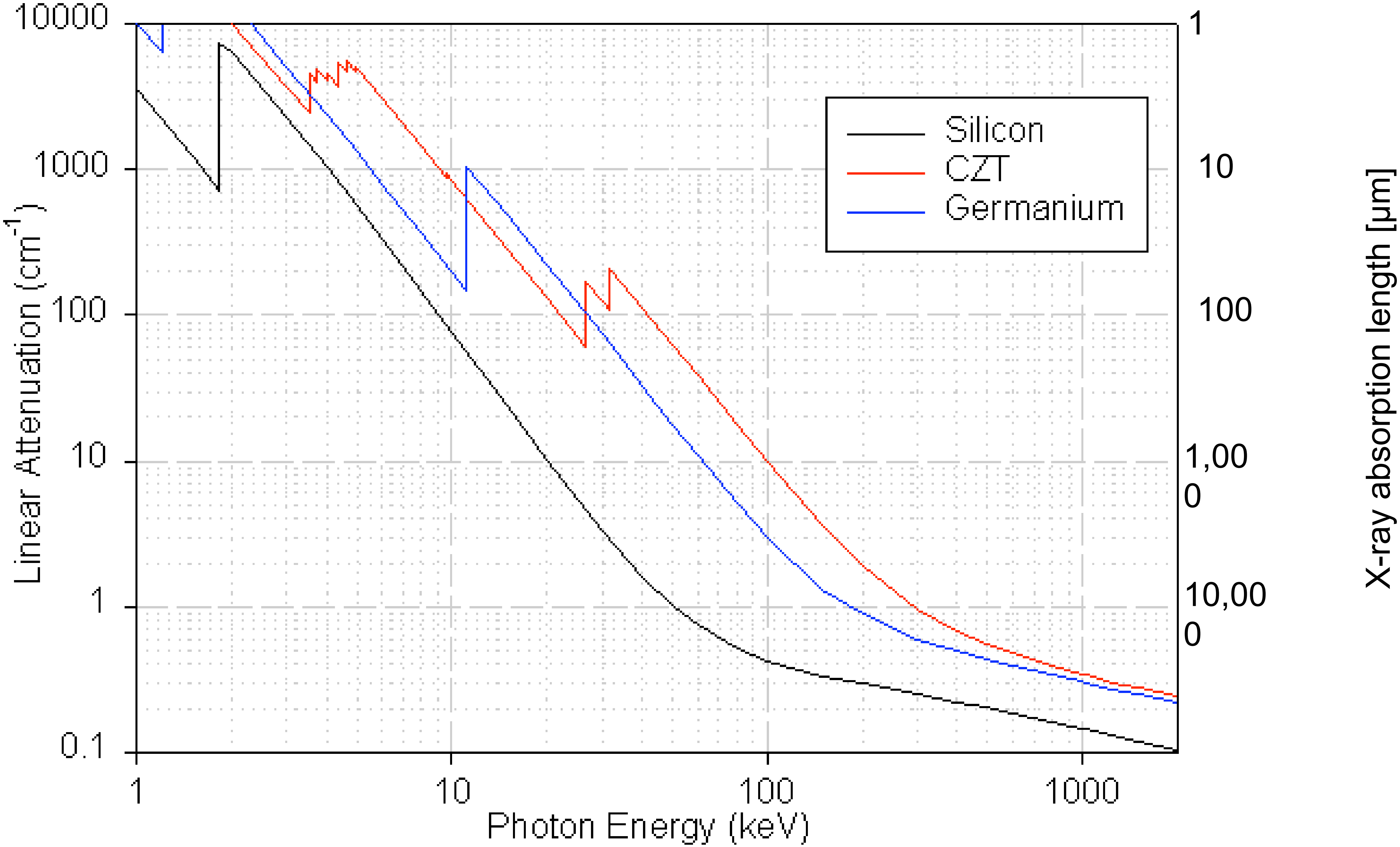
Interconnection: Technologies: **Piet De Moor,** IMEC

**Data Acquisition Session:**

HEP applications: **Matthew Wing,** University College London
PS applications: **Christopher Youngman,** DESY

**Round table discussion:** **How to build the bridge HEP and PS ?**

# Si vs Ge vs CZT




*SR*



**From: V. Radeka Joint WS-**

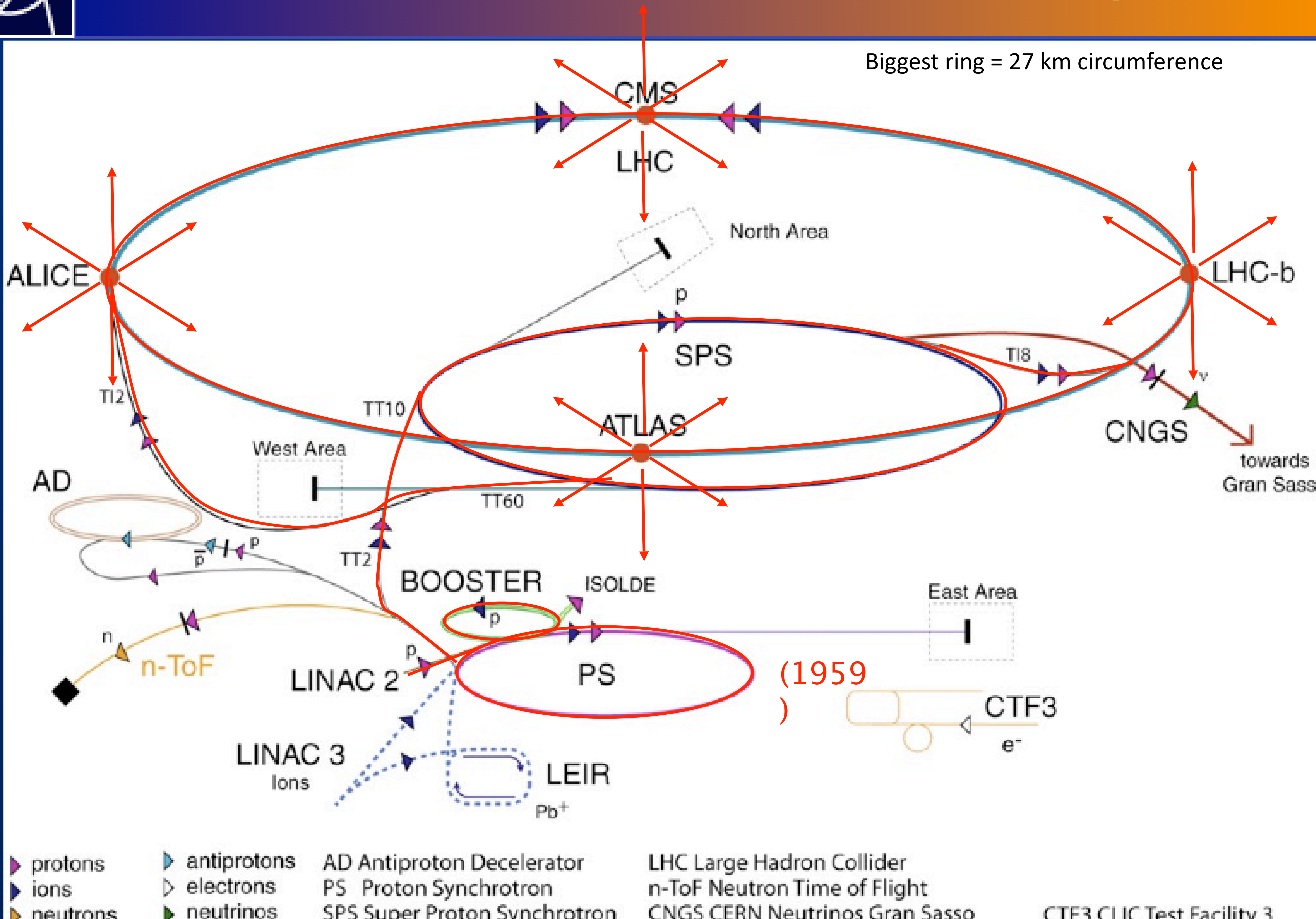
# Highlights from the Large Hadron Collider

- Physics at the Terascale
- The LHC: brief overview and status
- The LHC experiments: brief overview and status

Jos Engelen

CERN

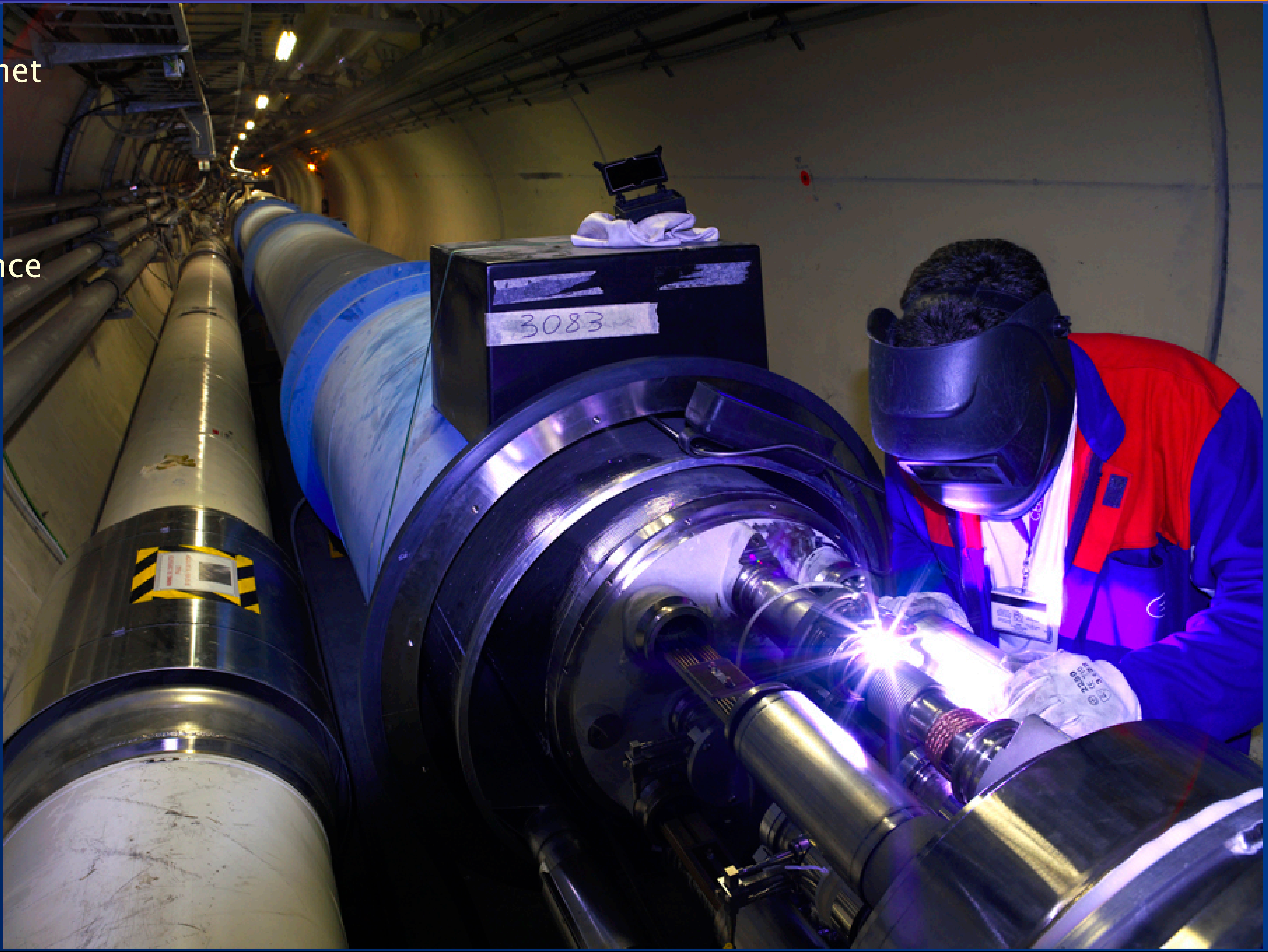
# Accelerator complex



# In the tunnel

15m long Magnet
inter-connect

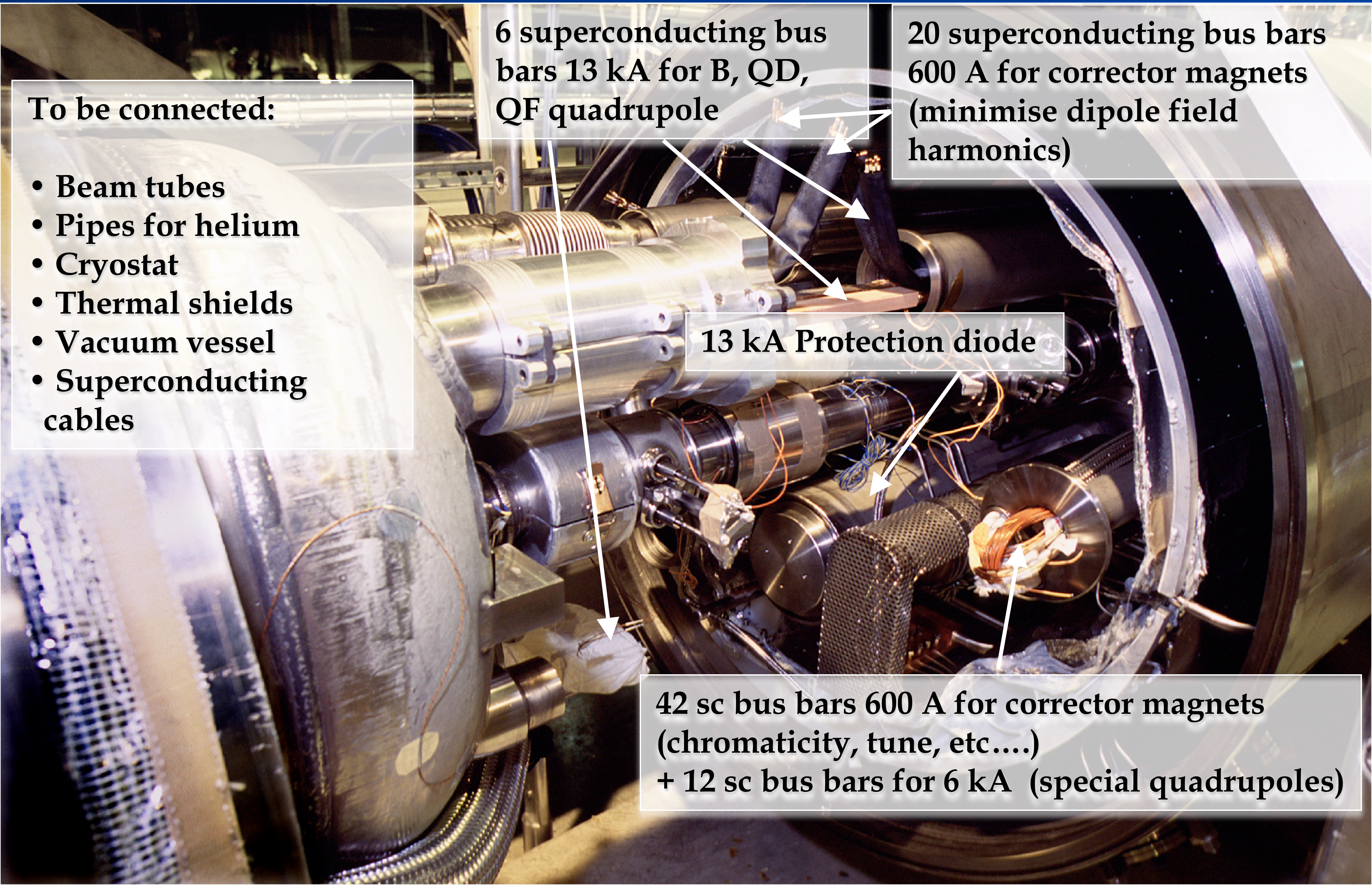
Quality control
and
Quality assurance



# Magnet Interconnect

To be connected:

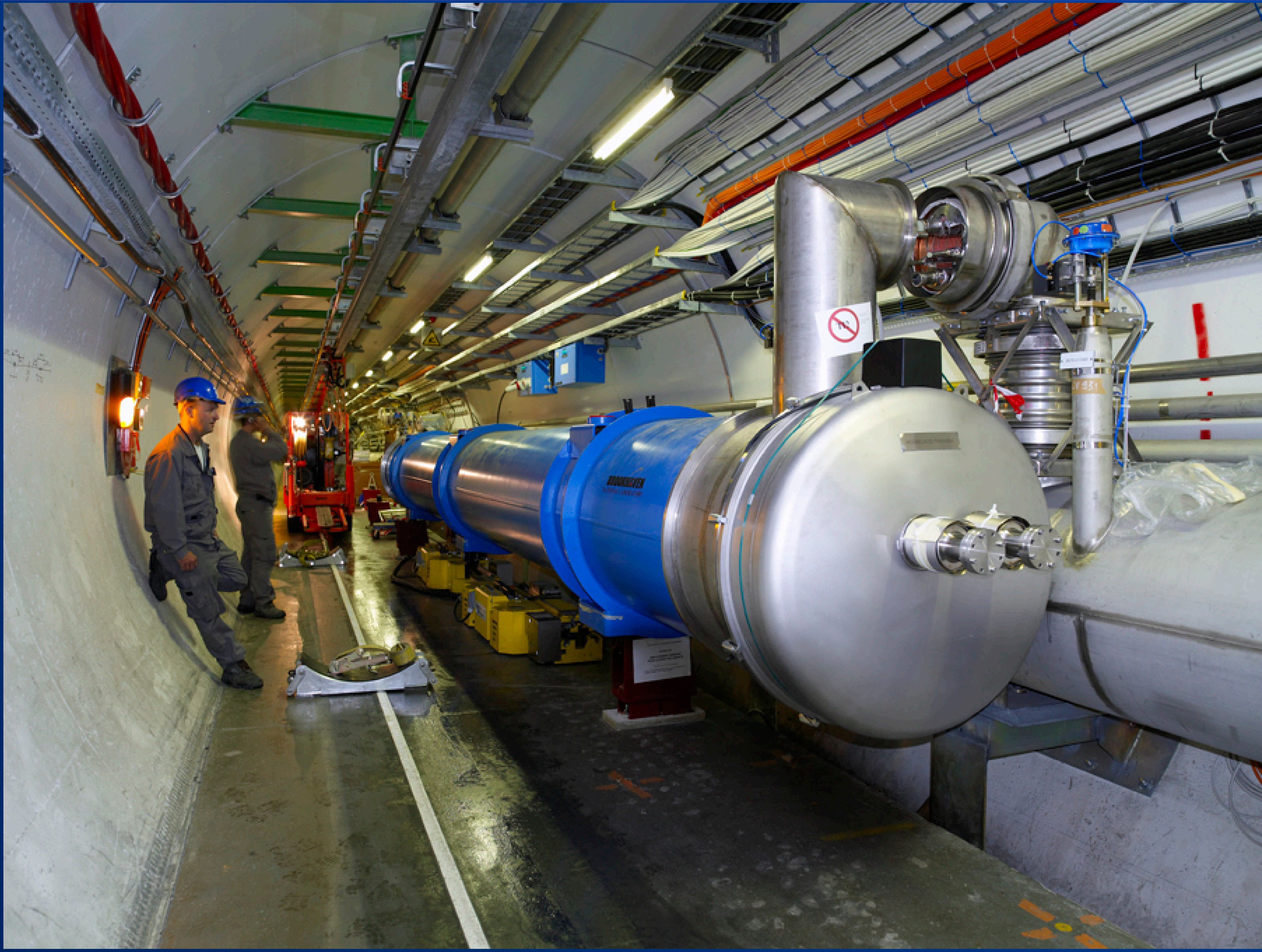
- Beam tubes
- Pipes for helium
- Cryostat
- Thermal shields
- Vacuum vessel
- Superconducting cables



# In the tunnel

Jumper connecting cryogenic distribution line and magnets (once every ~100 m)

(early photo, tunnel practically empty)



# Final Hardware Commissioning

The magnets in Sector ('Octant') 34 had not been commissioned yet to full current for operation at 5 TeV (i.e. commissioning to 5.5 TeV)

The 7 other octants of the LHC had been commissioned to 5 TeV (and well above) without problems

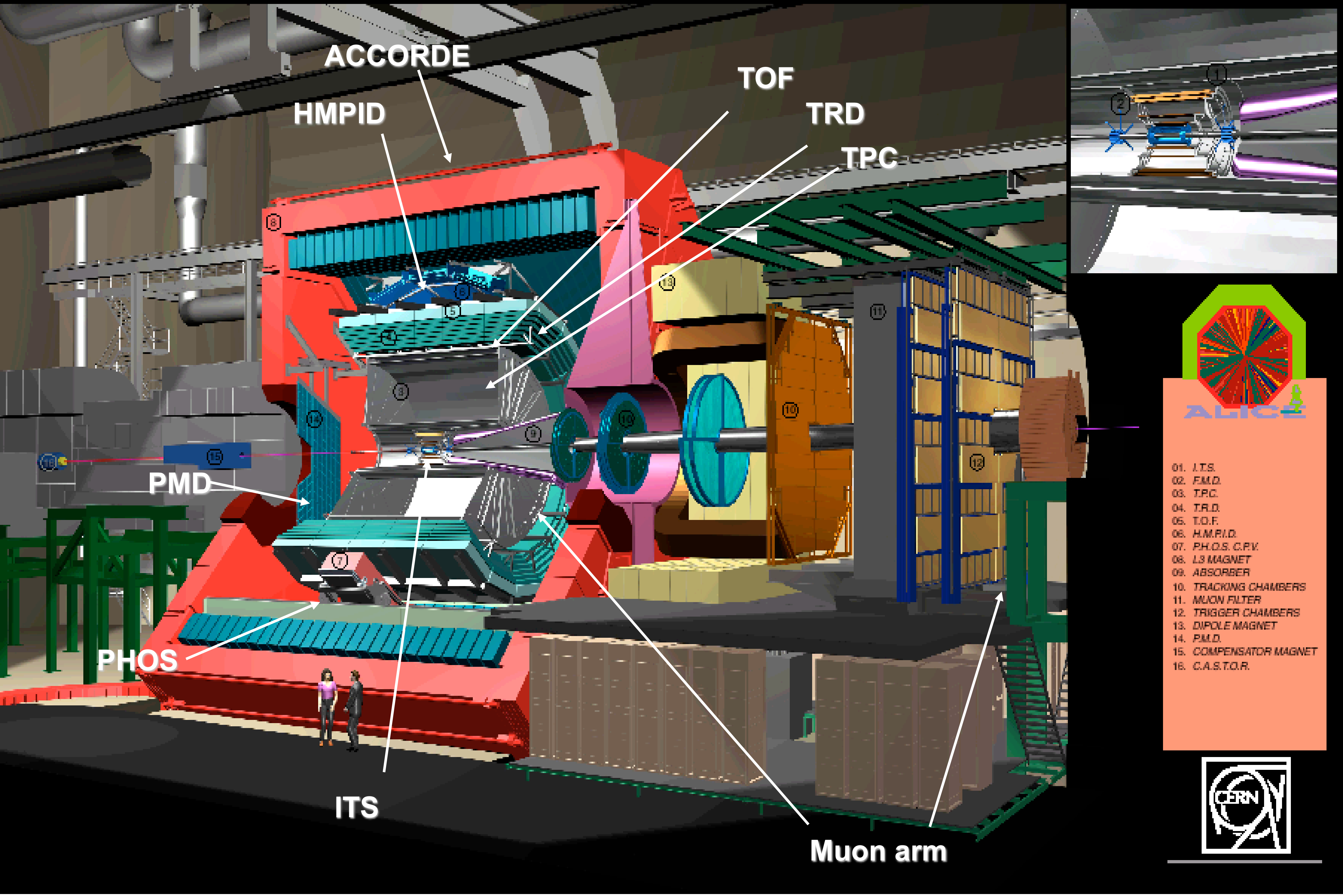
On September 19 (around 11:18) an incident occurred, leading to a large Helium leak in sector 34 – cold Helium escaped into the tunnel, the insulation vacuum was broken (up to vacuum barriers), the beam vacuum was broken (up to sector valves)

# Recovery Sector 34

It is now clear that recovery of Sector 34 will take until ('into') the planned (and obligatory) Winter shutdown – LHC operations will restart Spring 2009.
A precise planning is being worked out.

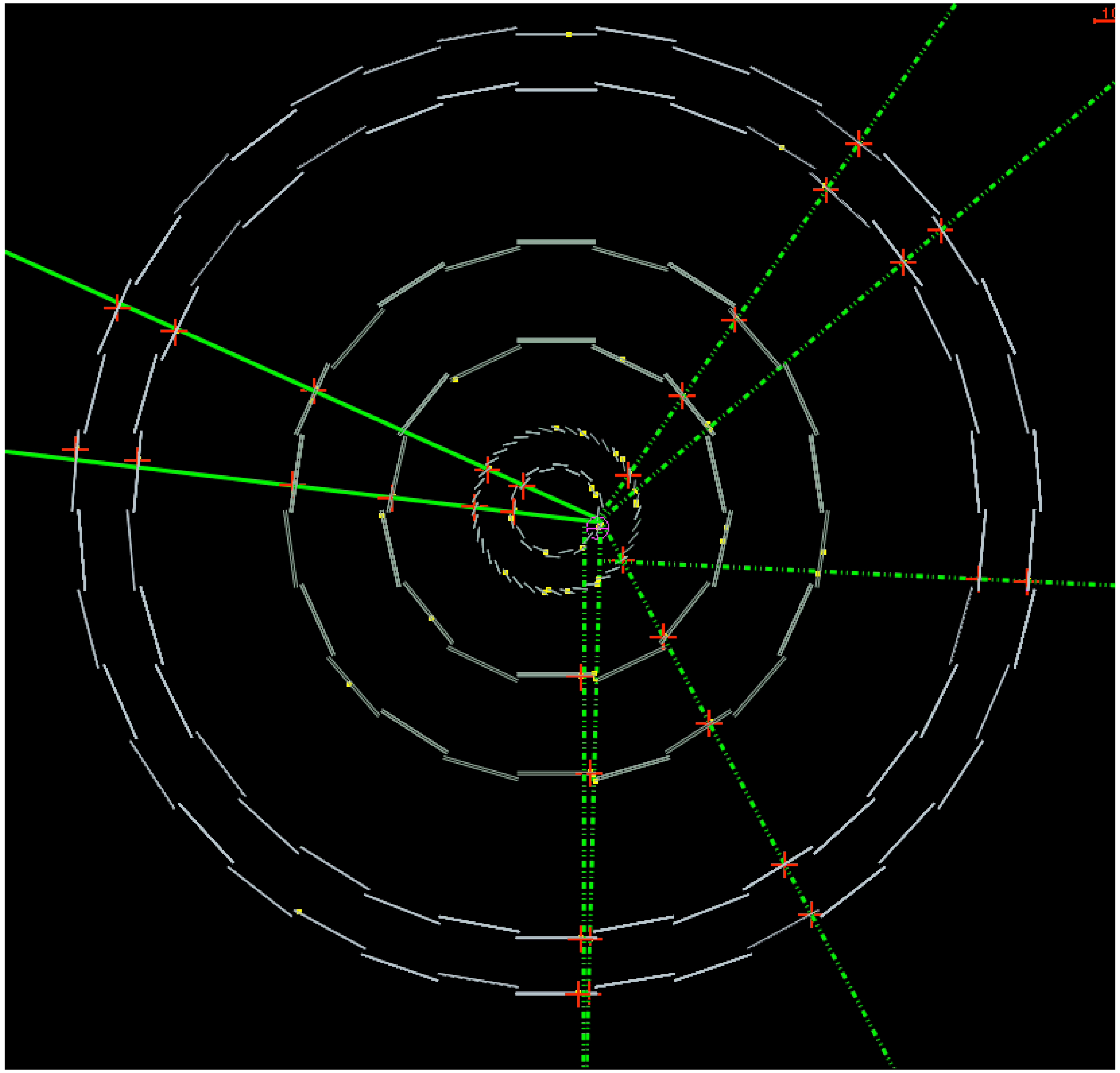
The nature of the incident has been understood – it is due to an electrical fault (resistive splice in interconnect)

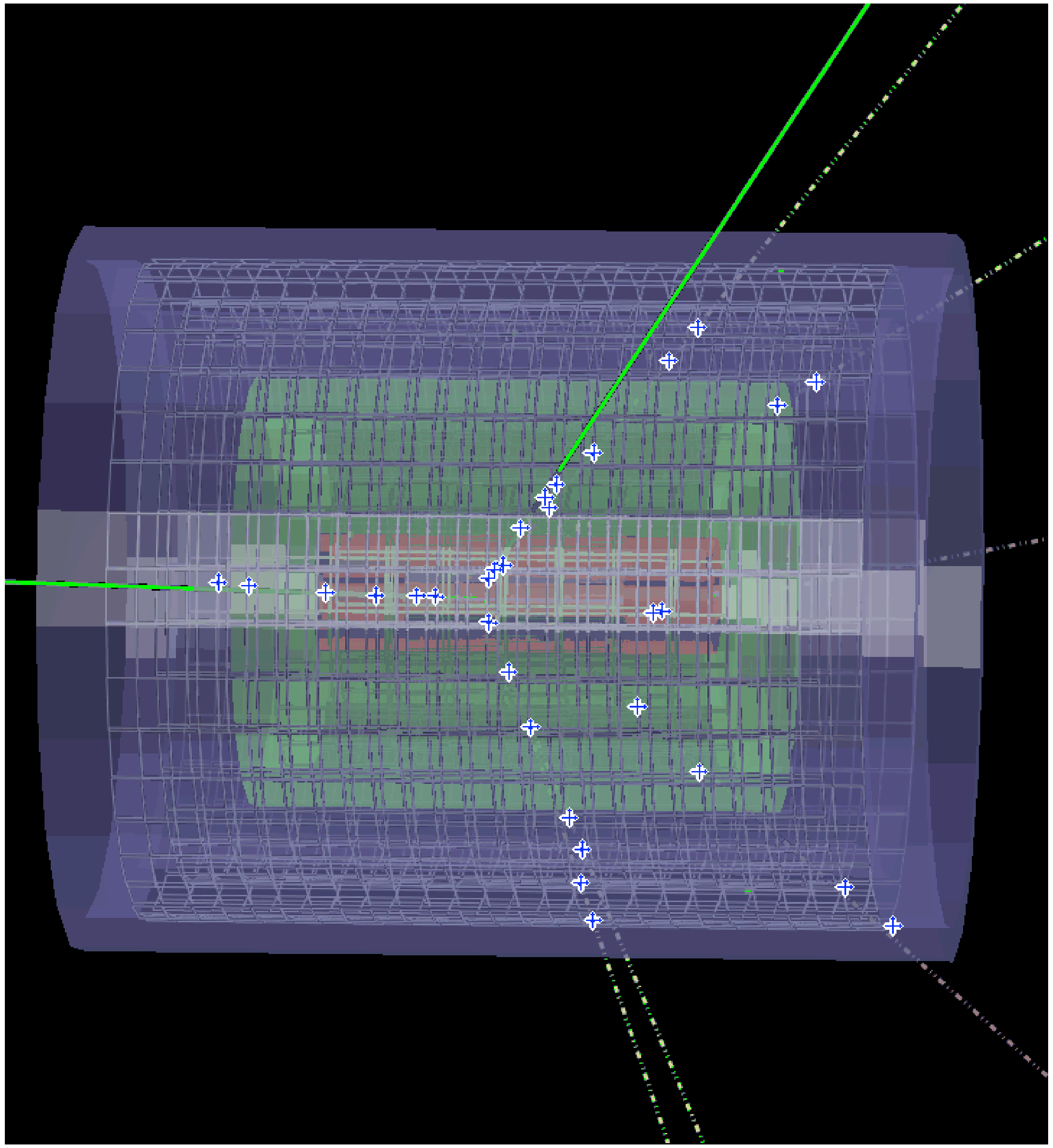
The loss of the insulation vacuum lead to some collateral damage – the logistics of the repair program are being worked out.
Very importantly: diagnostic tools are being designed to avoid such problems in the future




# ALICE Detector

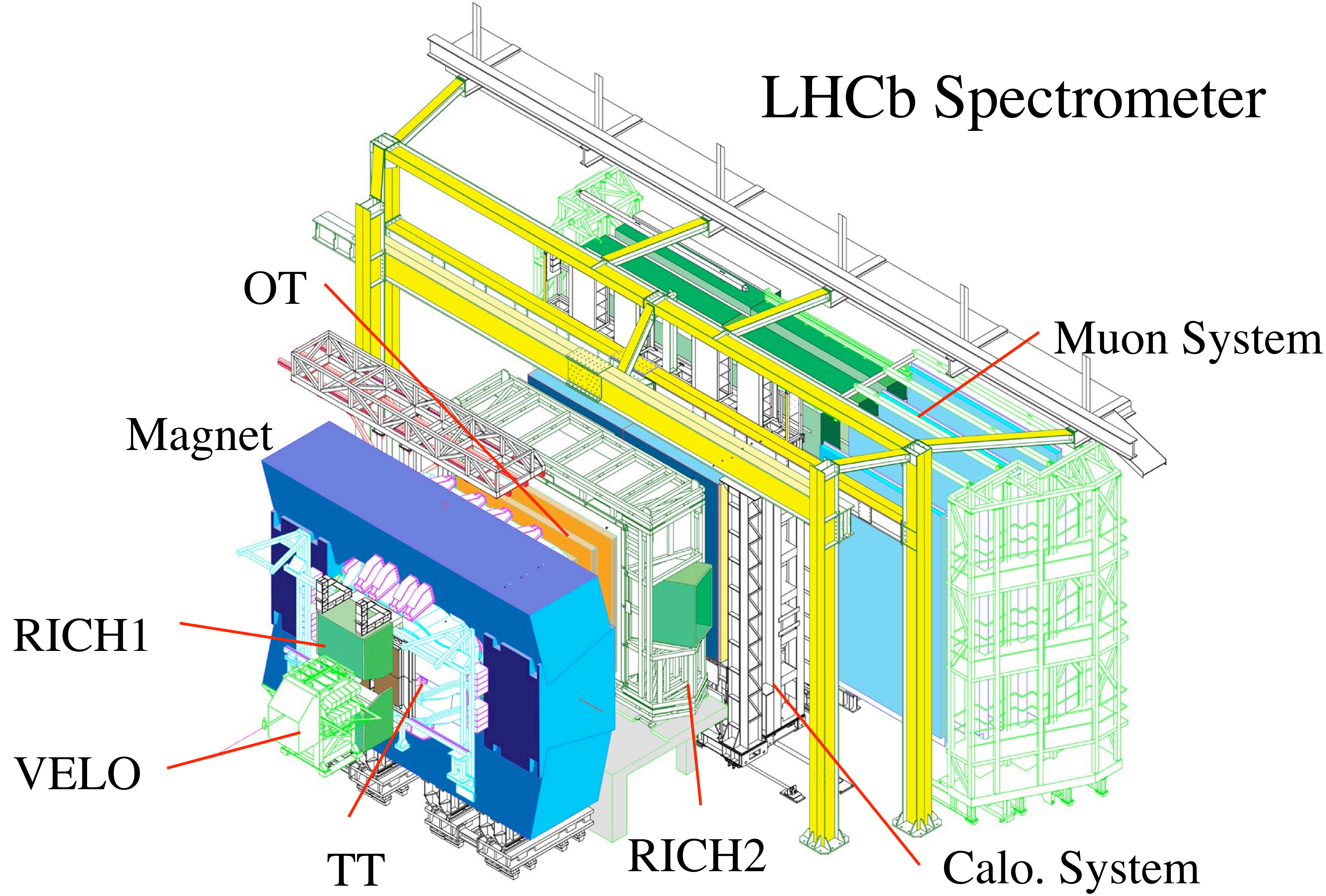
# First interactions 12th September



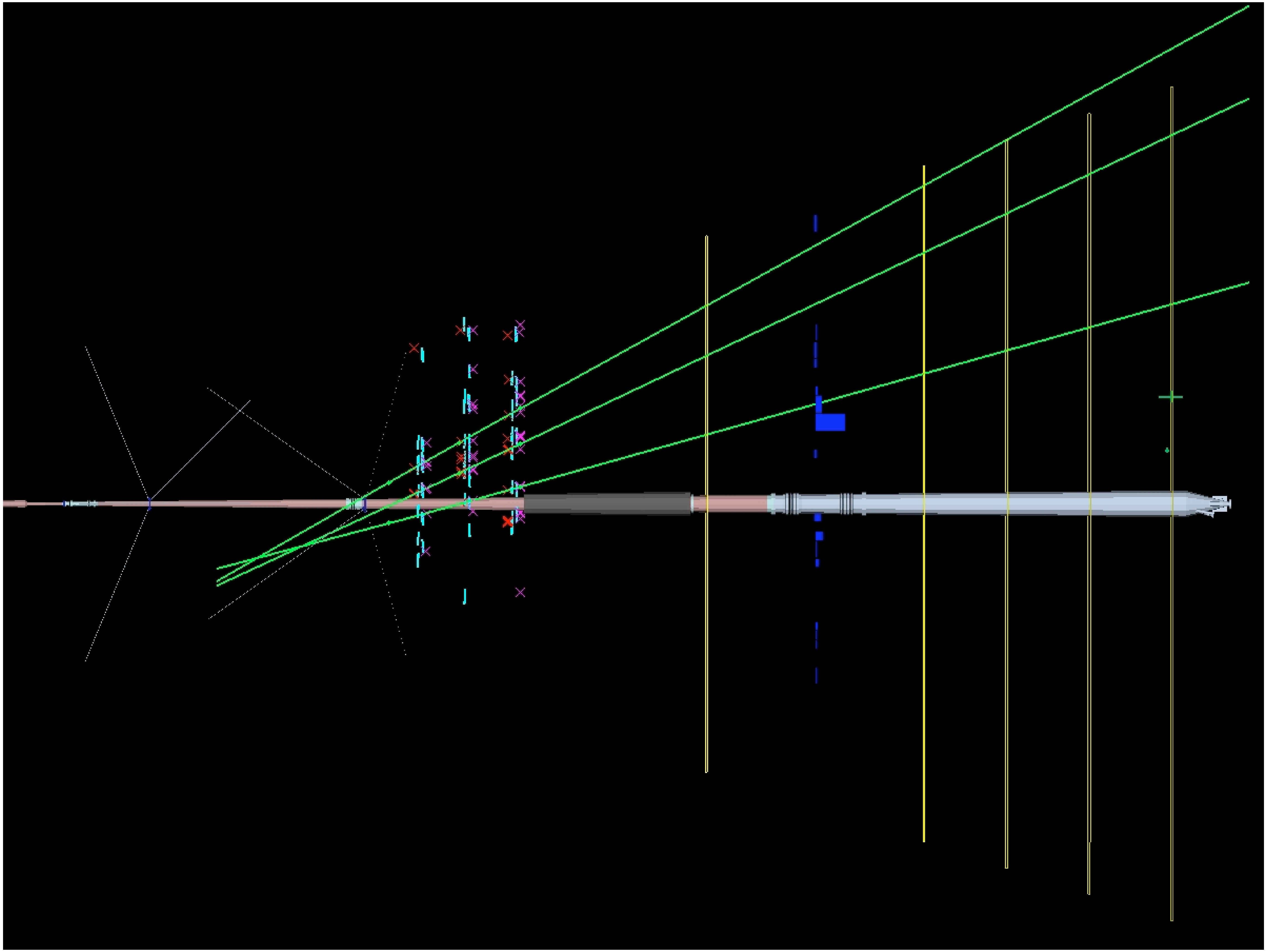


Circulating beam 2
stray particle causing an interaction
in the ITS

ITS tracks on 12.9.2008


LHCb Spectrometer
OT
Muon System
Magnet
RICH1
VELO
TT
RICH2
Calo. System

*Beam1 induced OT tracks originating close to the beam pipe*

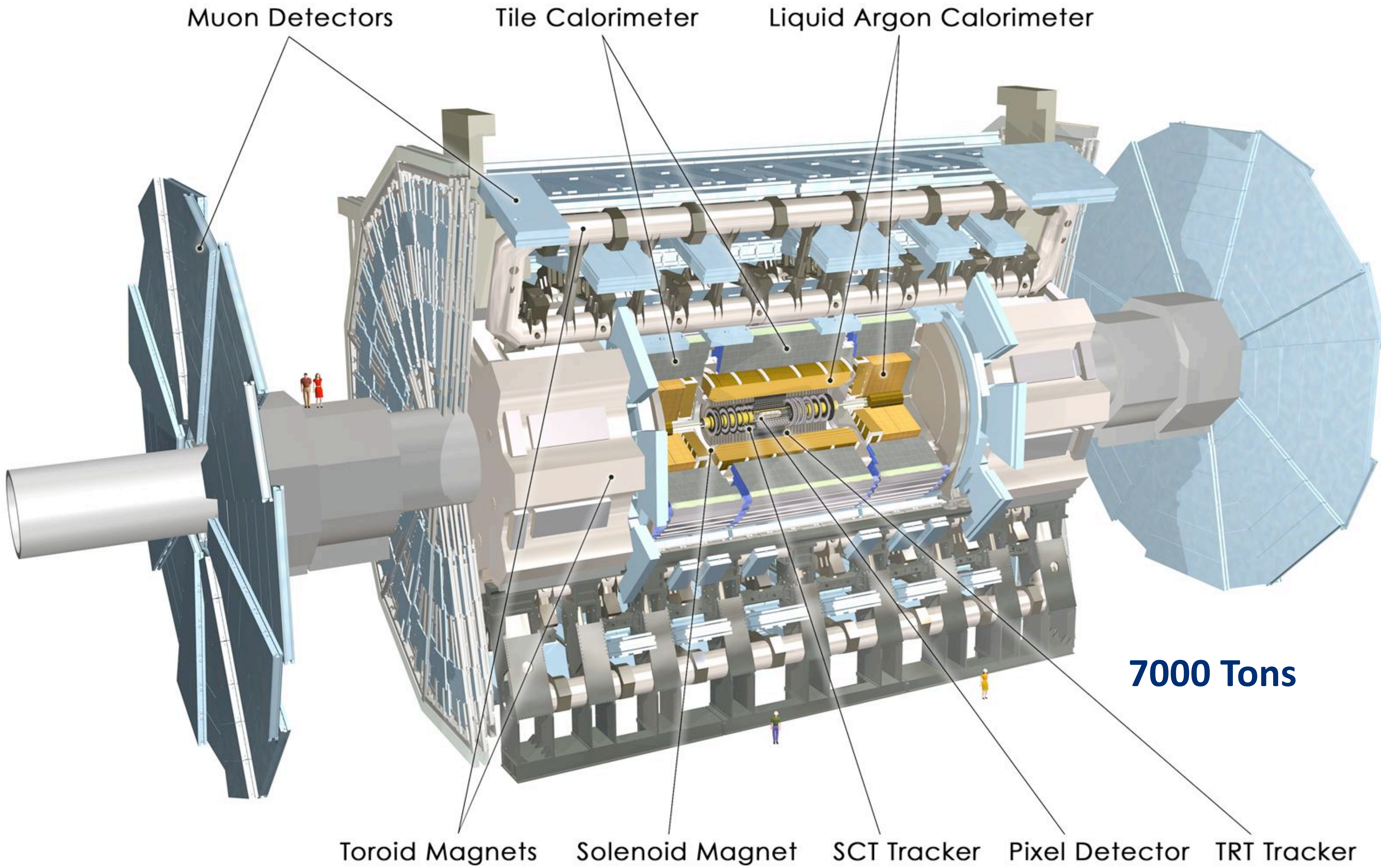


# *ATLAS*

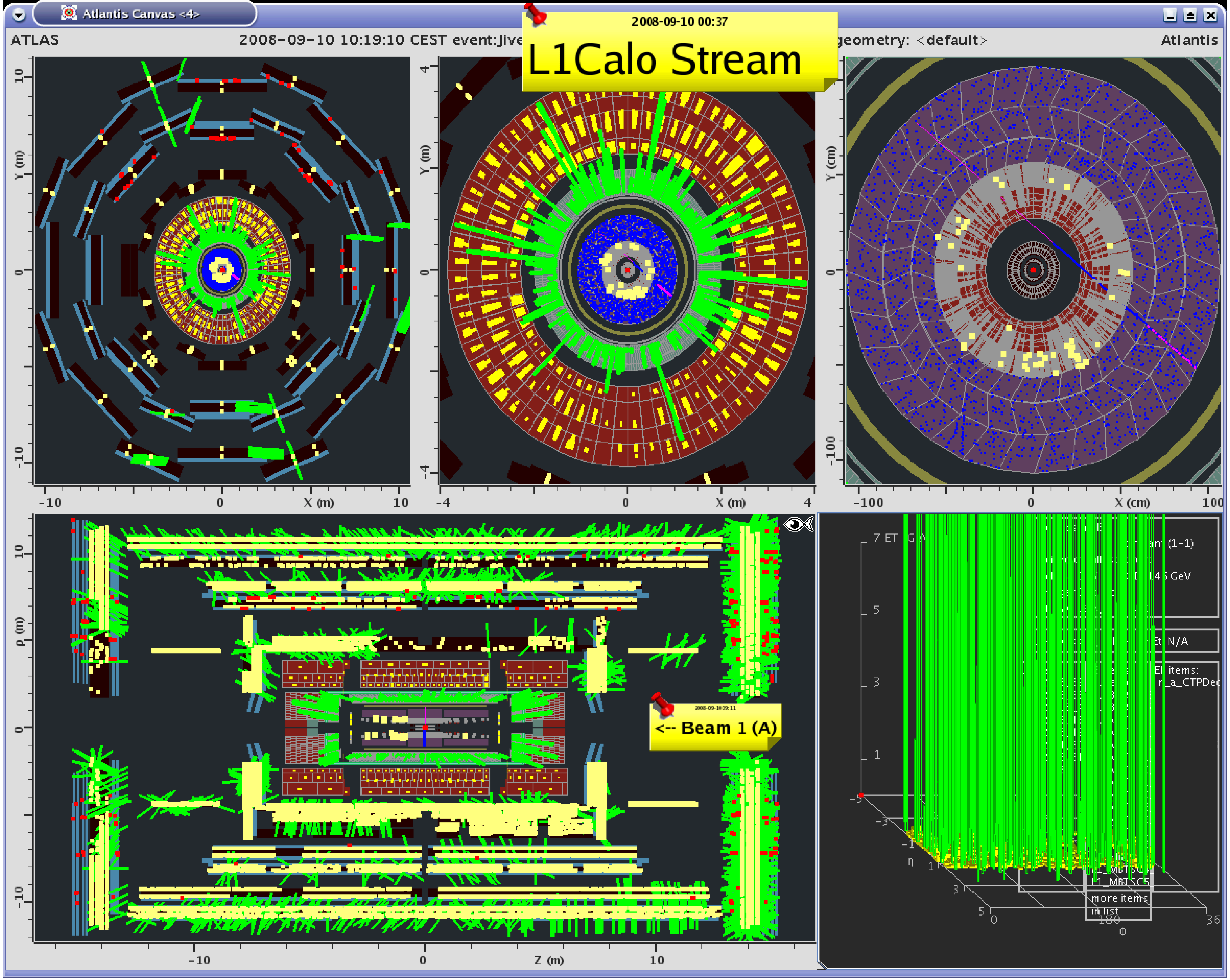
ATLAS superimposed to the 5 floors of building 40

**45 m**

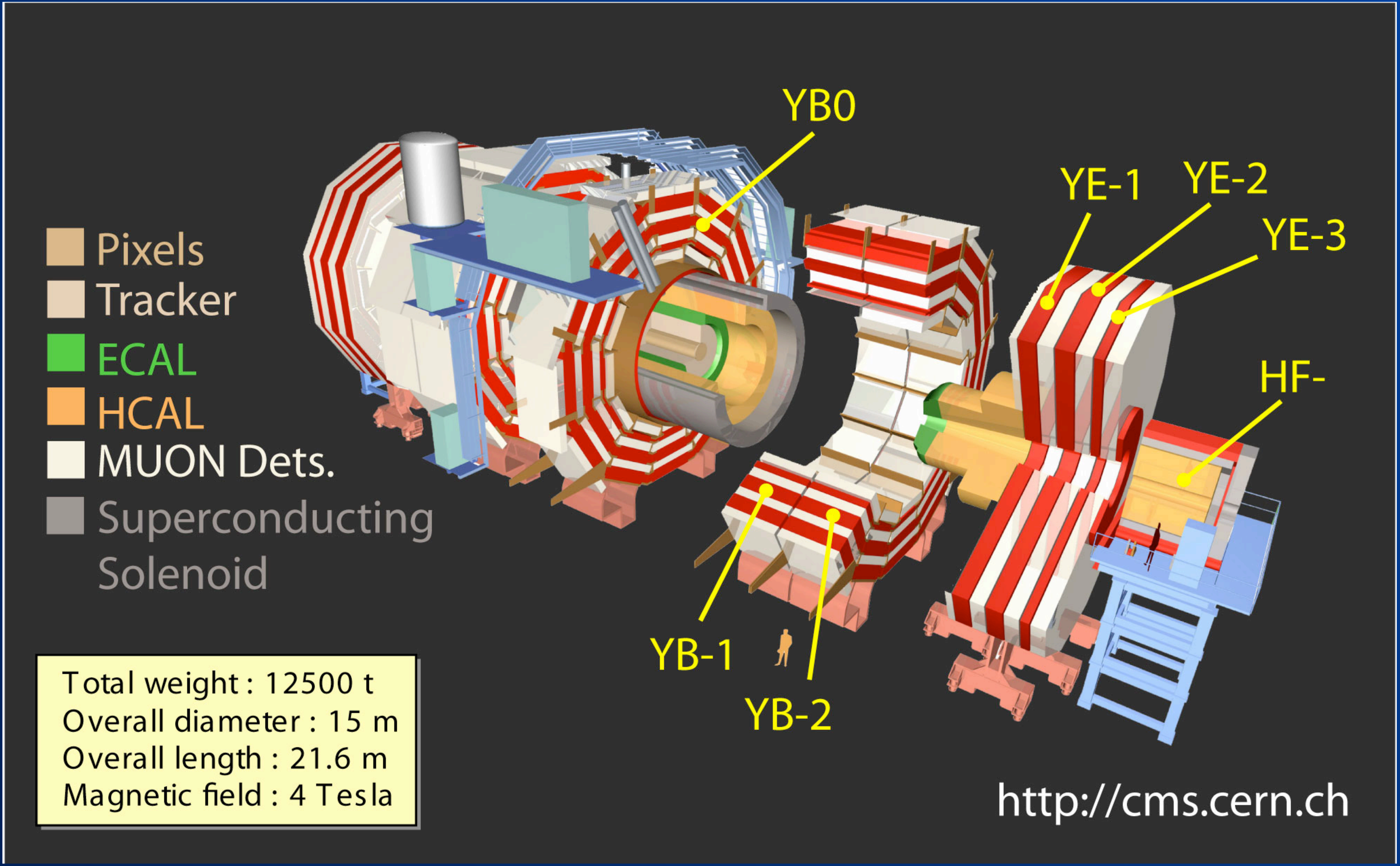
**24 m**



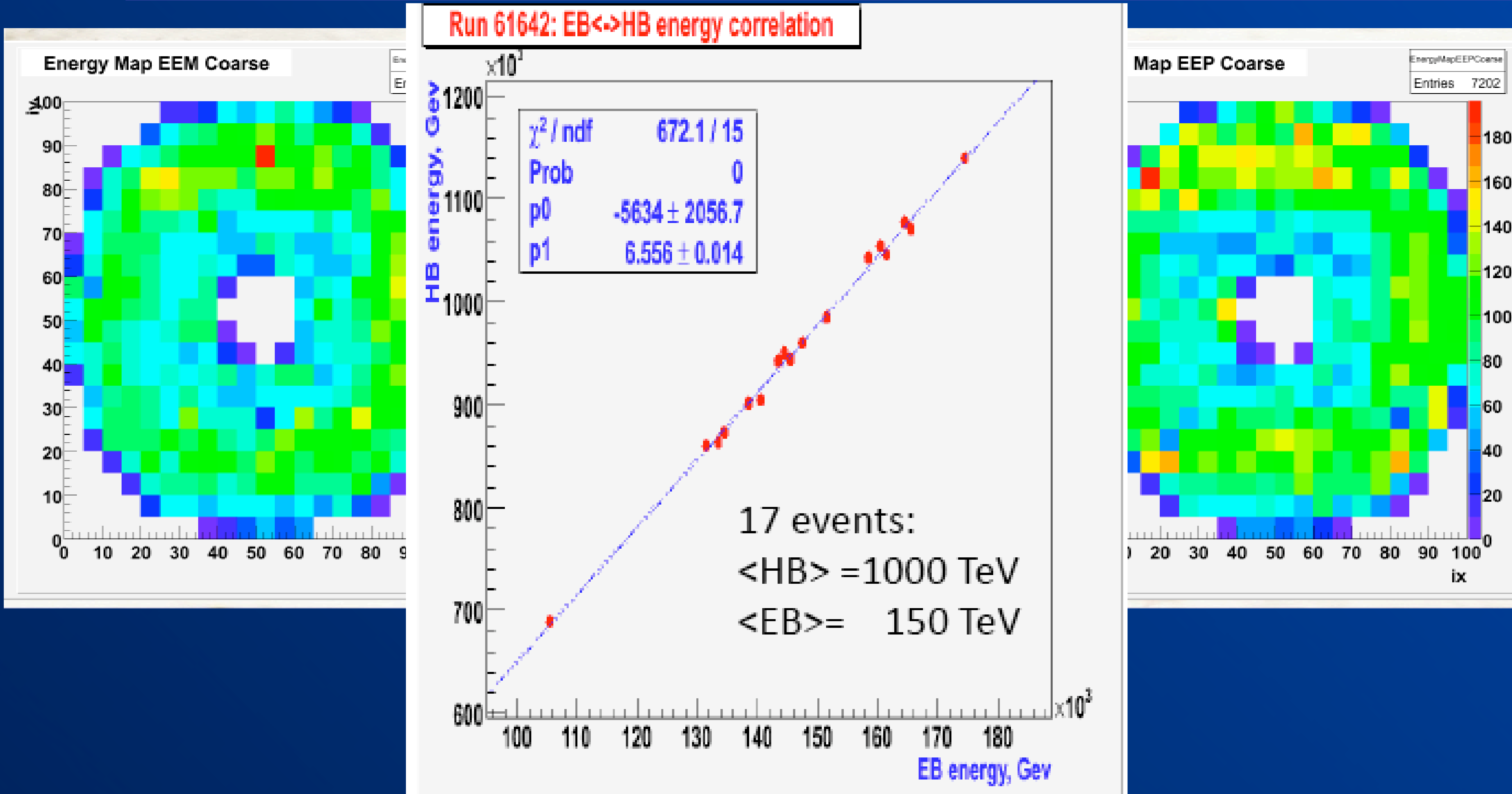

**7000 Tons**




Very first beam-splash event seen in ATLAS (as seen online in the ATLAS Control Room) on 10-Sep-2008 at 10:19


YB0
YE-1
YE-2
YE-3
HF-
YB-1
YB-2
Pixels
Tracker
ECAL
HCAL
MUON Dets.
Superconducting Solenoid
Total weight : 12500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla
http://cms.cern.ch

# Calorimeters: Collimators Closed




ECAL: Splash events provided a source for overall internal synchronization.
Crystals were time aligned to within 1ns !

# Recent Highlights from ILC Project

IEEE NSS @ Dresden

October 24, 2008

Sakue Yamada

# Call for LOIs made by ILCSC, October 2007

For detector designs to be implemented in the accelerator design to be completed in 2012

- Due date: end of March 2009
- Two contrasting, complementary detectors are expected by ILCSC
- Validation to be made by International Detector Advisory Committee（IDAG)

*on the detector's capability for the desired physics target and feasibility*.

# Plan

- Validation will be made through Spring and Summer 2009.
- **It is not the end of the story but start of more intense R&Ds.**

Design phase I ( ~ 2010)

**Focus R&D on prioritized area**

**Complete validated detector specification**

Design phase II ( ~ 2012)

**React to LHC results**

**Final confirmation of physics performance**

**Complete necessary R&D**

**Complete technical design for ILC proposal**

# Some milestones of
# Machine Detector Interface

- What are Issues

  Final focus ( luminosity, beam background ),

  shielding (Can the other group work in the hall ?)

  Infrastructure: cooling, crane, space

  installation of big components

- **Push-Pull mechanism and alignment**

  How to move the detectors

  Position reproducibility

  How do we align the focusing components and detector components after moving ?

  And how quickly and accurately? → How often to switch?

Studies will start before validation is made.

# Issues

• So far design studies are made mainly by simulations with an ideal detector components.

•The groups may need to verify the performance with large scale ‘realistic’ prototypes.

•Very concrete simulations including support structure, gaps, cables, cooling components may be needed.

•PFA and dual read-readout are to be studied further and verified experimentally.
How well do they work for many jets or at high energy?