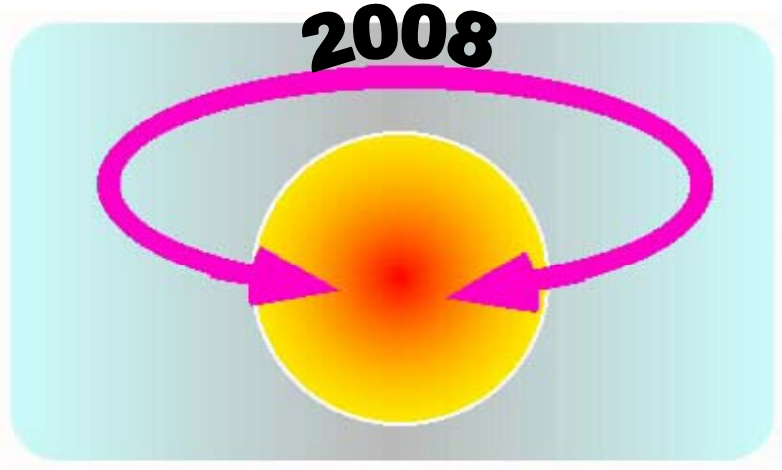
ALICE
A Large Ion Collider Experiment

- Looking for what ?: The ‘State of Matter’ at the LHC
- Looking back: The making of ALICE 1990-2007
- Looking forward: First physics with pp and Pb-Pb



ALICE
trough the Looking Glass

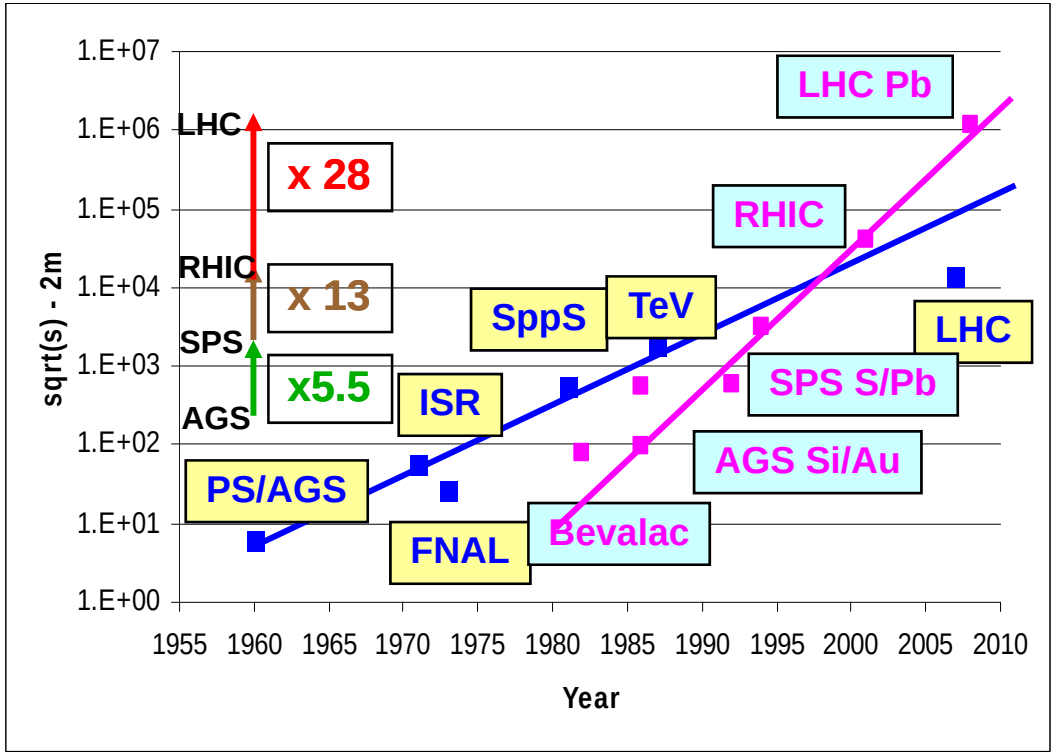
A Brief History of Hadron Accelerators

- **Particle Physics: energy doubling time ~ 4 years**
- **Heavy Ion Physics: doubling time ~ 2 years**
  - ⇨ starting around 1980 at Bevalac/LBNL
    - ✪ a few dozen physicists mostly from US, Germany, Japan
  - ⇨ energy increase by factor 10^4 in ~ 30 years with LHC in 2008
    - ✪ > 2000 physicists active worldwide today

Possible mostly by (re-) using particle physics machines.

Field went from the periphery into a central activity of contemporary Nuclear Physics.

Total center-of-mass energy versus time



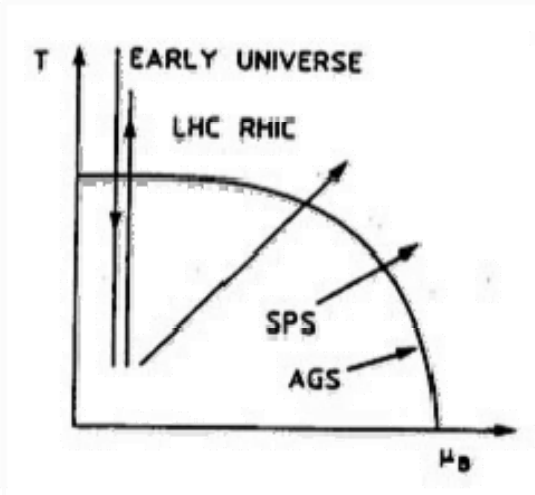
Matter under Extreme Conditions

- ‘state of matter’ at high temperature & energy density: **‘The QGP’**
  - ⇨ ground state of QCD & primordial matter of the Universe
    - ✪ partons are **deconfined**
    - ✪ **chiral symmetry** is restored (partons are ~ massless)
  - ⇨ **‘the stuff at high T where ordinary hadrons are no longer the relevant d.o.f’**

Theory

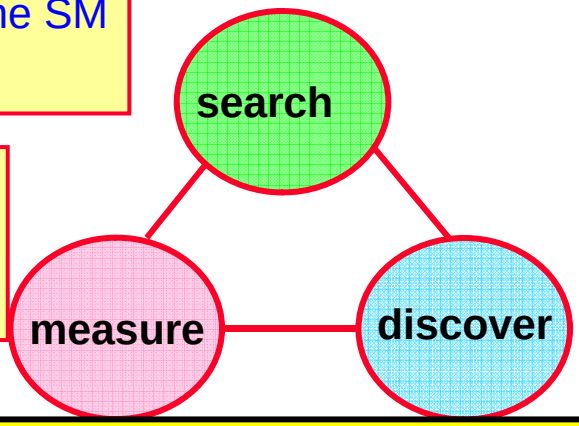
Experiment

- Mission of URHI
  - ⇨ **search** for the QGP phase
  - ⇨ **measure** its properties
  - ⇨ **discover** new aspects of QCD in the strongly coupled regime



Physics is QCD:
strong interaction sector of the SM
(where its strong !)

AdS/CFT: A BSM connection ?
SUSY strings <-> ‘’QCD’’
$\eta/s = 1/4\pi$



Central Concept of SM:
phase transitions and symmetry breaking

QCD transition is the only one directly accessible by experiment !

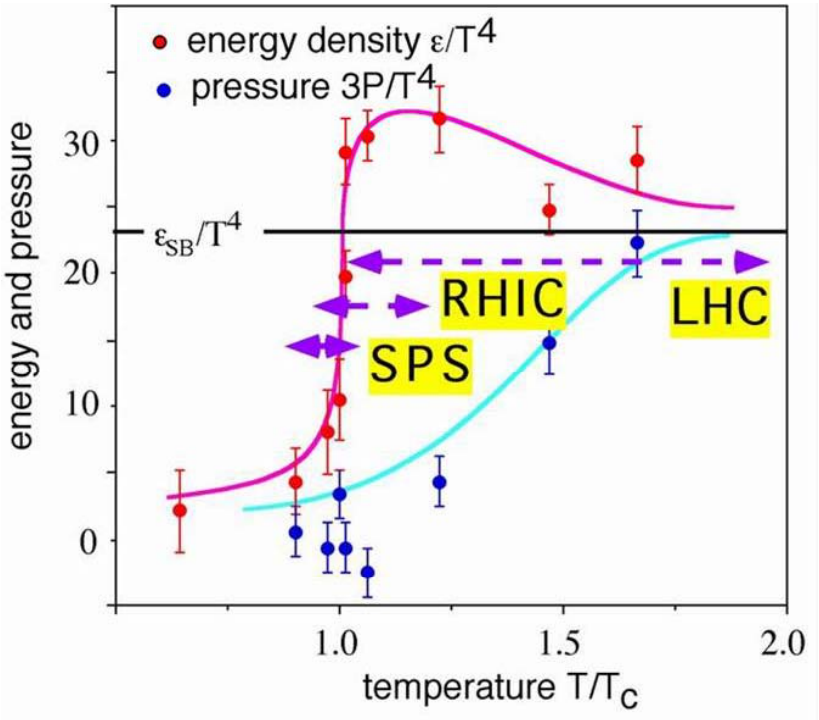
Where to look for the QGP

- the phase transition from lattice QCD

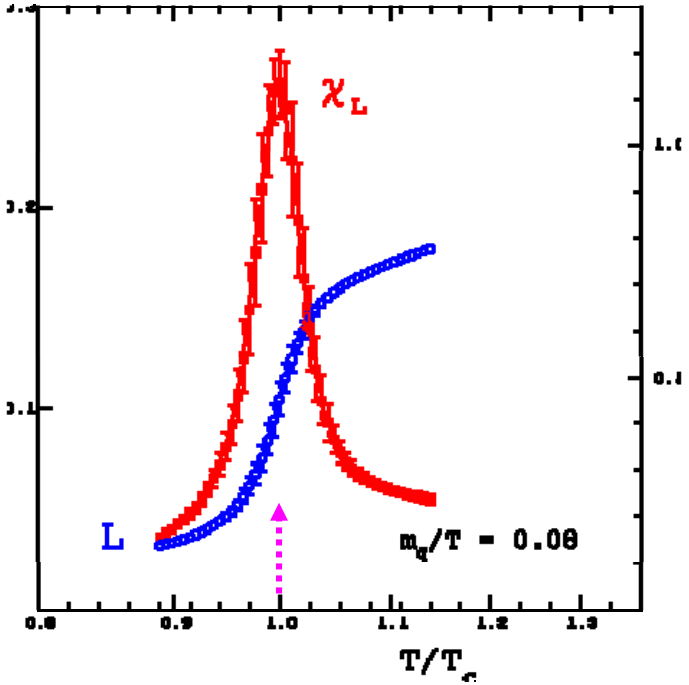
$\varepsilon \sim T^4$	$\varepsilon\ (\tau=1\ \text{fm/c}) \sim dN/dy \sim \ln(\sqrt{s})$

⇨ **T/T_c 0.9 -> 1.1 => factor ~2 in ε => factor ~ 9 in $\sqrt{s}$** **(SPS -> RHIC)**

⇨ we need big factors in energy to cover the QCD phase diagram



Order parameter for deconfinement



What is left to do at LHC ?

Assumption: 'QGP' has been produced at RHIC/SPS prior to LHC

- ⇨ **Search** for the 'QGP' is essentially over
- ⇨ **Discovery** of QGP is well under way (with fantastic results & surprises at RHIC)
- ⇨ **Measuring** QGP parameters has just begun

- pre-RHIC tasks: 'precision' measurements
  - ⇨ quantitative and systematic study of this state of matter
    (' LEP after W/Z discovery at SppS')
    - ✪ different state (by large factors) in energy density, lifetime, volume
    - ✪ new signals ('hard probes') : heavy quark states (b,c), jets

- post – RHIC result tasks: continue discovery !
  - ⇨ confirm interpretations by testing predictions/extrapolation to LHC
  - ⇨ transition from strongly coupled QGP -> ideal QGP ?
- surprises may still lie ahead more to search for ?
  - ⇨ is initial state dominated by yet another new state of matter (dense quantum state) ?
    - ✪ **Color Glass Condensate ?** (QCD in classical Field Theory limit)

H.I. Physics@LHC: Caveat

BIG Step ahead: SPS $\xrightarrow{\times 13}$ **RHIC** $\xrightarrow{\times 28}$ **LHC**

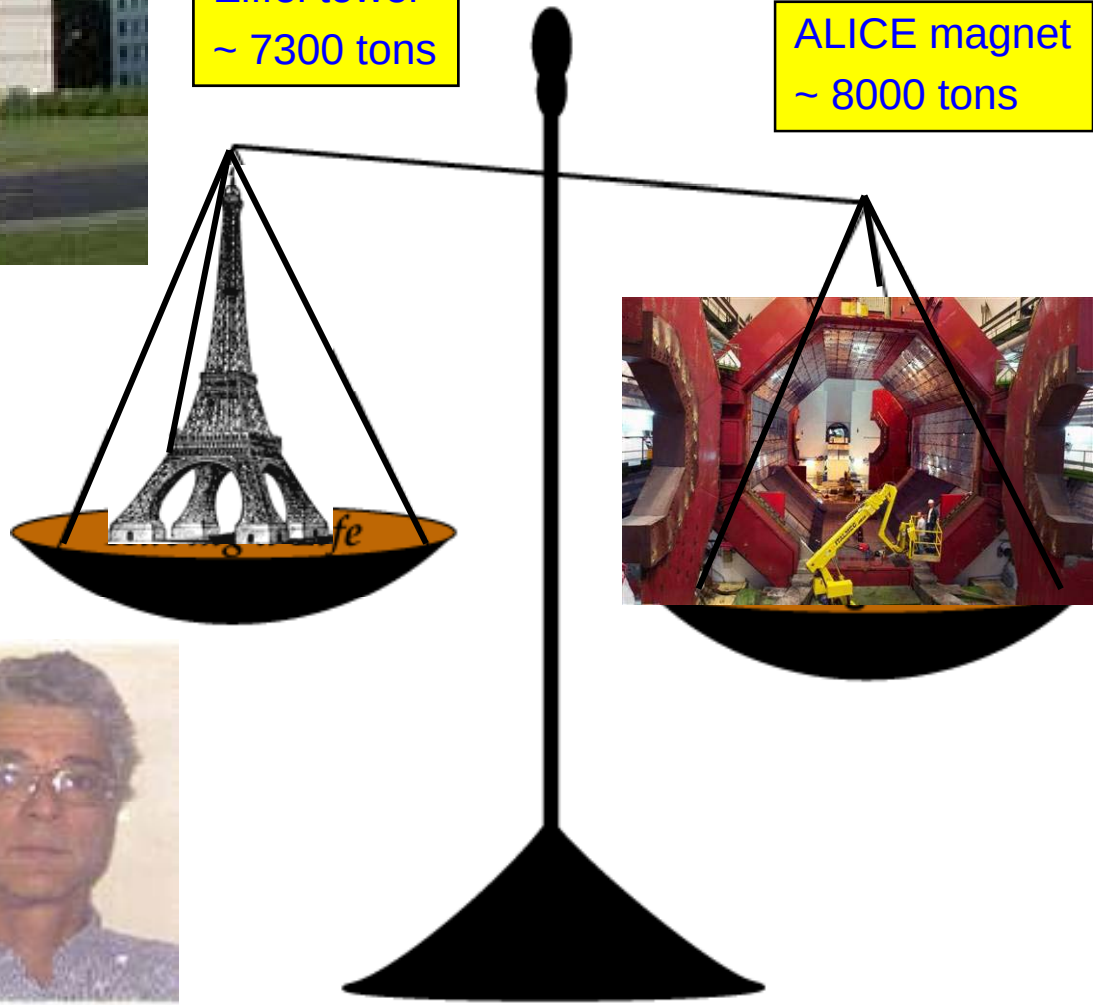
- long distance QCD is difficult to predict

Predictions are notoriously difficult, in particular if they concern the future..

  - ⇨ Theory well known, not so its consequences or manifestation
  - ⇨ HEP@LHC: Theory unknown, but each candidate makes precise predictions

- several surprises (both + and -) at SPS and RHIC
  - ⇨ **RHIC**: large elliptic flow, 'baryon anomaly', very large jet-quenching
    - ✪ 'QGP' is not a weakly interacting plasma, but behaves like an 'ideal fluid'
  - ⇨ **SPS, RHIC**: no strong event-by-event fluctuations (for 1st order phase transition)
- lesson when preparing for LHC
  - ⇨ **guided** by theory and expectations, but **stay open minded** !
- 'conventional wisdom'
  - ⇨ **soft physics**: smooth extrapolation of SPS/RHIC — necessary, but boring ???
  - ⇨ **hard physics**: new domain at LHC

- **Experiments at LHC are**
  - ⇨ **Big**
  - ⇨ **Heavy**
  - ⇨ **and took a looong time …**



The Making of ALICE

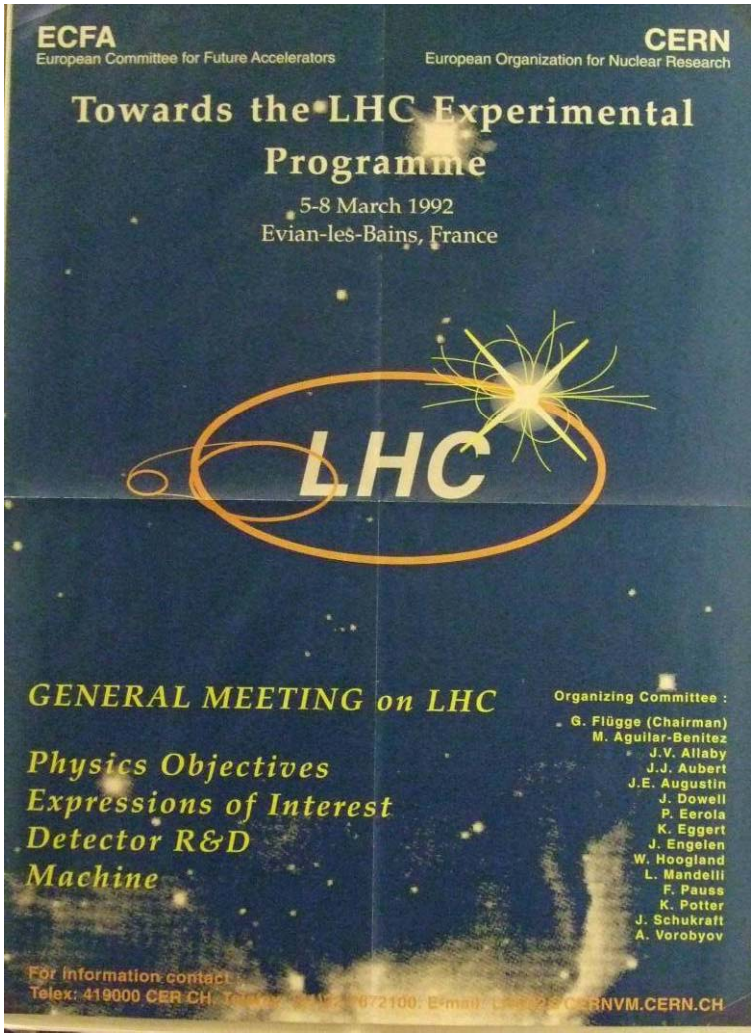
- Pre-History
  - ⇨ **early 80's**: Large **Hadron-Collider** pp machine in LEP tunnel (Lausanne WS)
  - ⇨ **1986:** start of heavy ion physics at SPS & AGS (light ions, ^{16}O and ^{32}S)
  - ⇨ **1987:** La Thuile WS to choose next CERN project (pp, ep, e^+e^-)
    - ✪ first mention of LHC as **Large-Hadron** Collider (large hadron = ^{208}Pb)
- Conceptual Studies
  - ⇨ **1990:** RHIC approved for construction at BNL; call for experiments LoI
  - ⇨ **1990: First ideas** developed for HI@LHC (LHC WS, Aachen)
    - ✪ Conclusion Theory (Convener H. Satz)

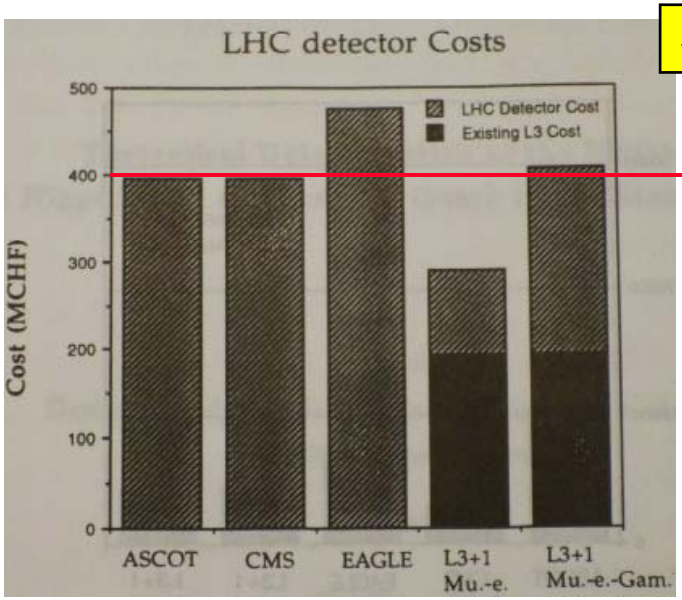
      'Heavy Ion **Collider best possible tool** for statistical QCD.

      LHC is unique in many respects'
    - ✪ Conclusion Experiment (Convener H.J. Specht)

      'A general purpose detector for all observables seemed impossible at LHC. Actually, such a **detector** concept **could be developed**'
  - ⇨ **1992: Expression of Interest** (Evian)
    - ✪ 1) re-use of **modified LEP experiment** (Delphi): **impossible**
    - ✪ 2) use of **pp experiment** (CMS): **seemed possible** for selected hard signals ($\mu\mu$)
    - ✪ 3) **dedicated** general purpose **HI detector** => **ALICE**

Evian Workshop 1992





Summary by C. Rubbia:

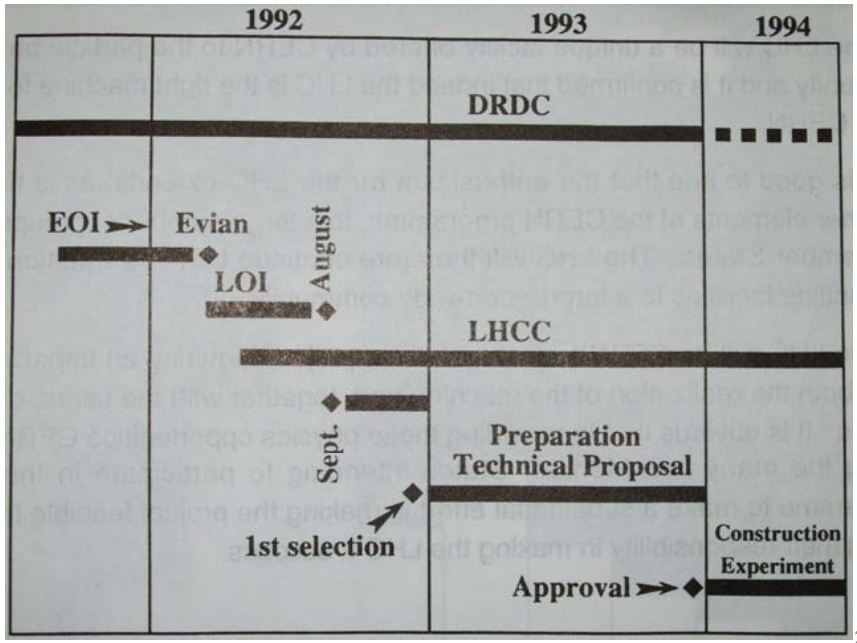
Ascot = 395 M

CMS = 395 M

ALICE = 395M

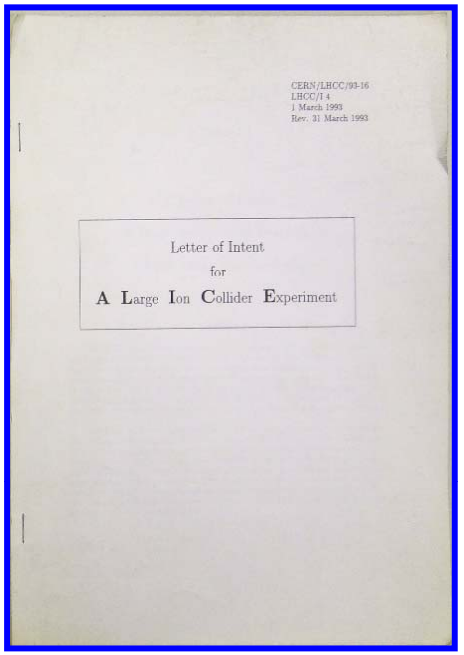
Construction: ‘94

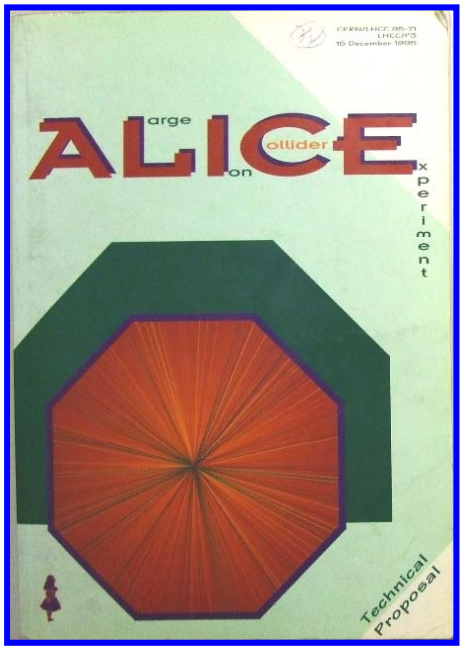
1st beam: ‘98



The Making of ALICE

- Design and R&D
  - ⇨ **1993: Letter of Intent** (central detector) 230 people, 42 Inst.
    - ✪ LHCC requests to add dimuon spectrometer
  - ⇨ **1995**: **Technical Proposal** **ALICE approved in 1997**
    - ✪ 1996 TP Addendum 1: add muon spectrometer
    - ✪ 1999 TP Addendum 2: add electron-spectrometer (TRD)
    - ✪ 2006 TP Addendum 3: add jet calorimeter (EMCAL)
    - ✪ **!! ALICE upgrades underway continuously since 1996 !!**
  - ⇨ **1998 – 2005:** Technical Design Reports
- Construction
  - ⇨ **2000 – 2007:** Bulk of construction
    - ✪ finished by 2010/11 (EMCAL)
- Installation, commissioning
  - ⇨ **2002-2005:** mechanical structures, magnets
  - ⇨ **2006 – early 2008:** detectors, services, cables
  - ⇨ **2007 – first beam:** detector commissioning in situ





HI Challenges I

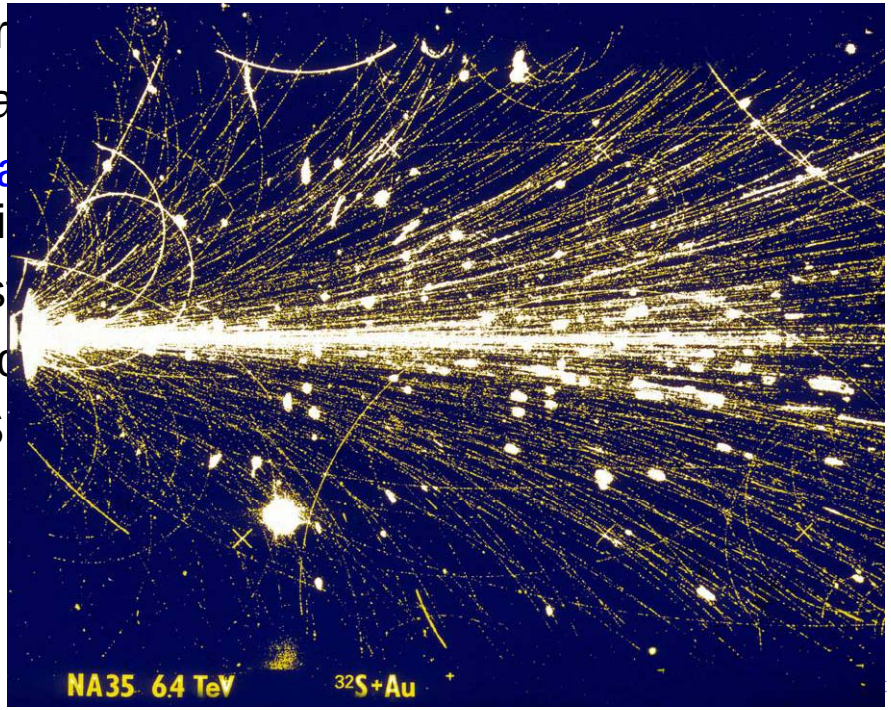
- Experimental Constraints
  - ⇨ extreme particle density ($dN_{ch}/d\eta$ ~ 2000 – 8000)
    - ✪ **x 500** compared to pp@LHC; **x 30** compared to ^{32}S@SPS
  - ⇨ large dynamic range in p_t:
    - ✪ from very soft (**0.1 GeV**) to fairly hard (**100 GeV**)
  - ⇨ both partons & hadrons matter: hadrons are part of the signal, not of the problem
    - ✪ secondary vertices, lepton ID, hadron ID
  - ⇨ modest Luminosity and interaction rates
    - ✪ **10 kHZ** (Pb-Pb) to **300 kHZ** (pp) (< 1/1000 of pp@10^{34})
- Experimental Solutions
  - ⇨ **$dN_{ch}/d\eta$:** high **granularity**, **3D** detectors, large **distance** to vertex
    - ✪ emcal at **4.5 m** (typical is 1-2 m !)
  - ⇨ **p_t coverage**: **thin** det, modest field (low p_t), large lever arm + resolution (large p_t)
    - ✪ ALICE: **< 10%X_0** in r < 2.5 m (typical is 50-100%X_0), B= **0.5T**, **BL^2** ~ like CMS !
  - ⇨ possible magnet configurations: **1)** open **2)** small and very thin **3)** very large
  - ⇨ **PID**: use of essentially all known technologies
    - ✪ dE/dx, Cherenkov & transition rad., TOF, calorimeters, muon filter, topological,
  - ⇨ **rate:** allows slow detectors (TPC, SDD), moderate radiation hardness

HI Challenges II

- Challenges for the Heavy Ion community in early ’90’s
  - ⇨ huge extrapolation from SPS to LHC (^{32}S at 20 GeV -> ^{208}Pb at 5500 GeV)
    - ✪ **x 7** in mass, **x 300** in energy (3 GeV Adone -> 1 TeV ILC)
    - ✪ => large uncertainties in what to expect
  - ⇨ limited experience in building large detectors
    - ✪ ‘pilot’ detectors (1986- 1990) assembled largely from existing detectors

      NA10 -> NA38, Omega spectrometer -> WA85

      ISR calorimeters -> NA34, NA9 streamer chamber + NA24 +UA1 -> NA35
  - ⇨ no previous example of a truly ‘general pur
    - ✪ AGS/SPS/RHIC: handful of complementa
    - ✪ significant conceptual (& sociological) cha
      all observables & people in a si
  - ⇨ resources (money and people) incredibly s
    - ✪ ongoing data analysis of SPS light ion pro
    - ✪ building 2nd generation experiments for S
    - ✪ RHIC approved in 1990, dedicated to HI,
    - ✪ **little left for LHC preparations…**



Early ALICE Designs

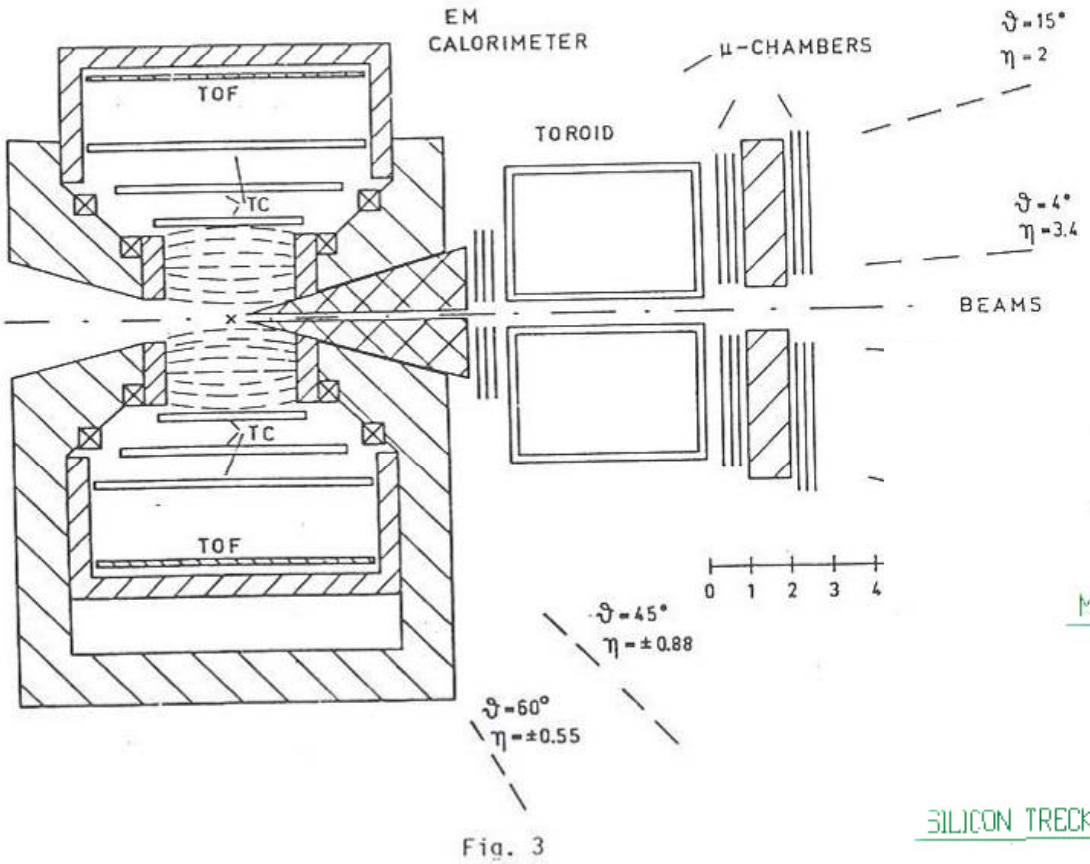


Fig. 3

1990 Design (Aachen)

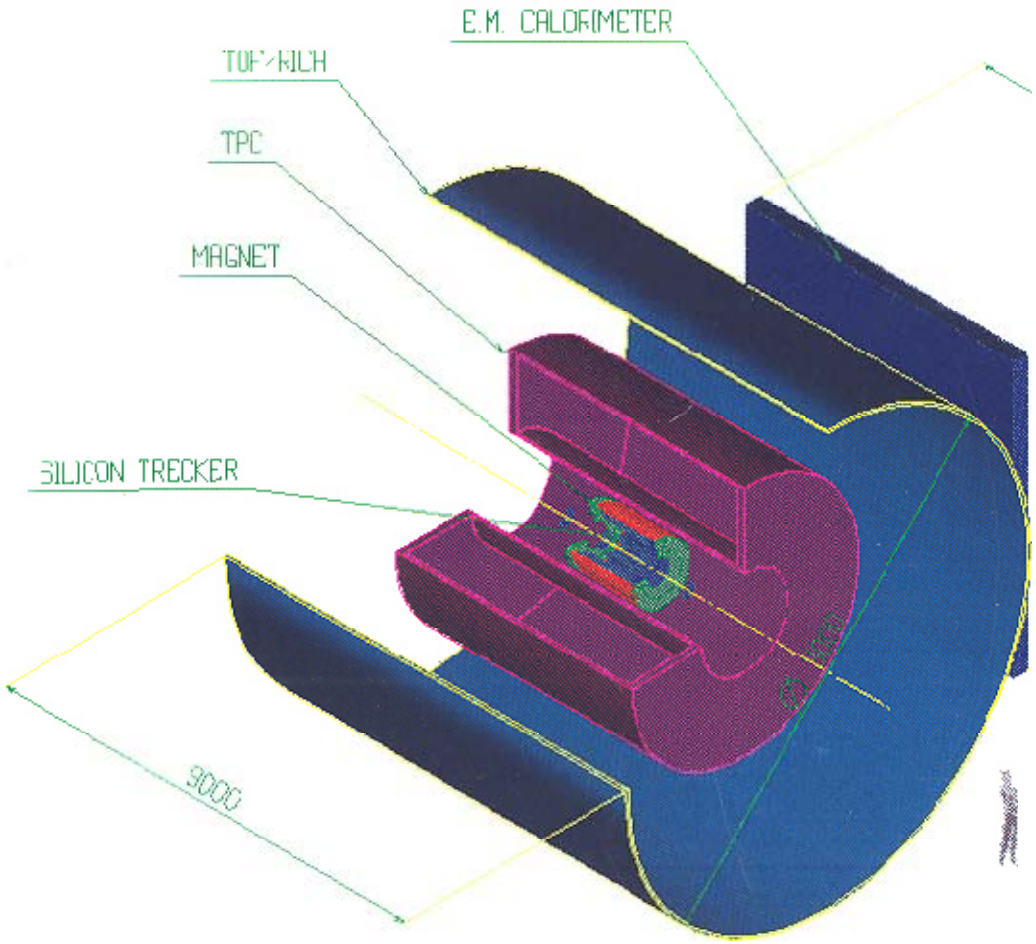
open axial field magnet

(AFS/ISR, + NA38 muons)

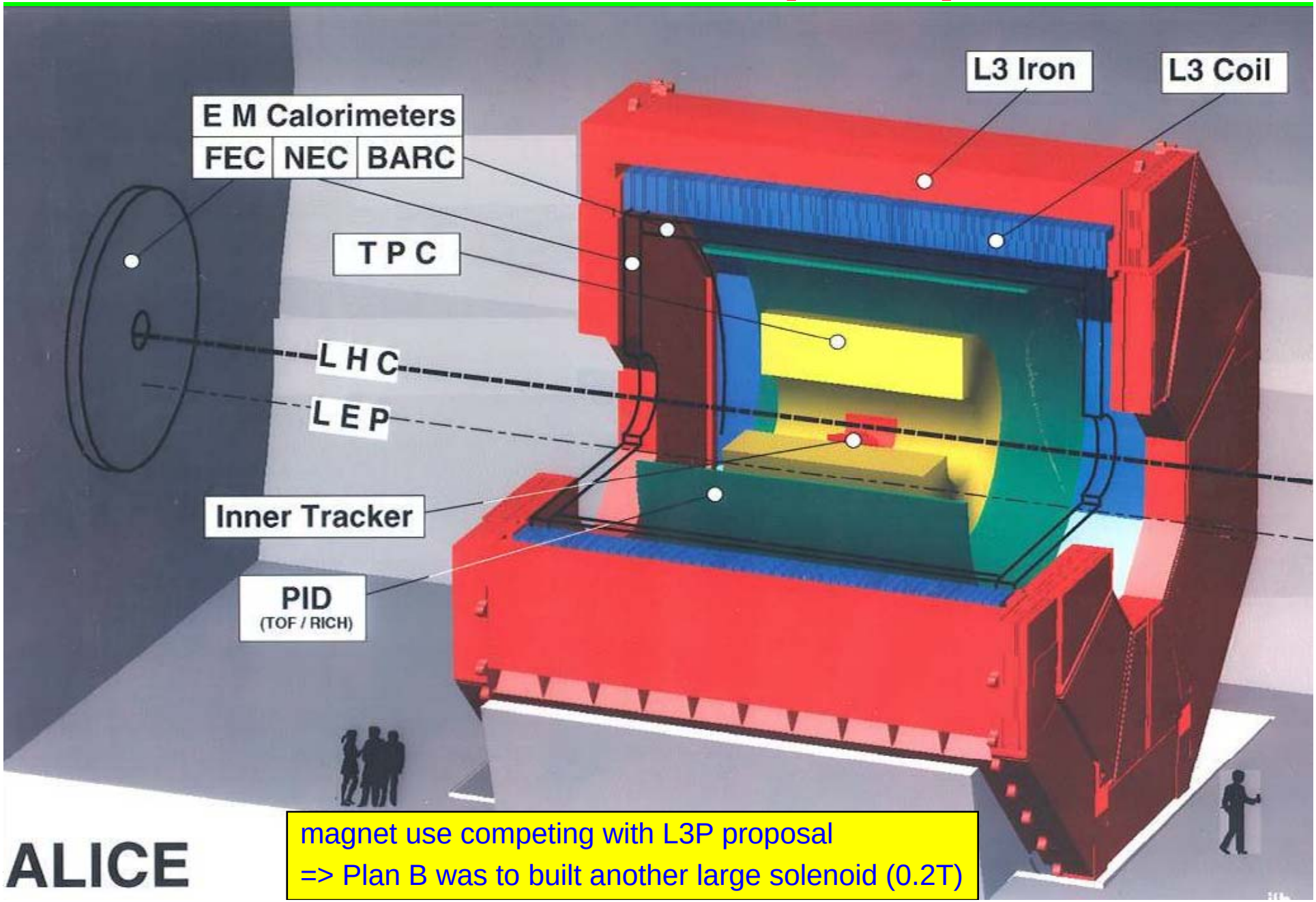
1992 Design (Evian)

no muons

thin (<17%X_0) and small solenoid



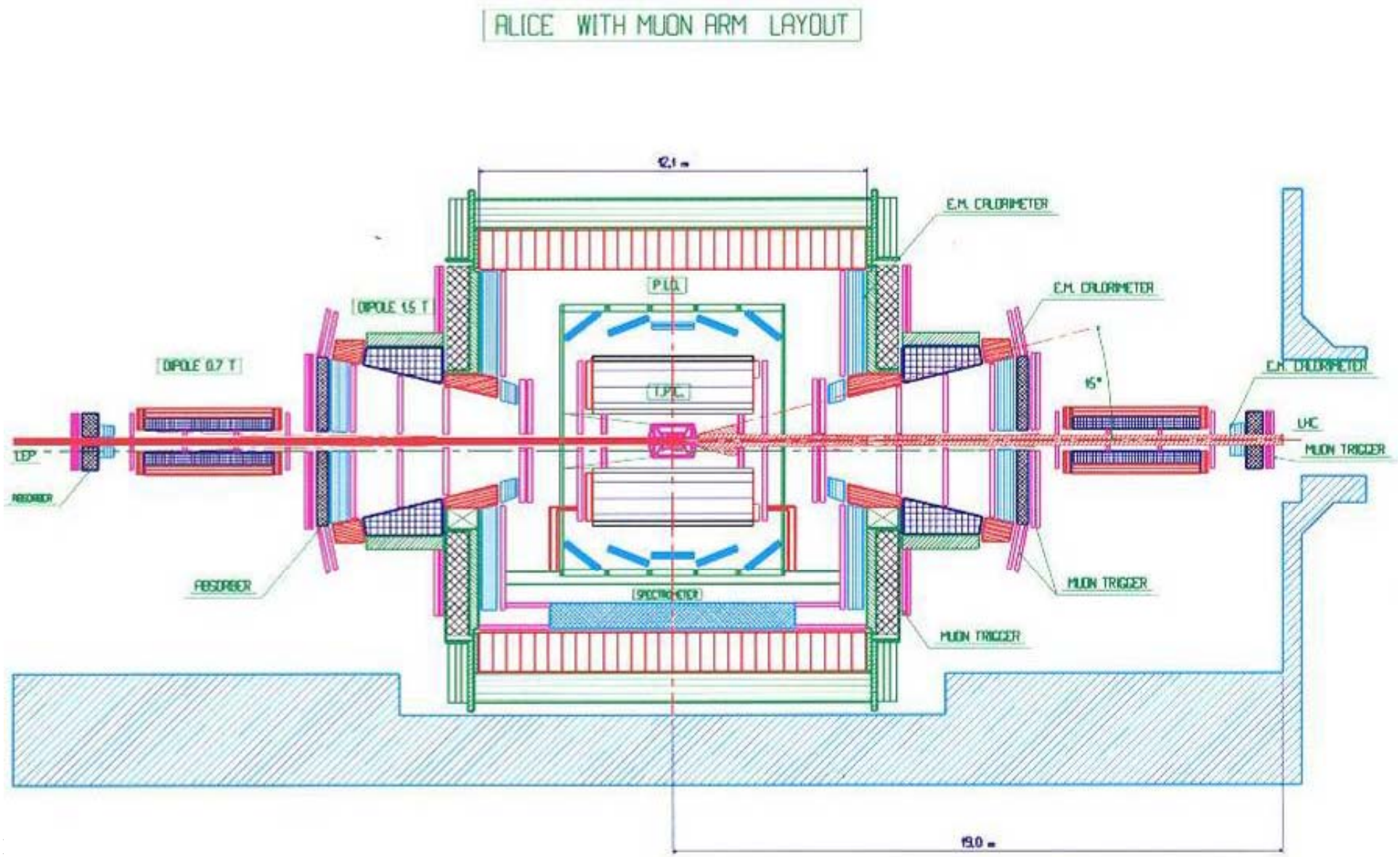
LoI Detector (1993)



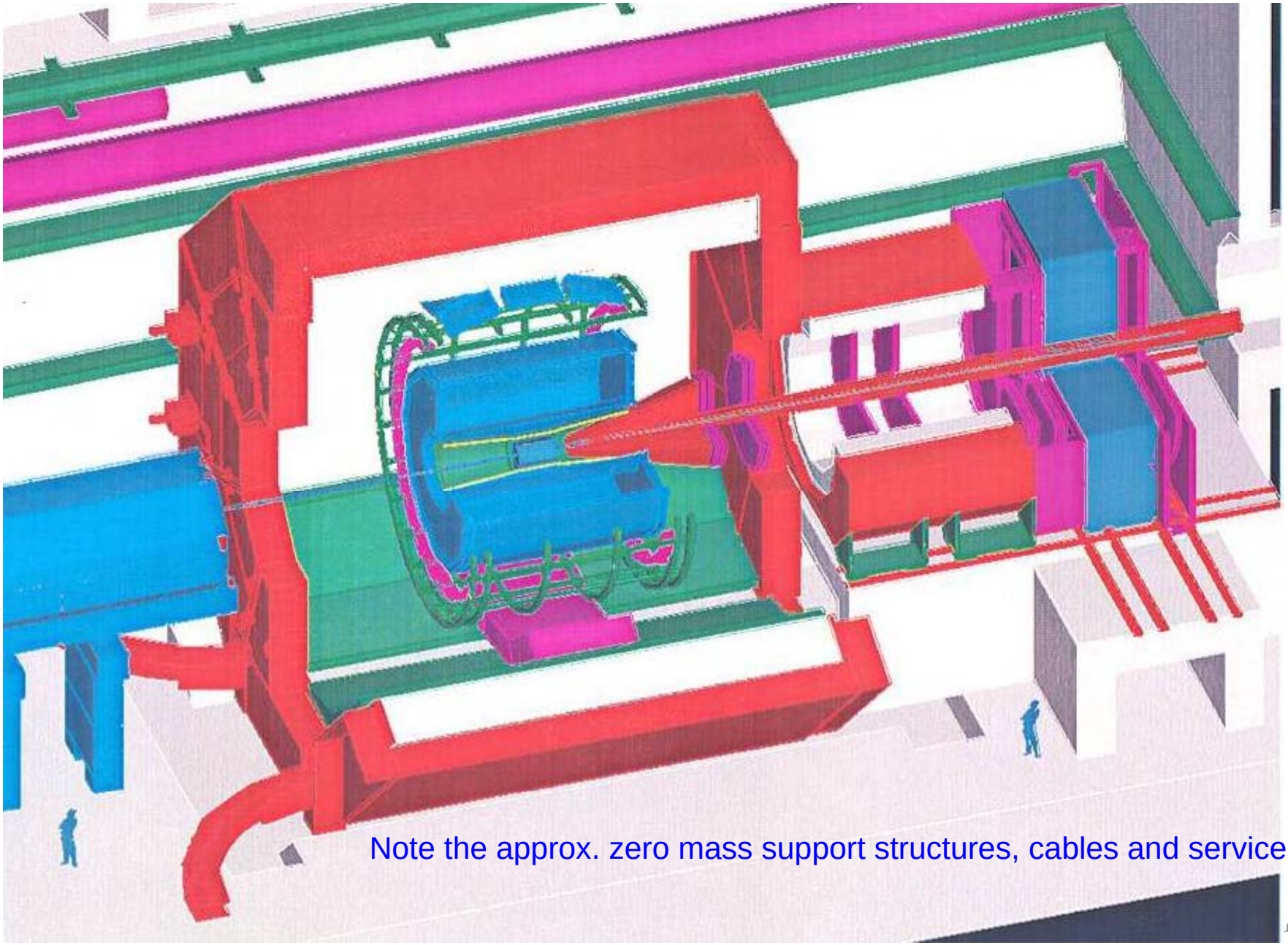
magnet use competing with L3P proposal
=> Plan B was to built another large solenoid (0.2T)

Mega-ALICE (1994)

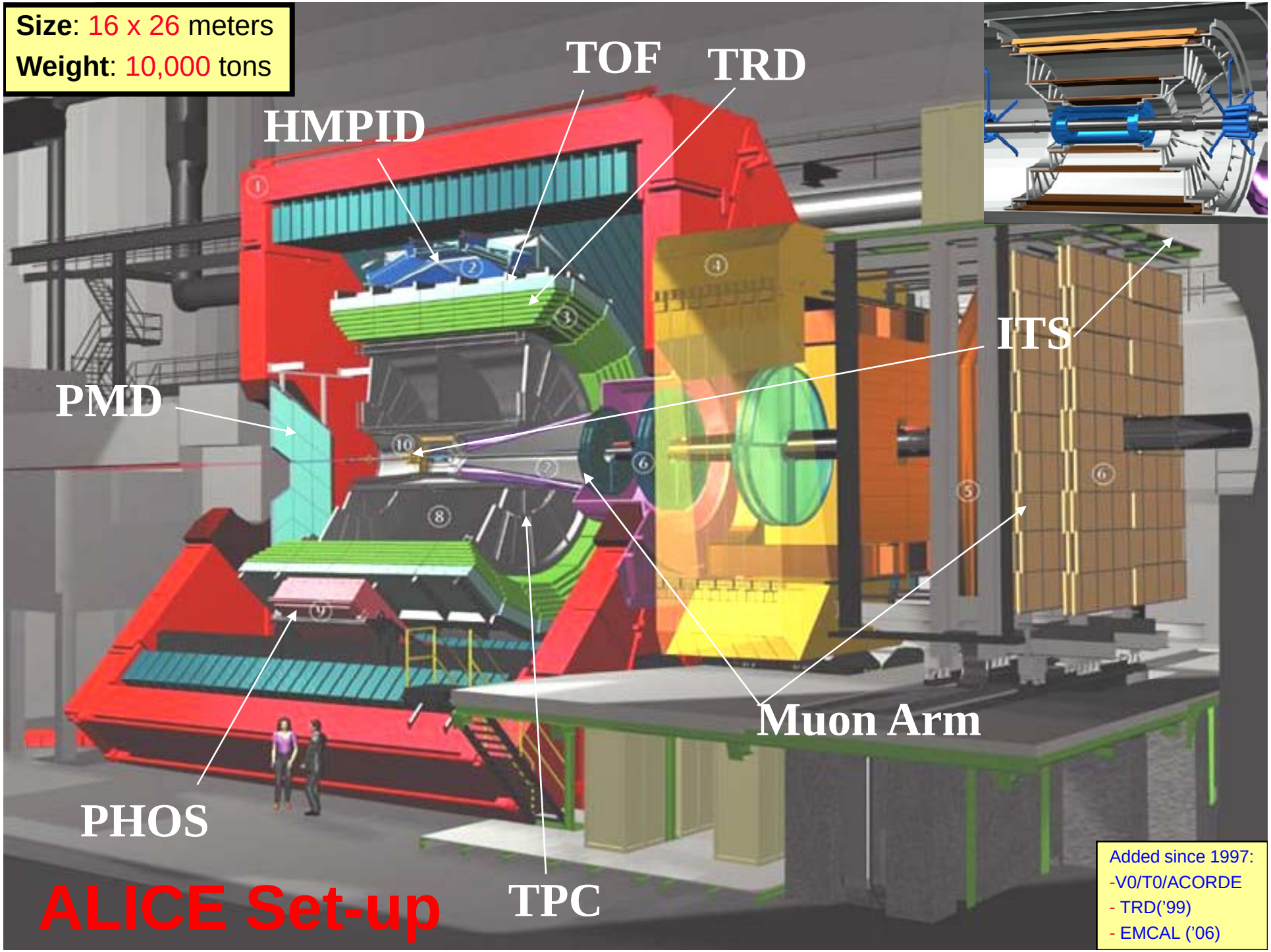
2 muon arms + assorted forward detectors (later outsourced to ‘Felix’ proposal)



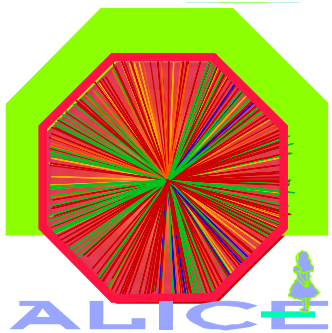
TP Design (1995)



Note the approx. zero mass support structures, cables and services !


Size: 16 x 26 meters
Weight: 10,000 tons
TOF
TRD
HMPID
ITS
PMD
Muon Arm
PHOS
TPC
ALICE Set-up
Added since 1997:
-V0/T0/ACORDE
- TRD('99)
- EMCAL ('06)

ALICE Collaboration



~ 1000 Members

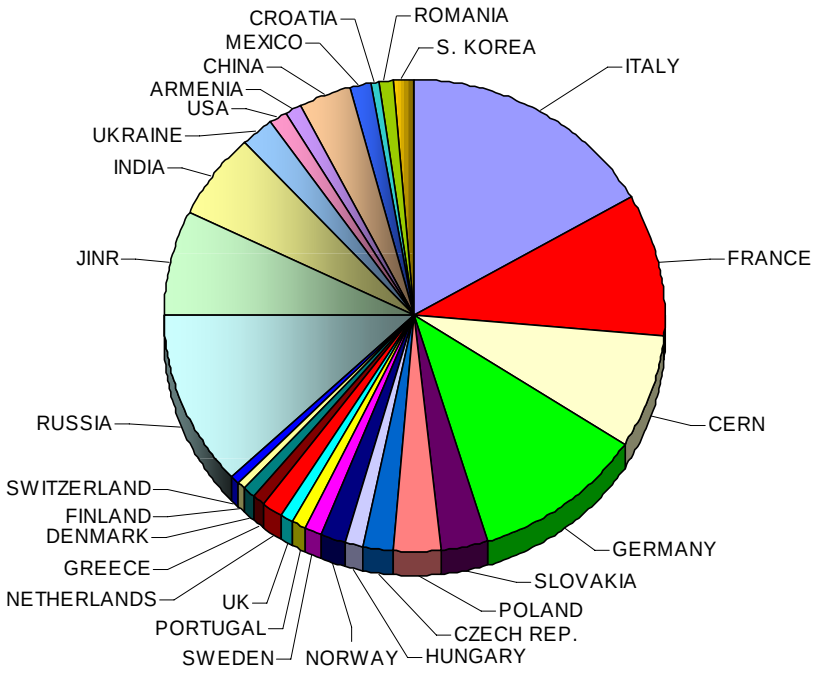
(63% from CERN MS)

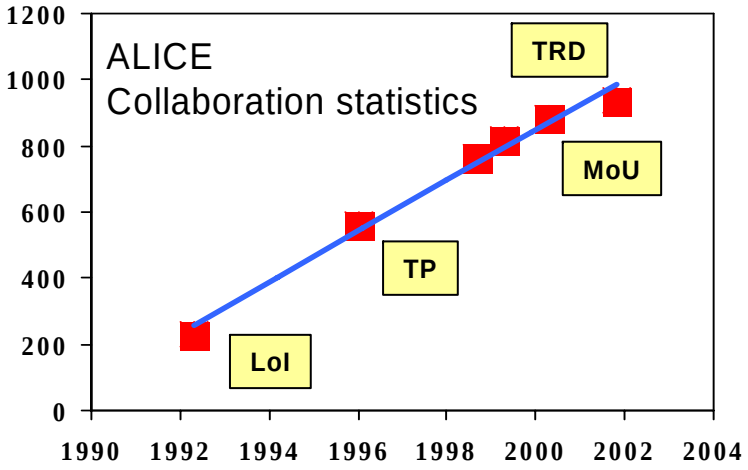
~30 Countries

~100 Institutes

~ 150 MCHF capital cost

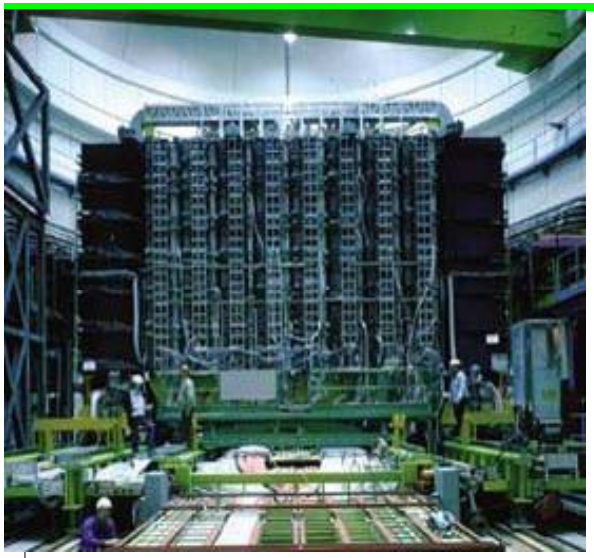
(+ 'free' magnet)

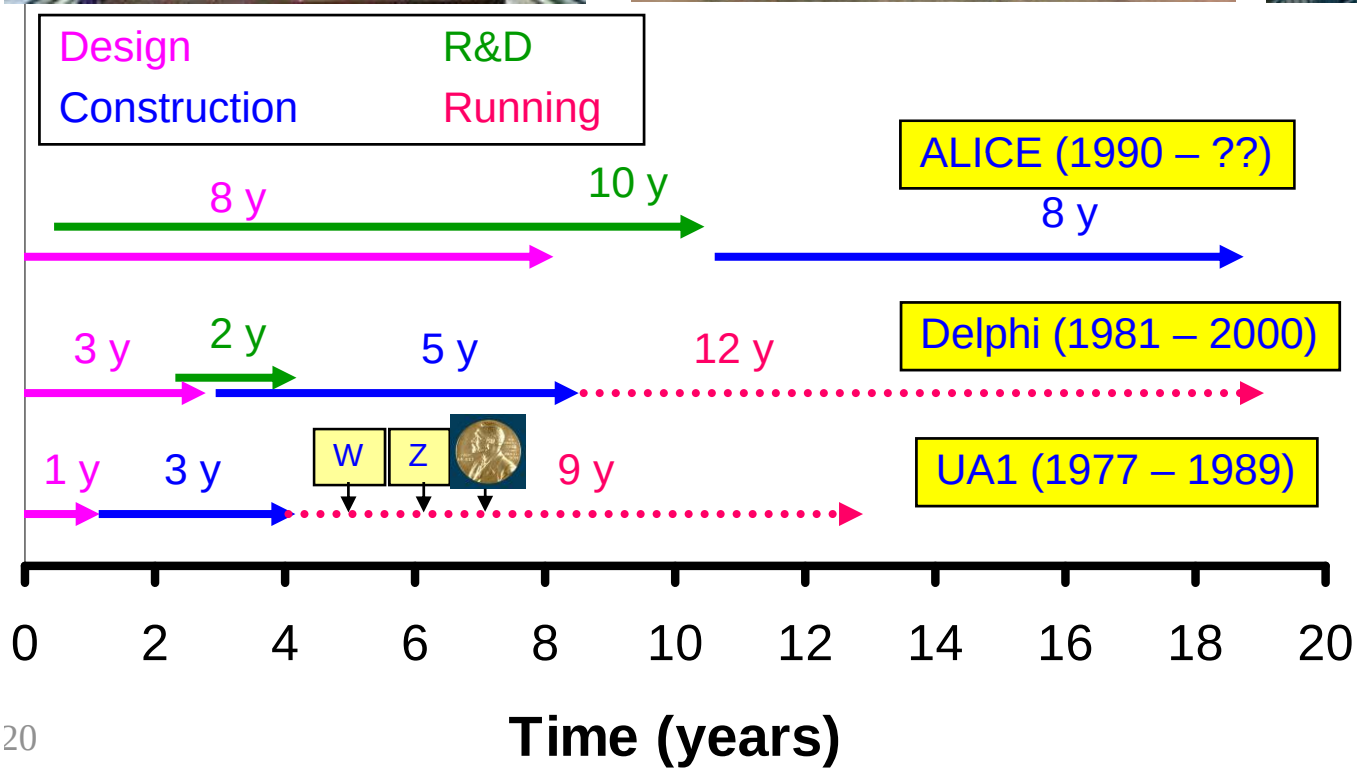





ALICE

The Life of Collider Experiments





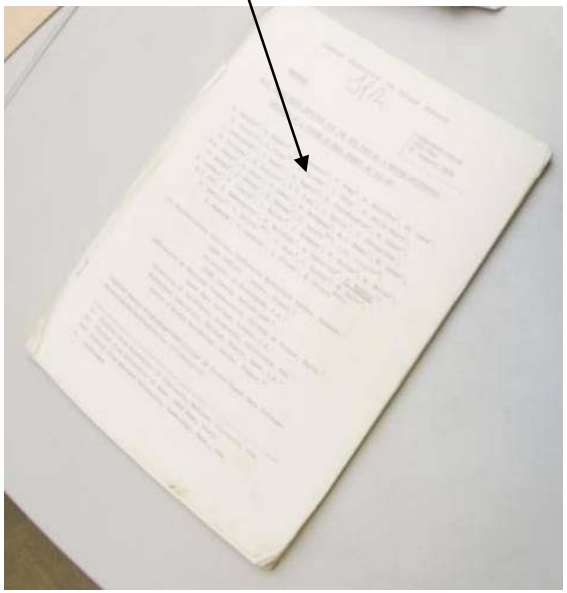
Paper and Committee work..

UA1 proposal (154 p.)
sub. Jan '78, approved June '78

Delphi LoI, TP, 7 Addenda (500 p.)

Alice:
EoI
LoI + 1 Add
TP + 3 Add
12 TDR's + 3 Add
3 Vol PPR

4422 p.



ALICE R&D

1990-1998:Strong, well organized, well funded R&D activity

- **Inner Tracking System (ITS)**
  - ⇨ Silicon Pixels (RD19)
  - ⇨ Silicon Drift (INFN/SDI)
  - ⇨ Silicon Strips (double sided)
  - ⇨ low mass, high density interconnects
  - ⇨ low mass support/cooling

RHIC RHIC

- **PID**
  - ⇨ Pestov Spark counters
  - ⇨ Parallel Plate Chambers
  - ⇨ Multigap RPC's (LAA)
  - ⇨ low cost PM's
  - ⇨ CsI RICH (RD26)

RHIC RHIC

- **TPC**
  - ⇨ gas mixtures (RD32)
  - ⇨ new r/o plane structures
  - ⇨ advanced digital electronics
  - ⇨ low mass field cage

RHIC

- **DAQ & Computing**
  - ⇨ scalable architectures with COTS
  - ⇨ high perf. storage media
  - ⇨ GRID computing

? ? ?

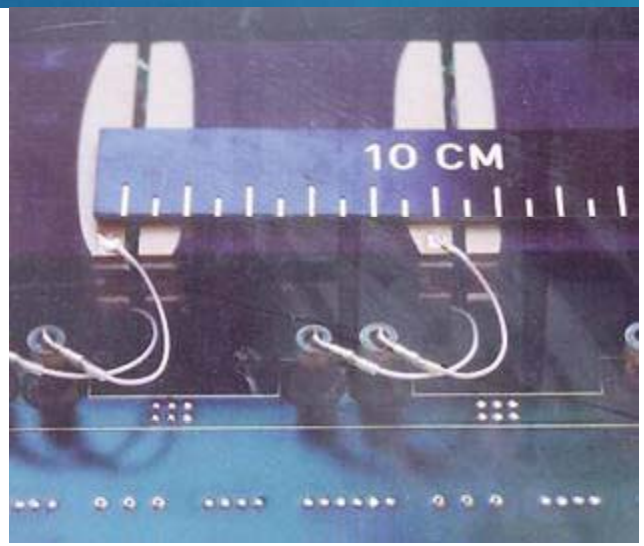
- **em calorimeter**
  - ⇨ new scint. crystals (RD18)

- **misc**
  - ⇨ micro-channel plates
  - ⇨ rad hard quartz fiber calo.
  - ⇨ VLSI electronics

- **R&D made effective use of long (frustrating) wait for LHC**
- **was vital for all experiments to meet LHC challenge !**

R&D: Time of Flight Detectors

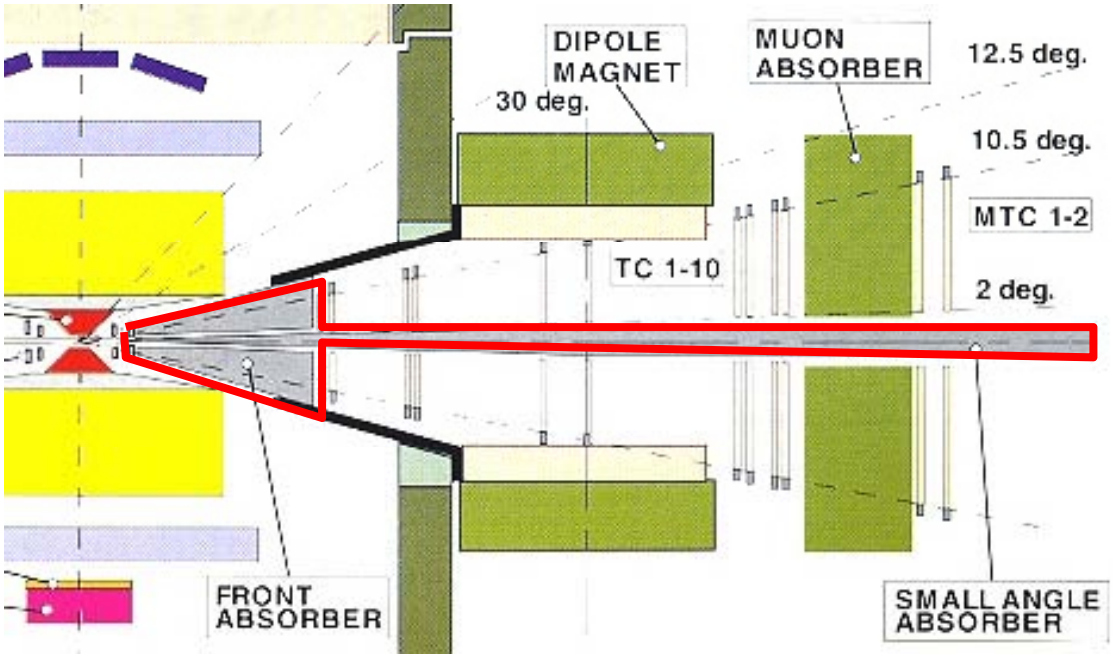
- aim: state-of-the-art TOF at ~1/10 current price !
  - ⇨ requirements: area > 150 m^2, channels ~ 150,000, resolution σ < 100 ps
  - ⇨ existing solution: scintillator + PM, **cost > 150 MSF !**
    - ✪ R&D on cheaper fast PM's failed
- gas TOF counters + VLSI FEE
  - ⇨ **Pestov Spark Counter** (PSC) **HIGH TEC**
    - ✪ 100 μm gap, > 5 kV HV, 12 bar, sophisticated gas
    - ✪ **σ < 50 ps,** but only (!) **~ 1/5 cost**
    - ✪ technology & materials **VERY challenging**
  - ⇨ **Parallel Plate Chamber** (PPC) **LOW TEC**
    - ✪ 1.2 mm gap, 1 bar, simple gas & materials
    - ✪ **1/10 cost,** but only **σ = 250 ps**
    - ✪ **unstable operation, small signal**
  - ⇨ **Multigap Resistive Plate Chambers** (MRPC)
    - ✪ breakthrough end 1998 after > 5 years of R&D !
    - ✪ many small gaps (10x250 μm), 1 bar, simple gas & materials
    - ✪ **~ 1/10 cost, σ < 100 ps** , simple construction & operation,..



found immediate wide use:
HARP, STAR,PHENIX, HADES/CBM@GSI,..
option for time-stamping at ILC/CLIC

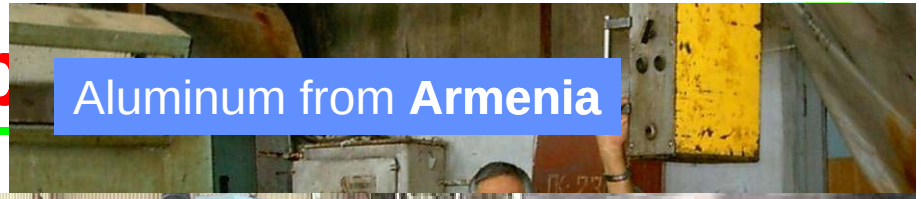
R&D: Muon Absorber

- **Muon Absorber:**
  - ⇨ minimize punchthrough & multiple scattering for muons
    - ✪ ‘standard’ task, well known and simulated
  - ⇨ **crucial**: minimize side leakage into TPC/muon chambers
    - ✪ involves low energy processes (*n transport, (n,γ), nuclear reactions..)*
  - ⇨ engineering challenges (heavy & long, cantilever support, contains fragile beampipe, ..)
- **Design effort 1994 - 2002: 2 teams (CERN, Sarov)**
  - ⇨ 3 independent simulation programs (FLUKA, GEANT, C90)
  - ⇨ 2 beamtests (p, Pb) to validate simulation & chamber response



Muon Ab

Steel cone from **Finland**



Aluminum from **Armenia**

Concrete from **France**,
Engineering & Supervision by **CERN**
Design by **Russia** (Sarov/ISTC)

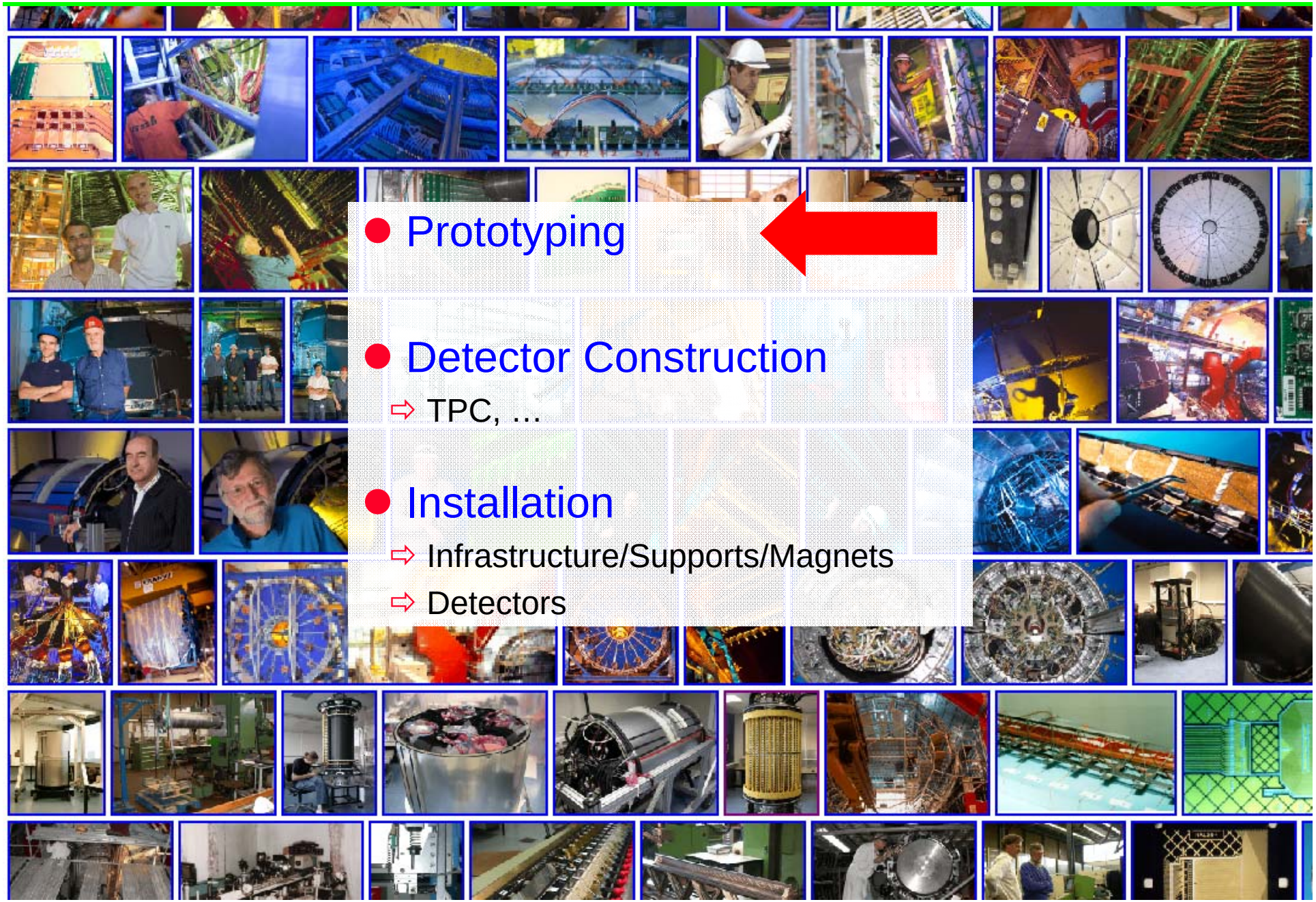
Graphite & Steel from **India**

Lead from **England**

Italian polyethylene

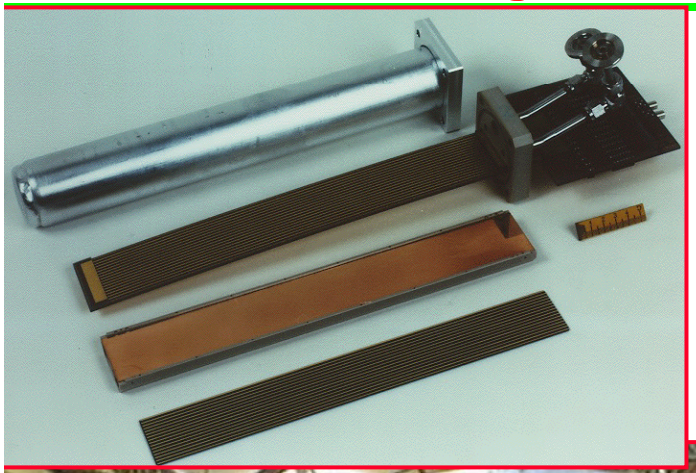
en from **China**

ALICE in Pictures



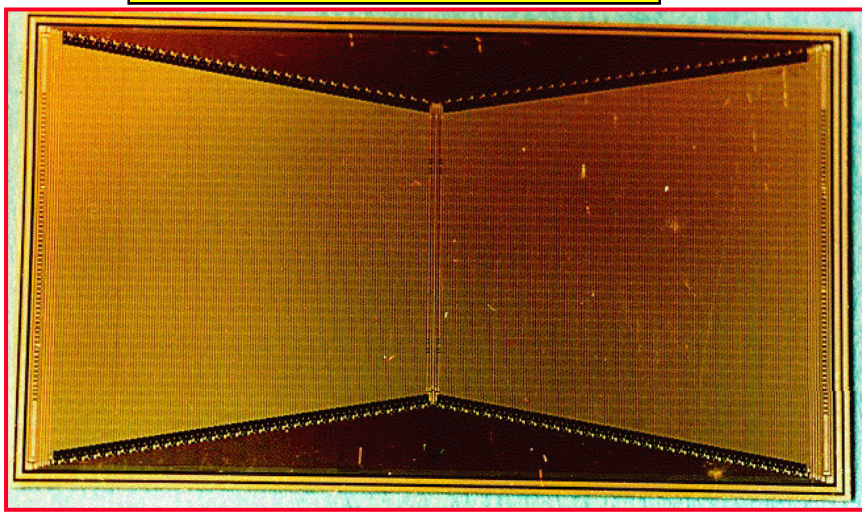
- Prototyping
- Detector Construction
  - ⇨ TPC, …
- Installation
  - ⇨ Infrastructure/Supports/Magnets
  - ⇨ Detectors

Early Prototypes (1991-1998)



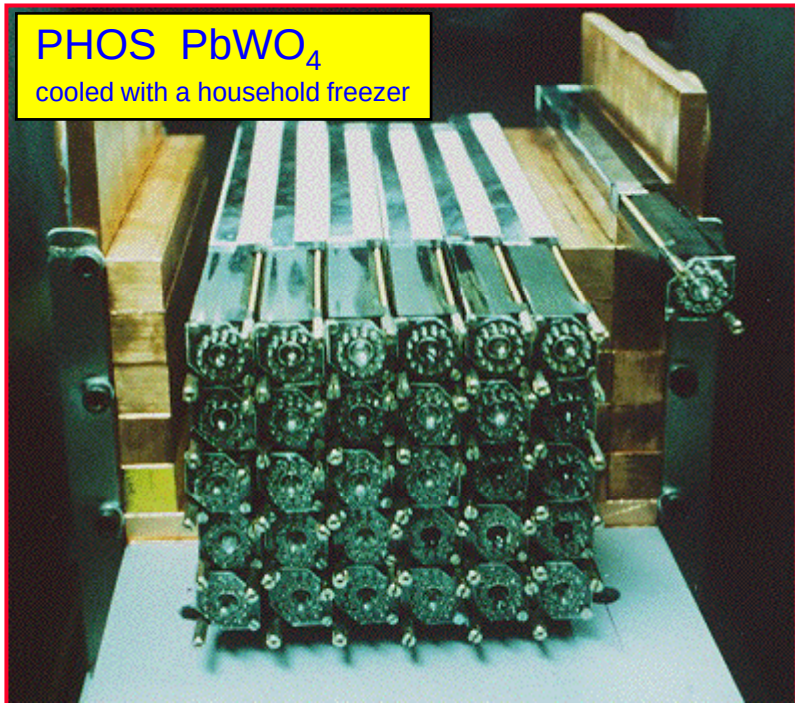
Pestov TOF

Silicon Drift Detector SDD

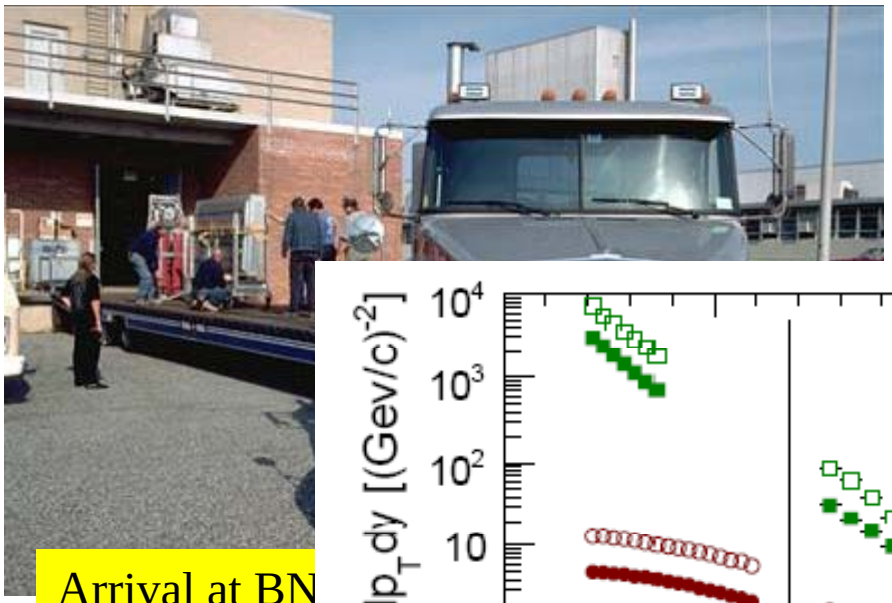


1998: TPC FC proto (1:2.5)

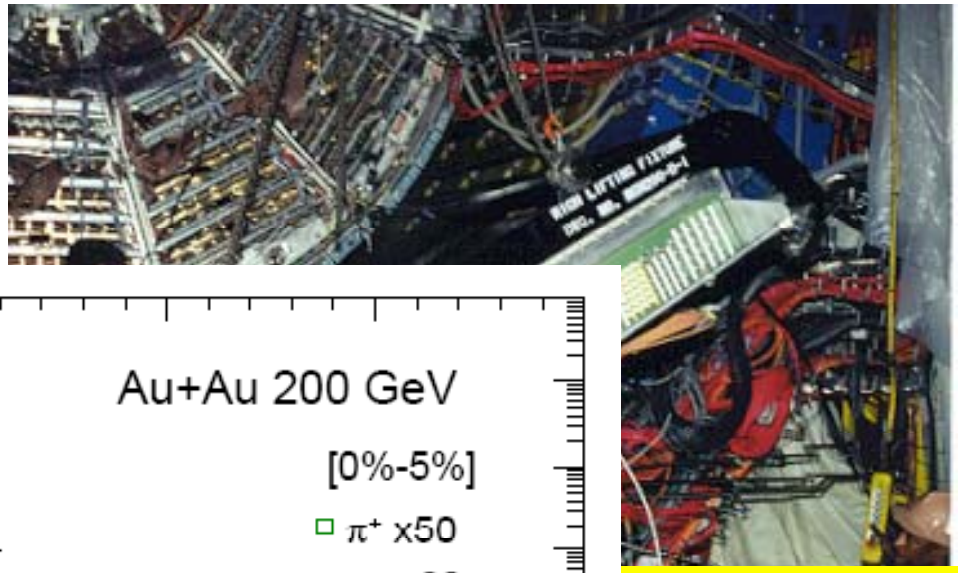
PHOS $PbWO_4$
cooled with a household freezer



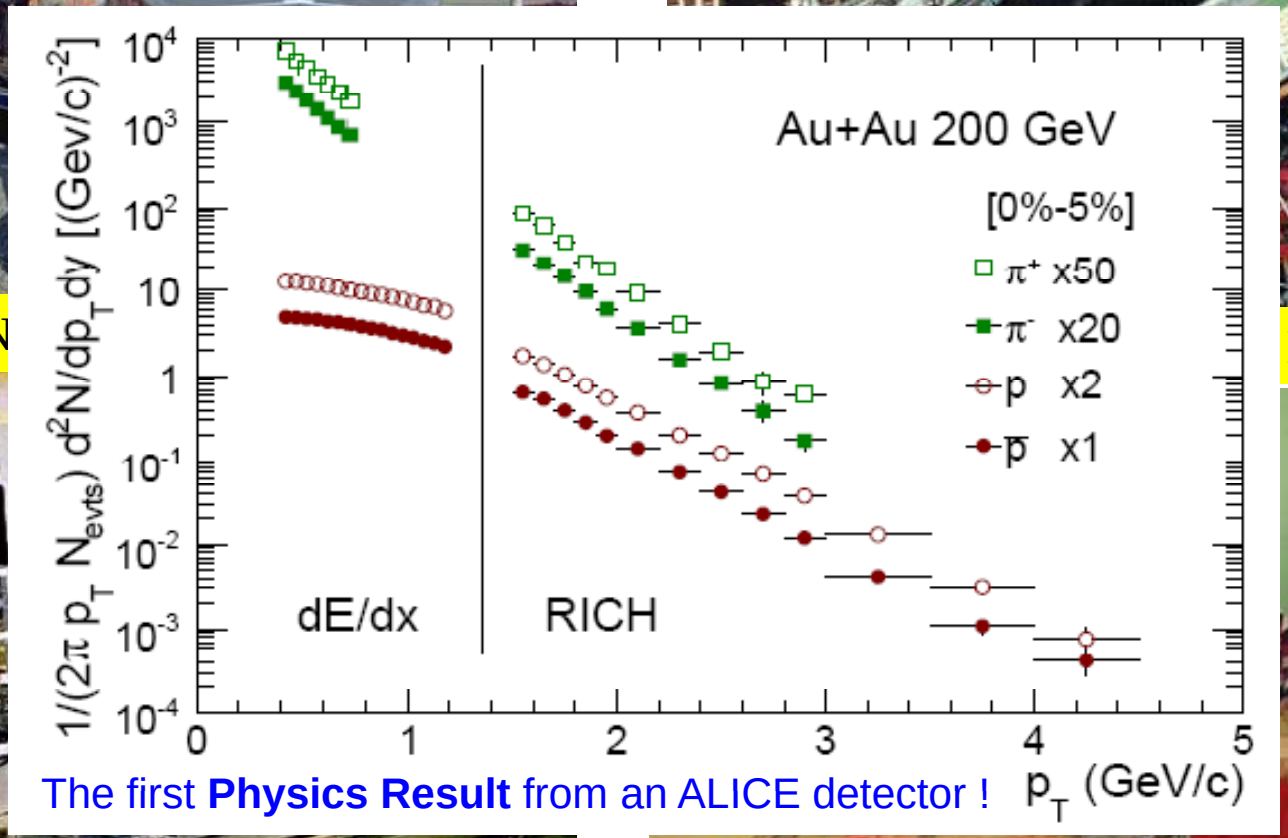
RICH proto-2: Sabbatical at RHIC



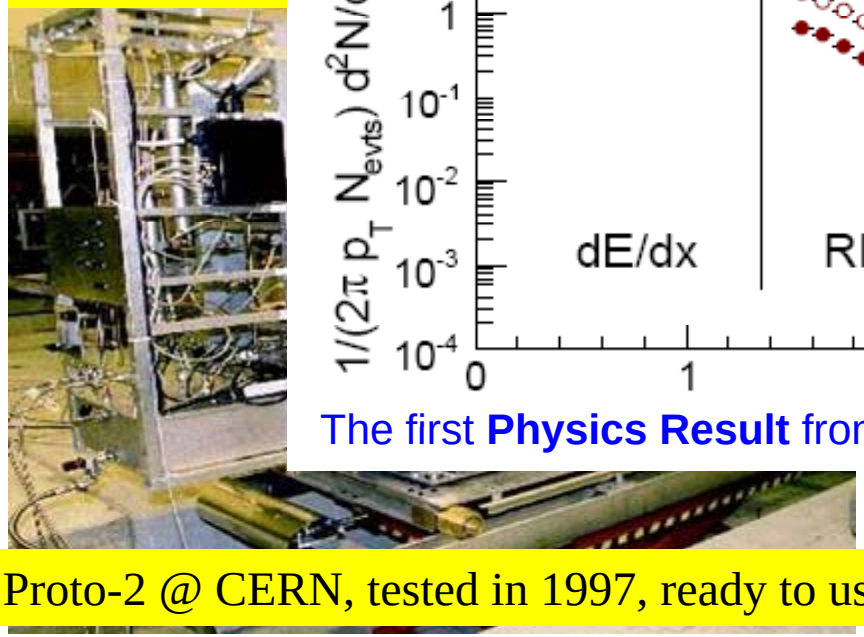
Arrival at BN



November 1999



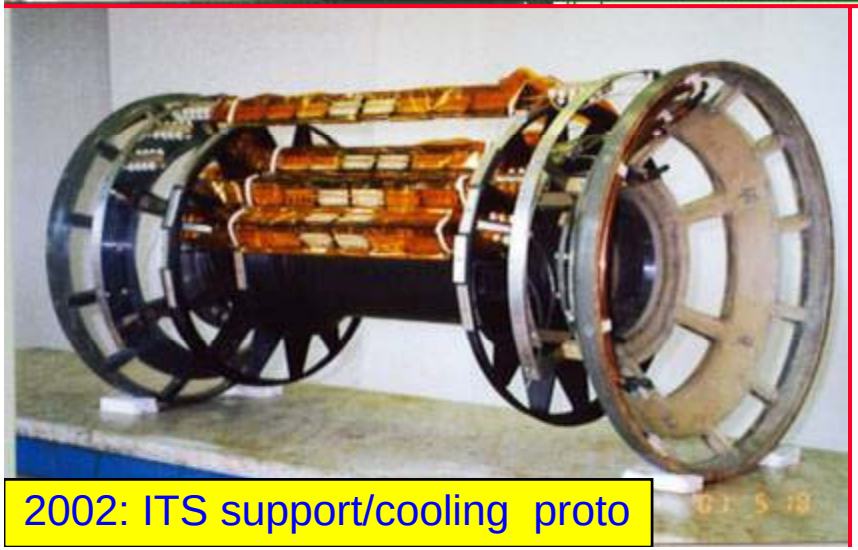
The first **Physics Result** from an ALICE detector !

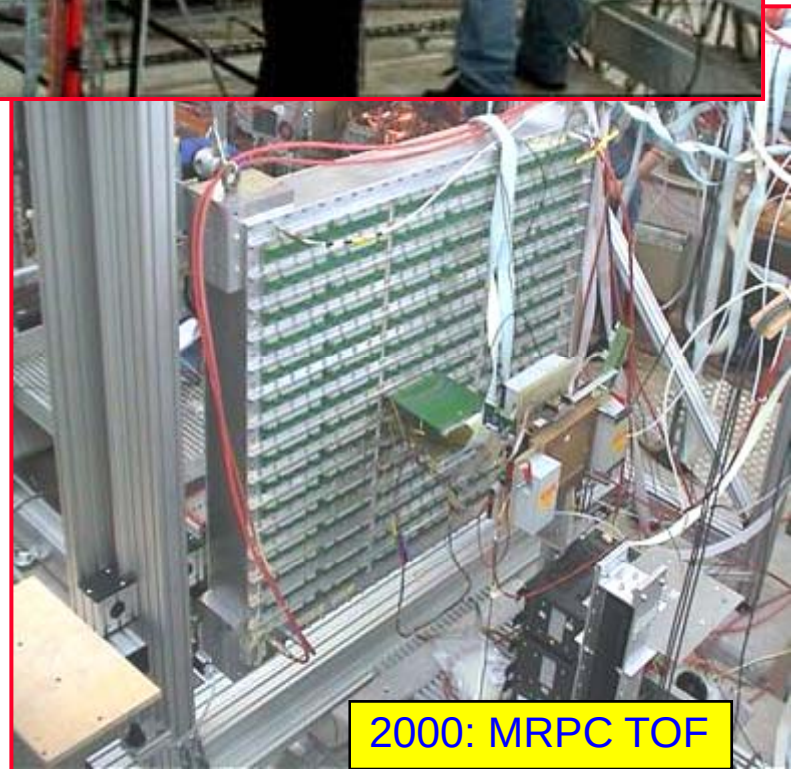


Proto-2 @ CERN, tested in 1997, ready to use

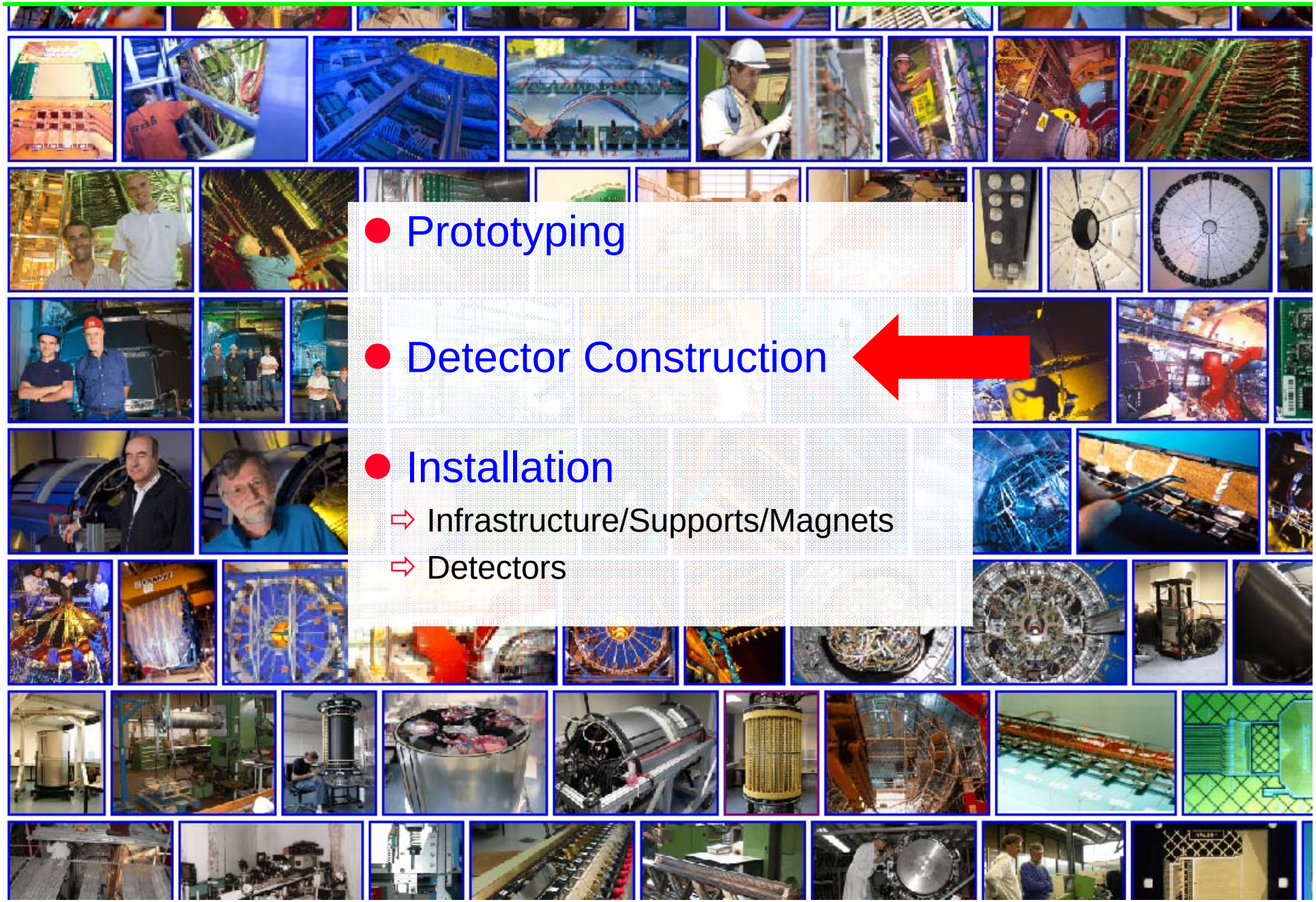
July 2002: Back home again

Full Size Prototypes





ALICE in Pictures



- Prototyping
- Detector Construction
- Installation
  - ⇨ Infrastructure/Supports/Magnets
  - ⇨ Detectors

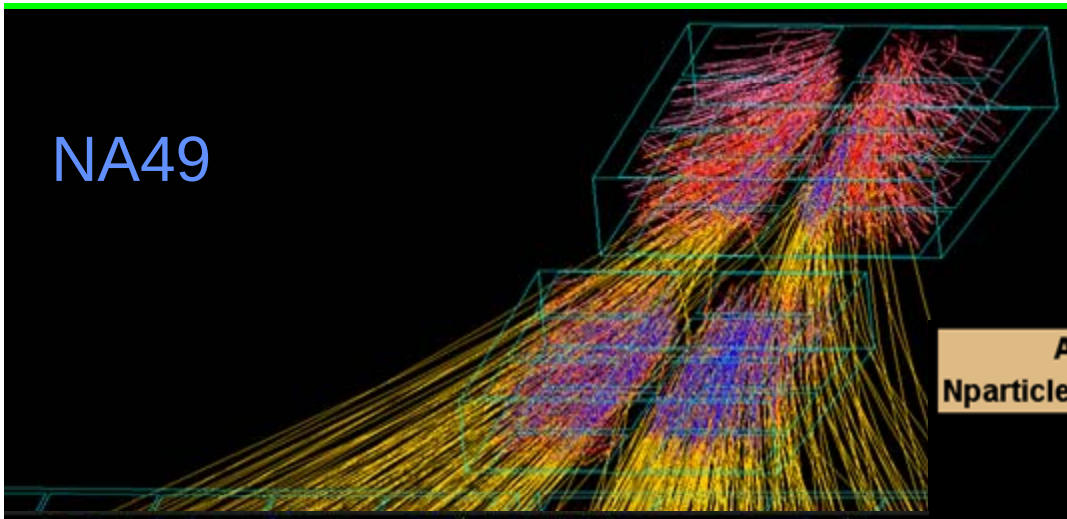
Production Start in 2000

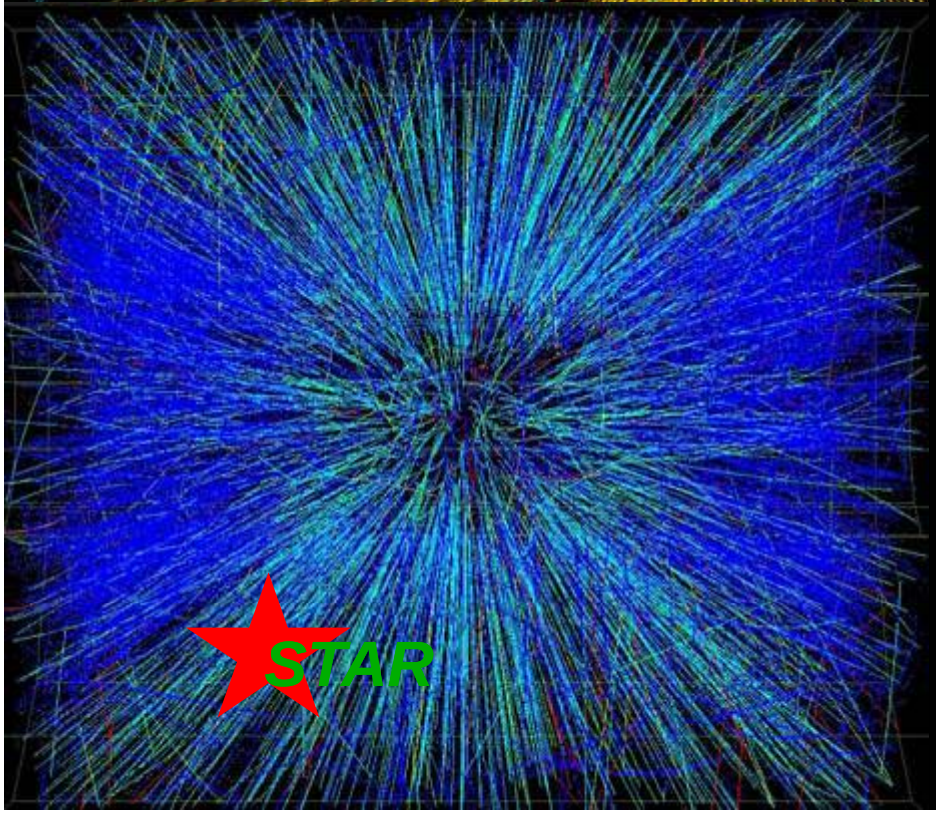
2000: C-fiber ladders for ITS (St. Petersburg)

First production item actually installed in ALICE

Quality Assurance Test:
Deformation < 200 µm under load of 1 kg

Tracking Challenge

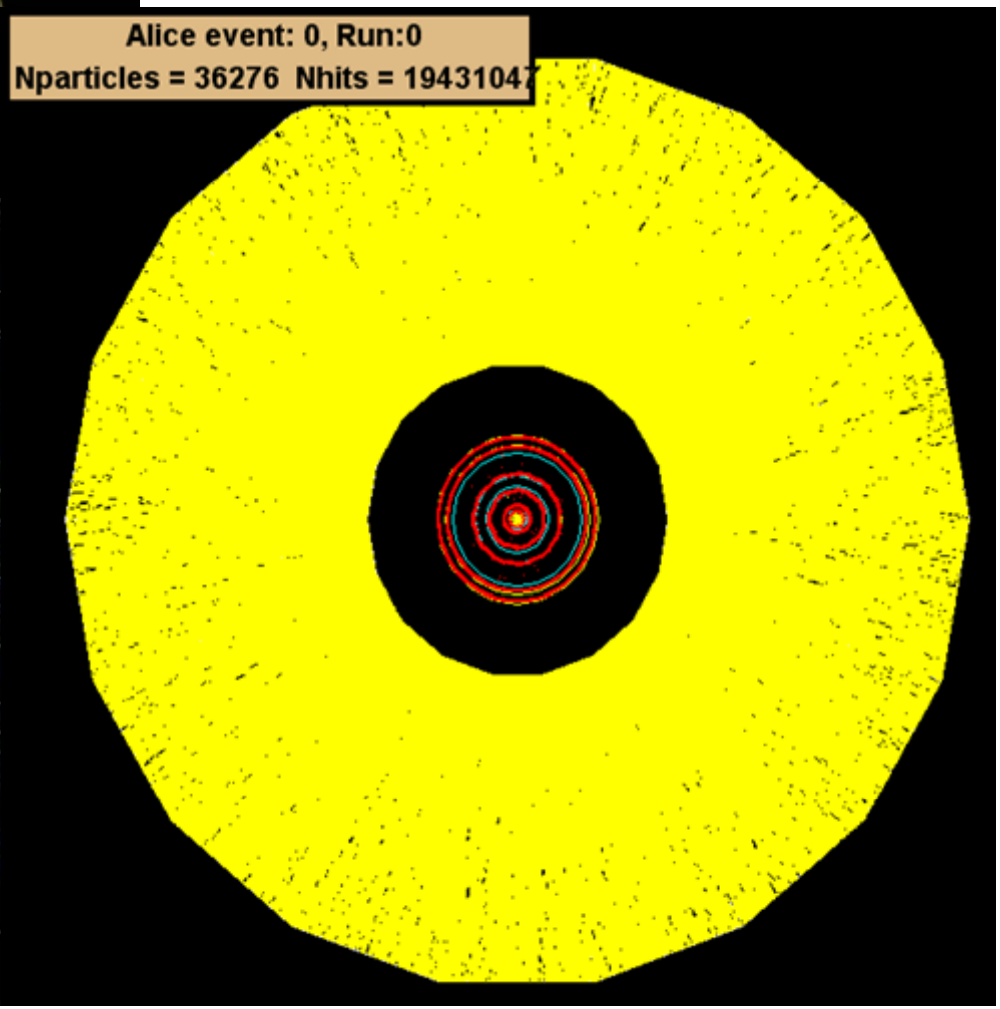




LHC: dN_{ch}/dy = 2000 - 4000

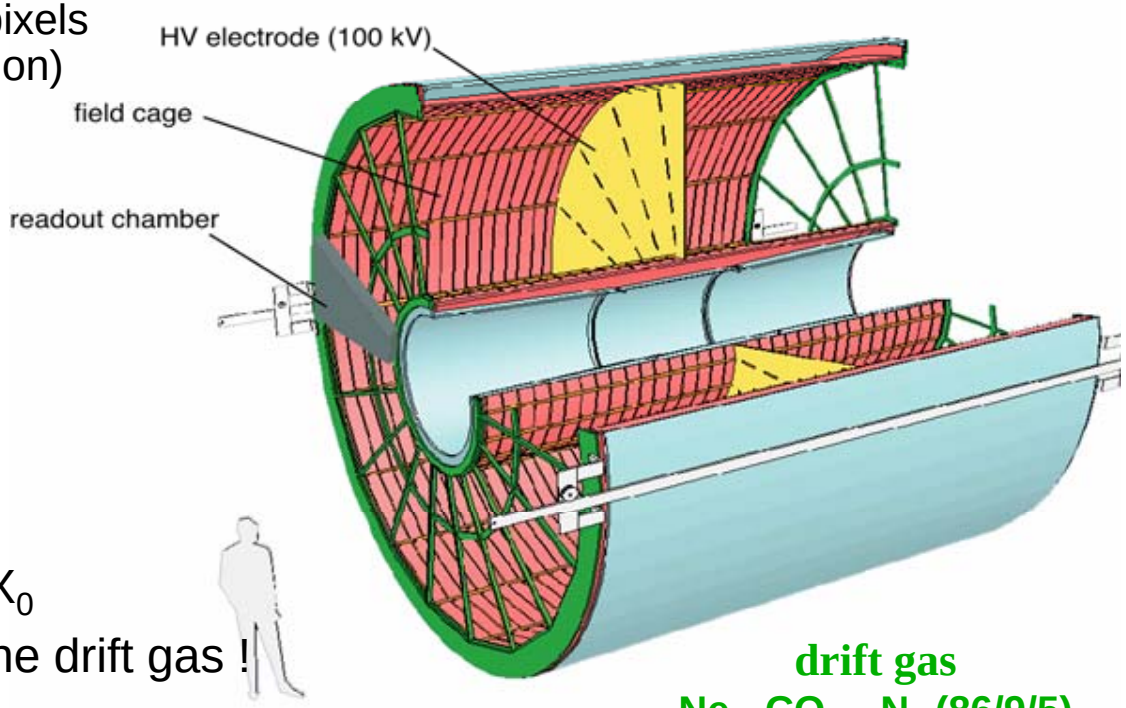
ALICE 'worst case' scenario:

dN_{ch}/dy = 8000



TPC – at the Heart of ALICE

- largest TPC
  - ⇨ l = 5 m, Ø = 5.6m, ~90 m^3, ~ 20 tons
    570 k channels, 500 x 10^6 space-time pixels
    up to 80 Mbyte/event (after 0 suppression)



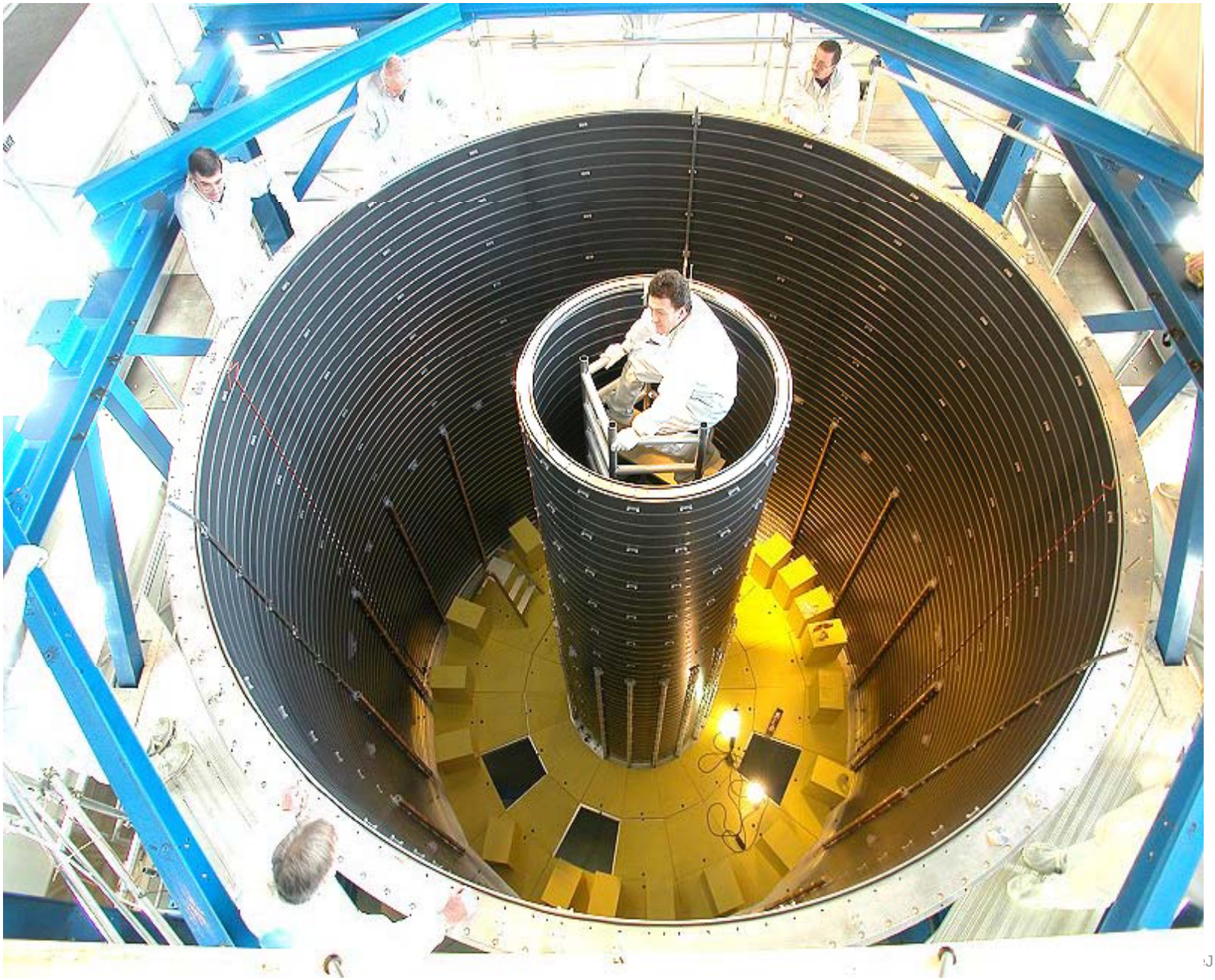
drift gas
Ne - CO_2 – N_2 (86/9/5)

- novel features
  - ⇨ very thin & lightweight FC ~3% X_0
    - ✪ ~3 mm Al, only 5x more than the drift gas !
    - ✪ very delicate & fragile
  - ⇨ high track density & small space charge
    - ✪ drift gas, chamber lay-out, field strips, ..
    - ✪ HV=100 kV (400V/cm), temperature sensitive $\Delta t < 0.1^0$ C
  - ⇨ novel digital electronics (ALTRO)
    - ✪ highly integrated, digital shaping + many other features

TPC

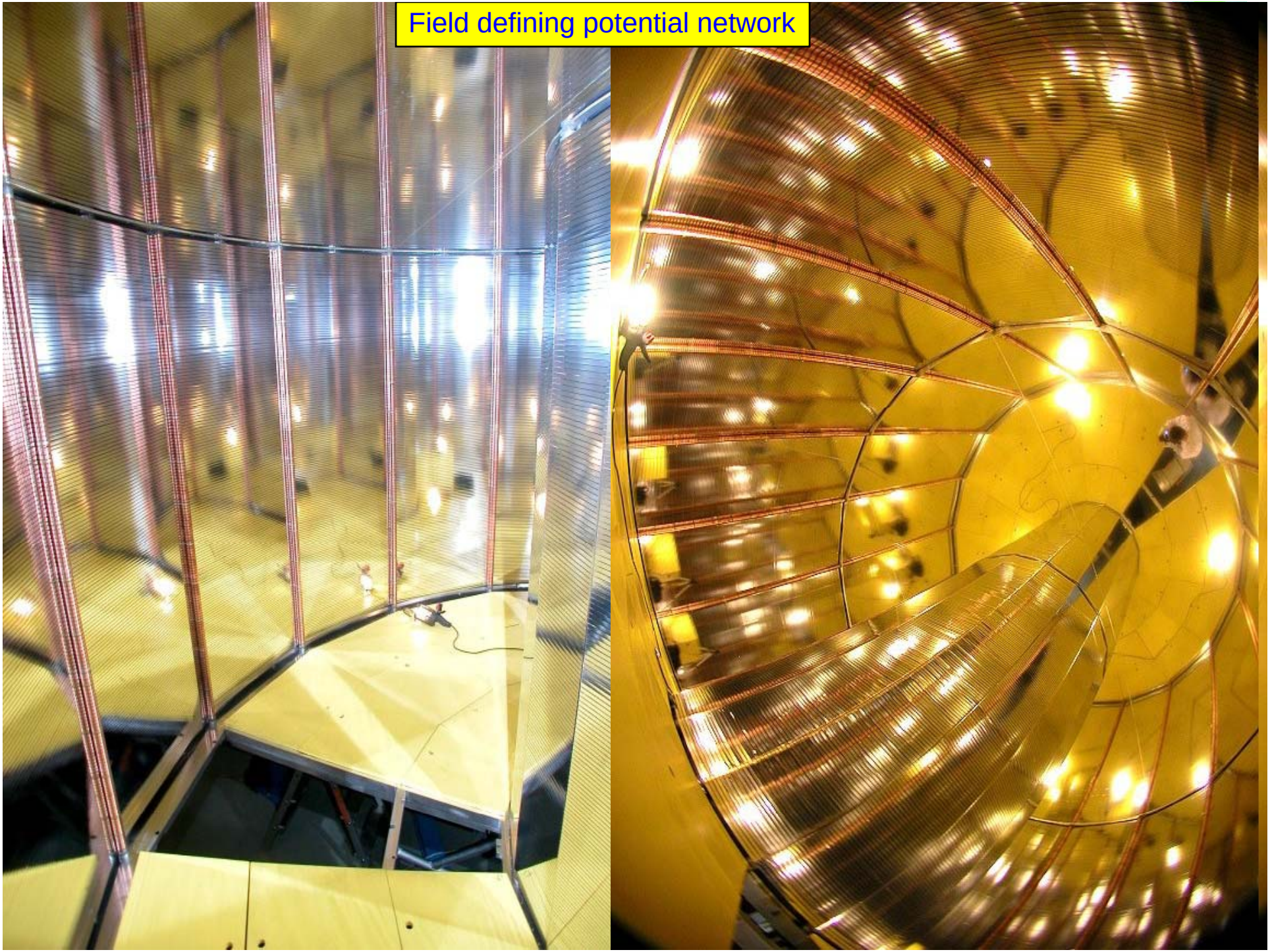
2002-2006: ~ 5 years of
TPC Construction & Assembly
single unique piece, 'artisan' production

TPC Field Cage



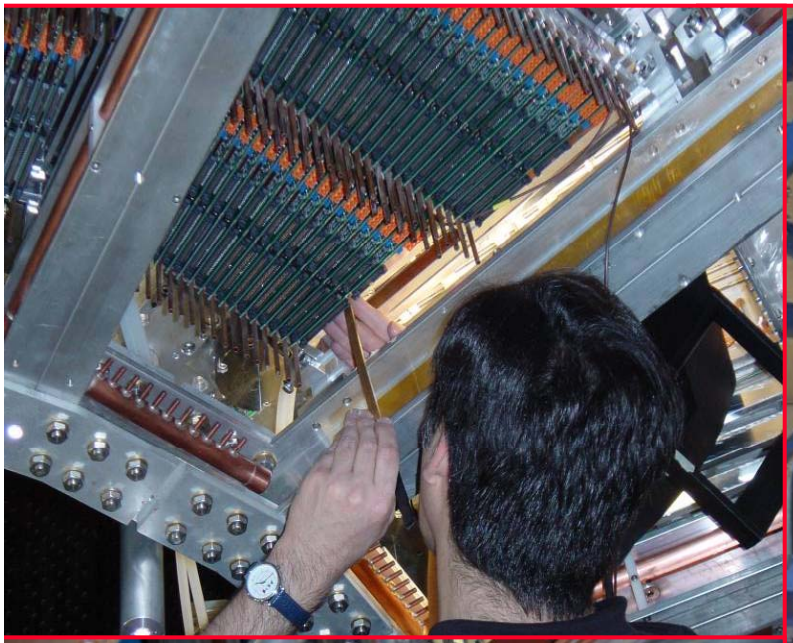

Inserting central membrane
100 μm alumised Mylar

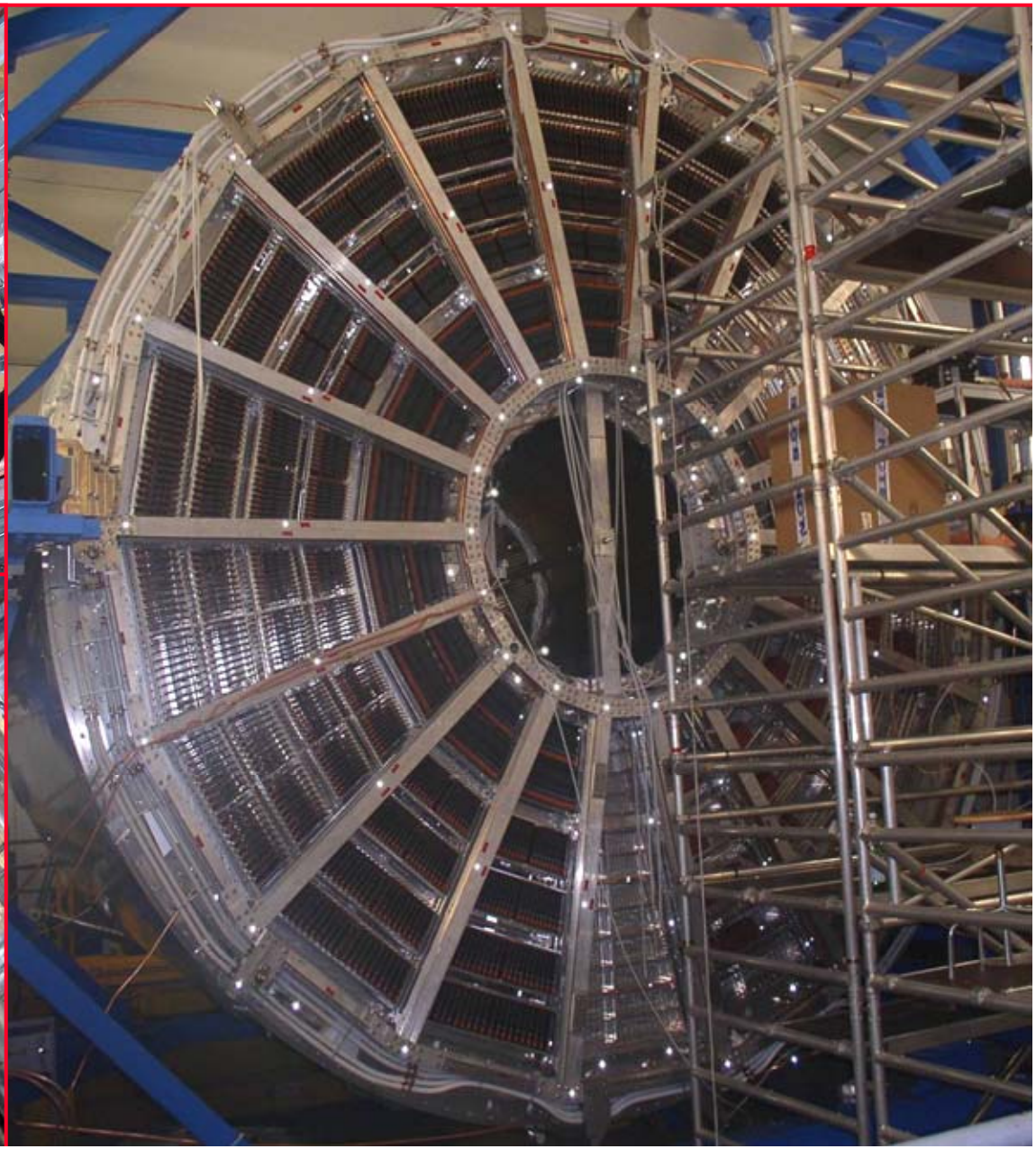
Field defining potential network

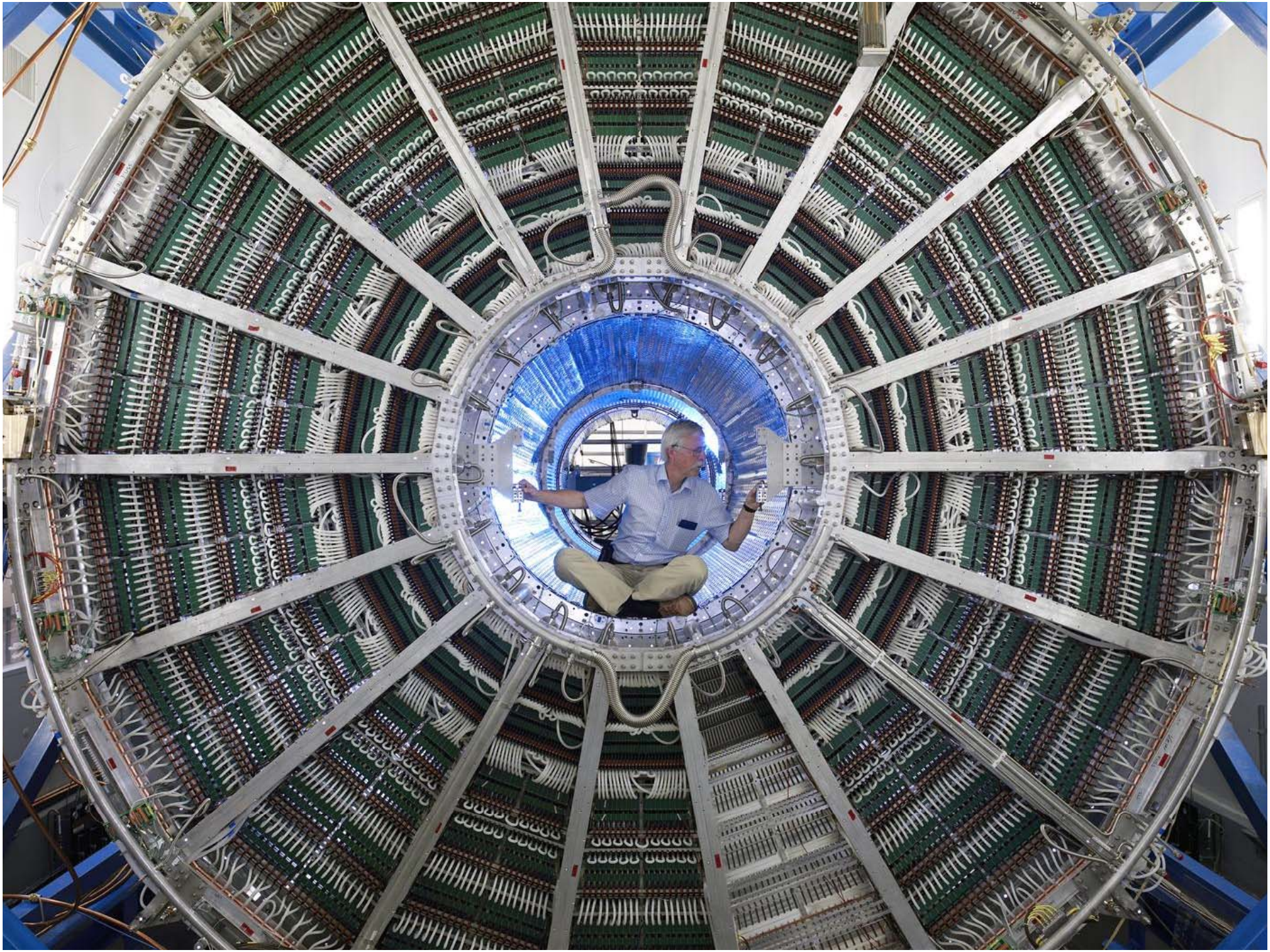


TPC Chambers

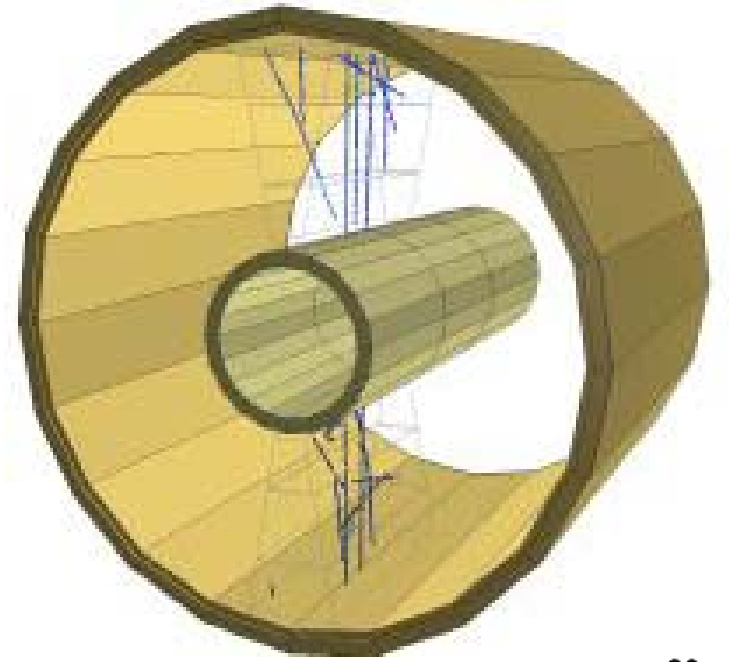
FEE installation





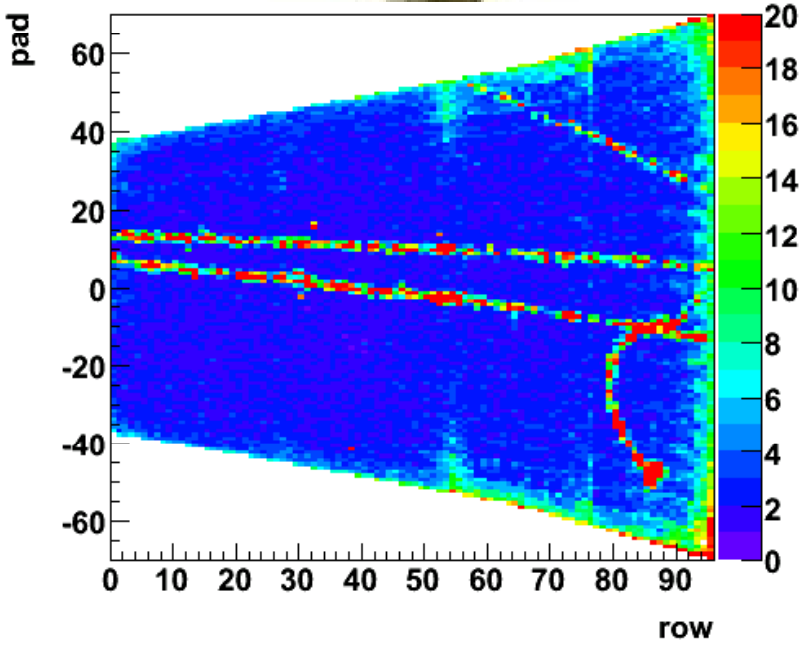


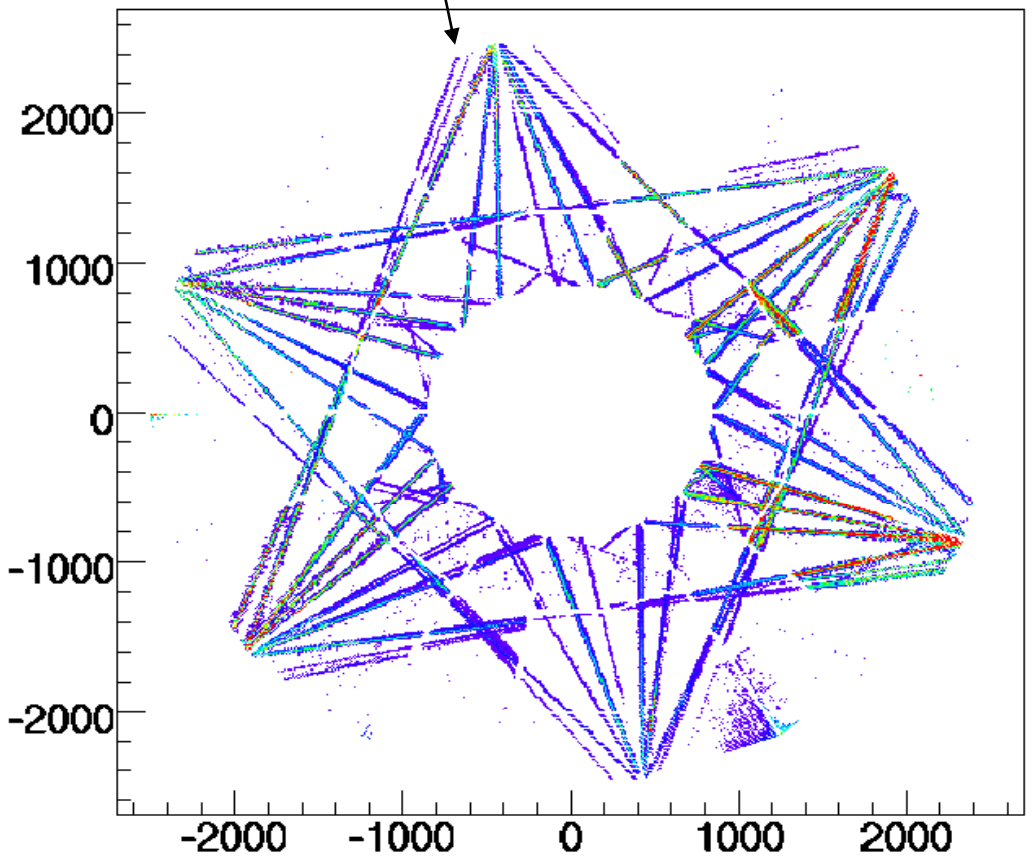
First TPC Tracks

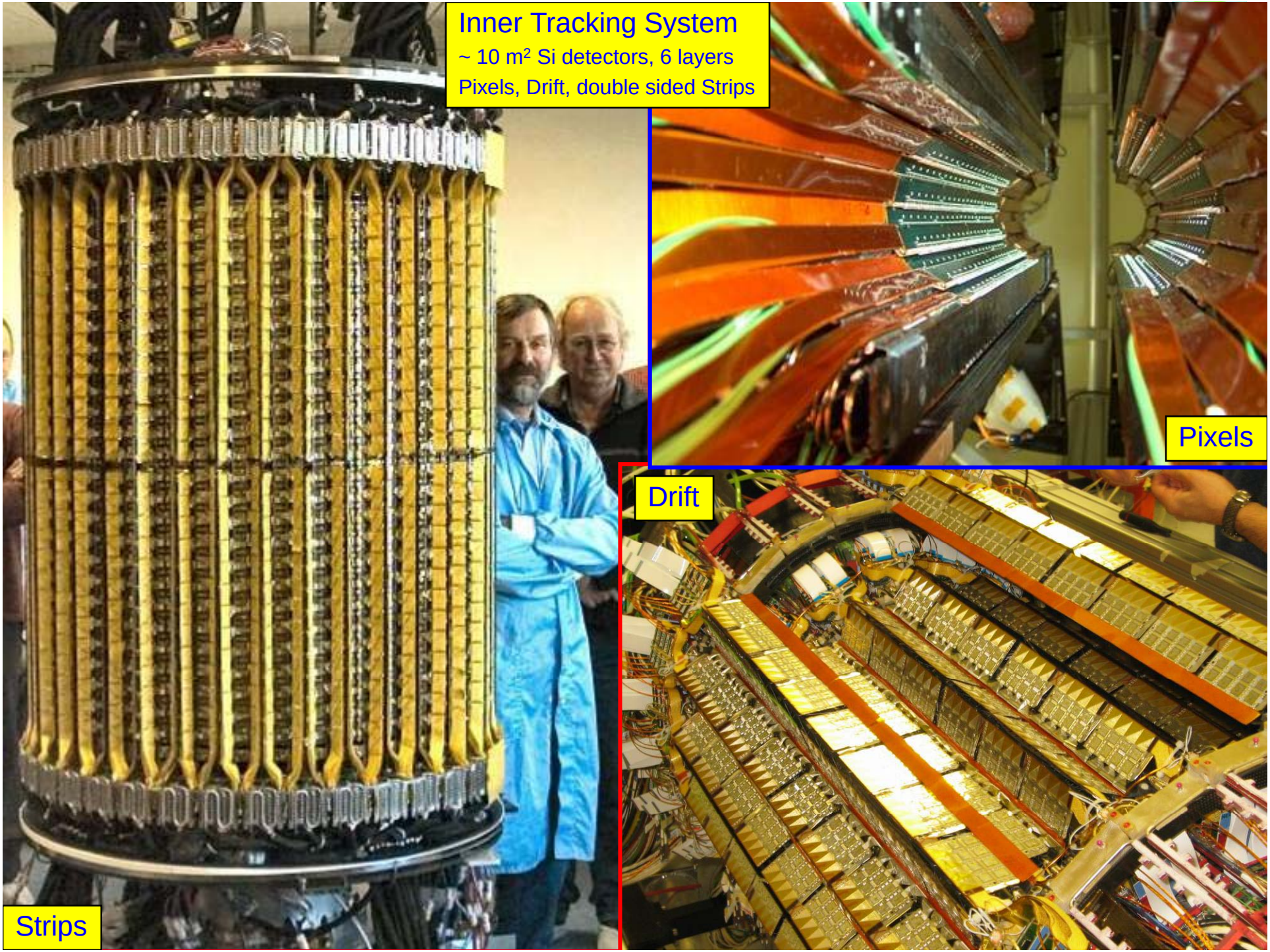


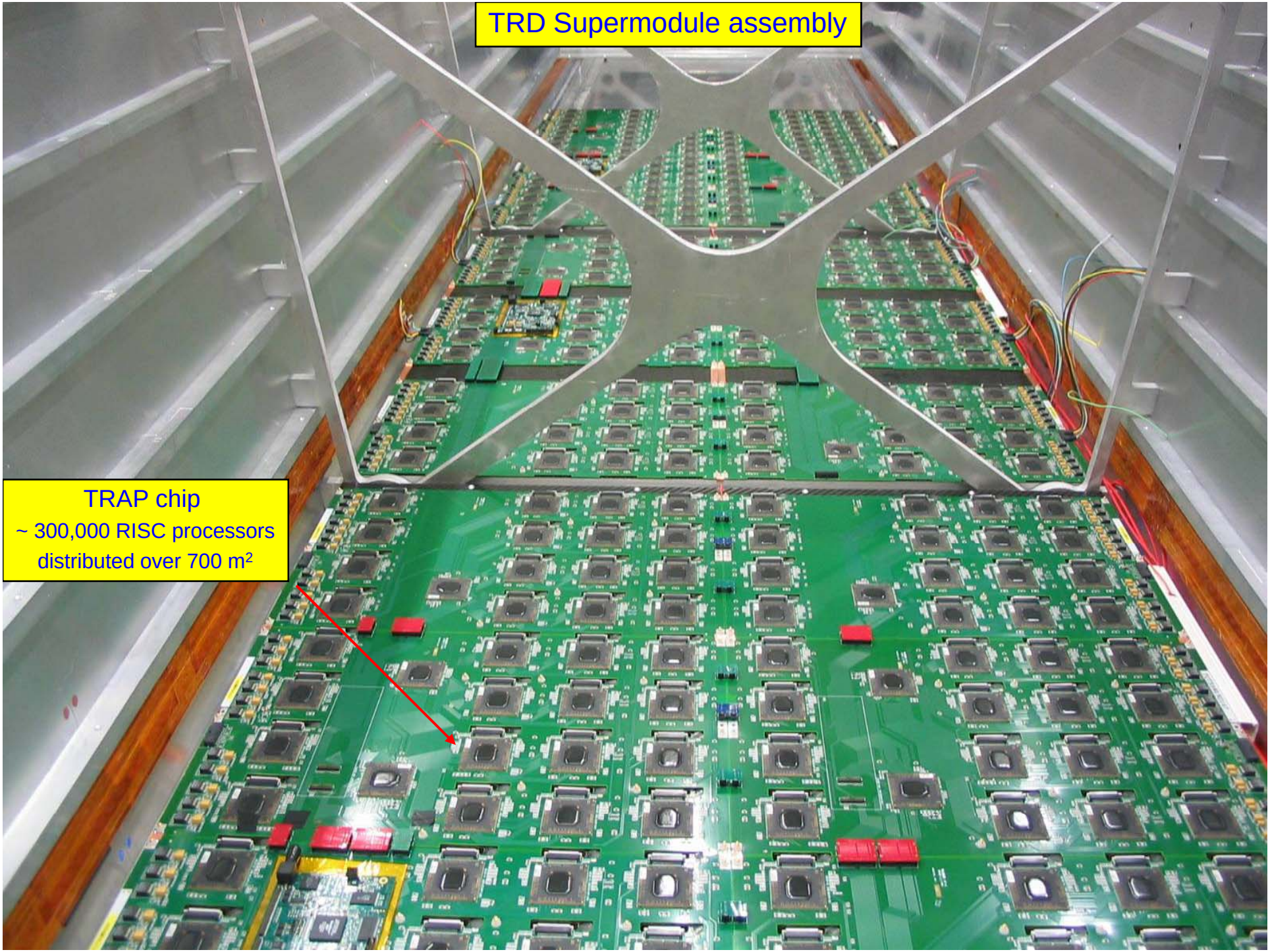
16 May 2006

First cosmic and laser tracks !

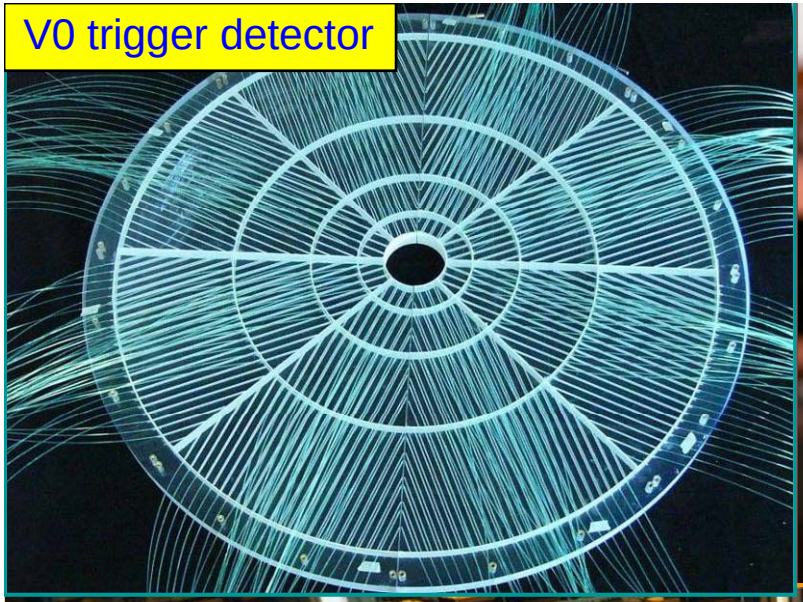


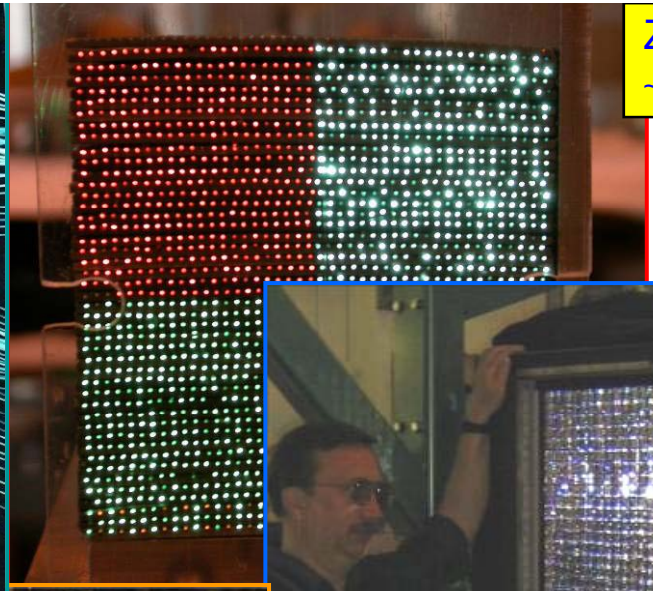



Inner Tracking System
~ 10 m² Si detectors, 6 layers
Pixels, Drift, double sided Strips
Pixels
Drift
Strips


TRD Supermodule assembly
TRAP chip
~ 300,000 RISC processors
distributed over 700 m²

V0 trigger detector





Zero Degree Calorimeter

~ 100 m in the machine tunnel

PHOS module

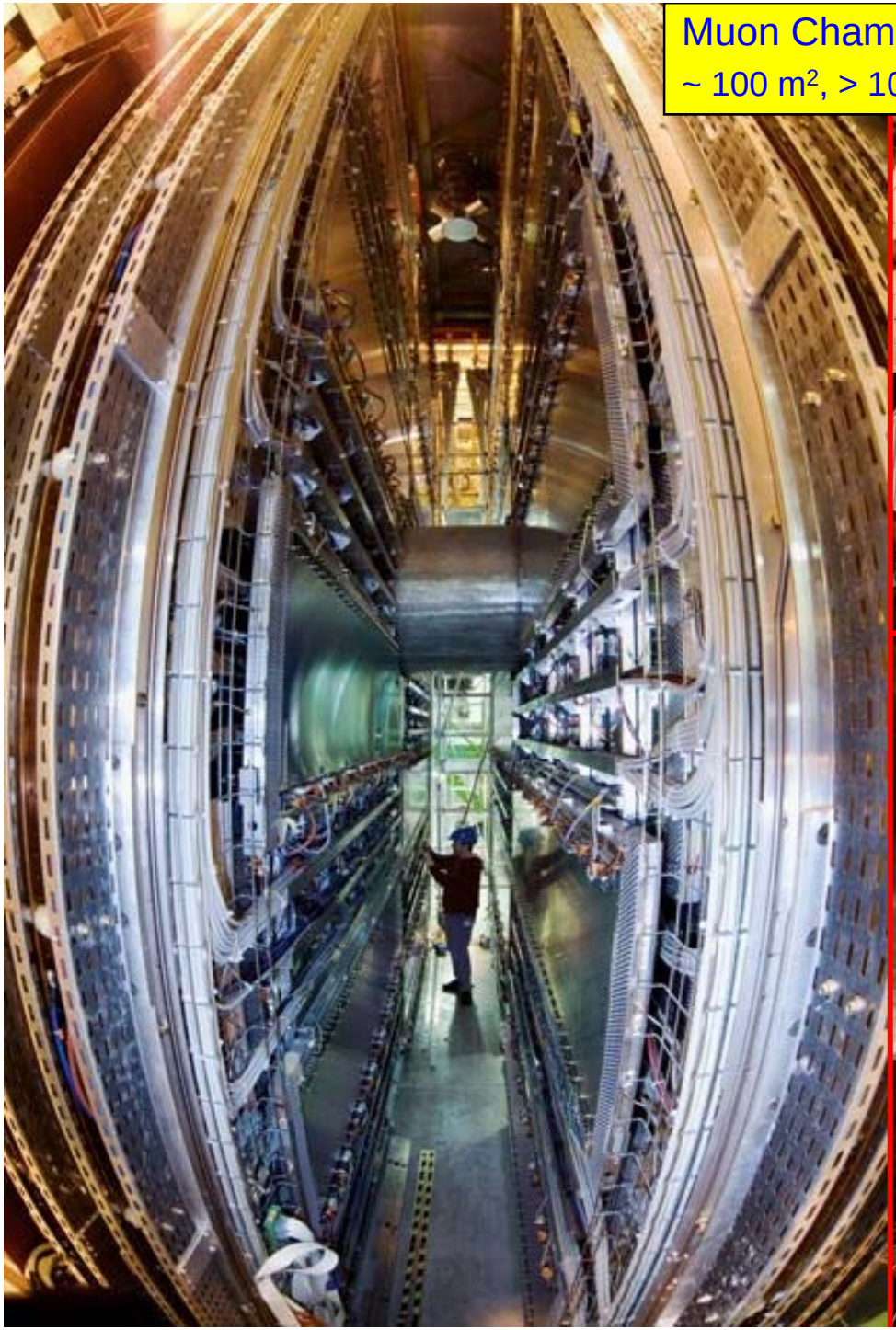
~ 20,000 $PbWO_4$ crystals

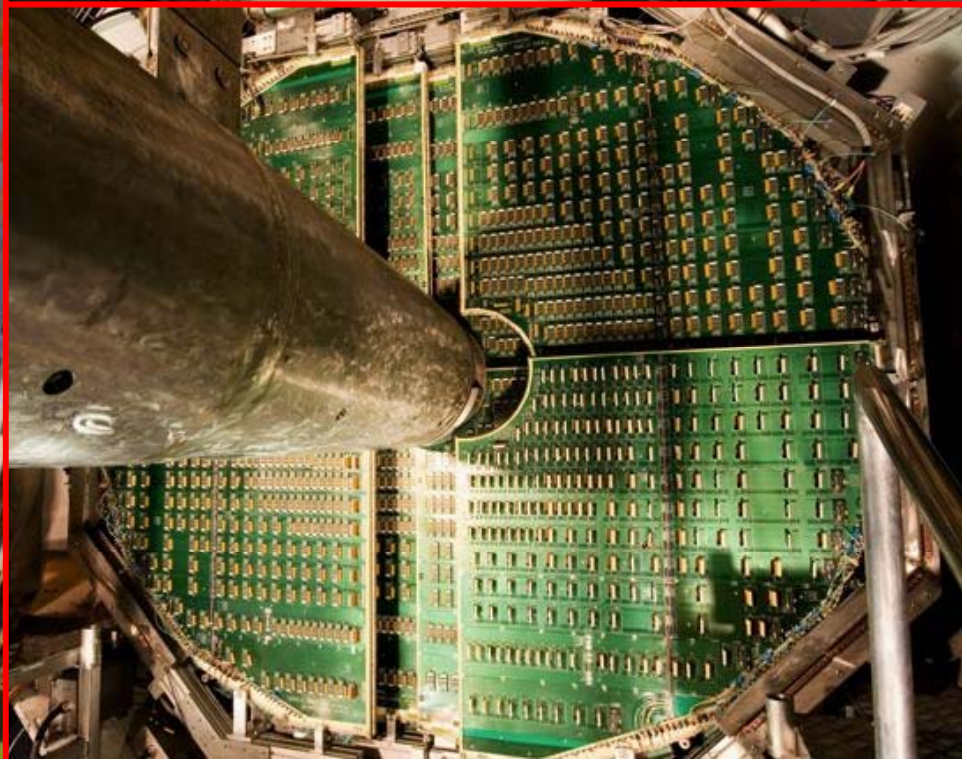
TOF strip production

~ 150 m^2, 150,000 channels

Muon Chambers

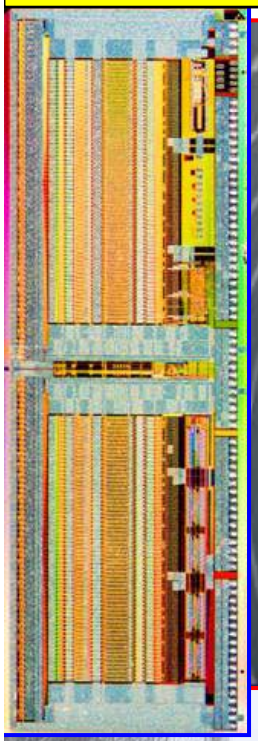
~ 100 m^2, > 10^6 channels





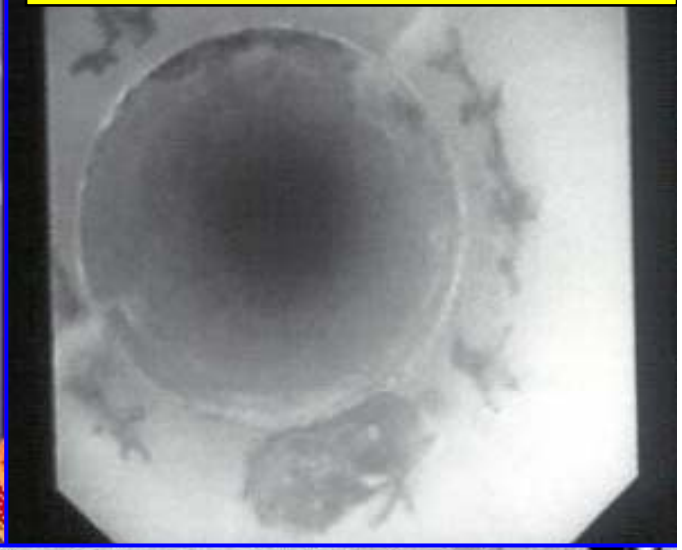
Worries & Mishaps ..

2002: FEE production problems ~ 1 year
several ALICE/Alas chips in 0.25 μ rad hard technology



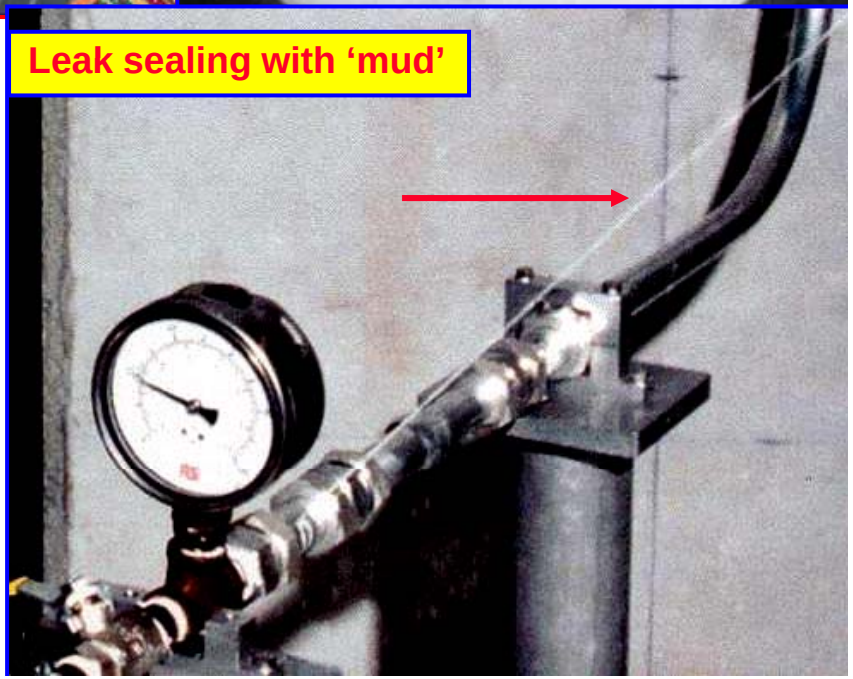
2003: TPC inner FC leaking
inner vessel had to be remade

2002: Corrosion in L3 cooling circuits
endoscope picture



2003: Transport of μ-magnet iron
delayed by 10 months ! (transport > construction)

Leak sealing with 'mud'



Landslides and other Disasters

2007: Landslide closed the Mt Blanc tunnel

~~2 days before transport of emcal frame => several weeks delay~~

2004/5: Political Landslide in Ukraine

almost closed the microcable production plant in Kharkov

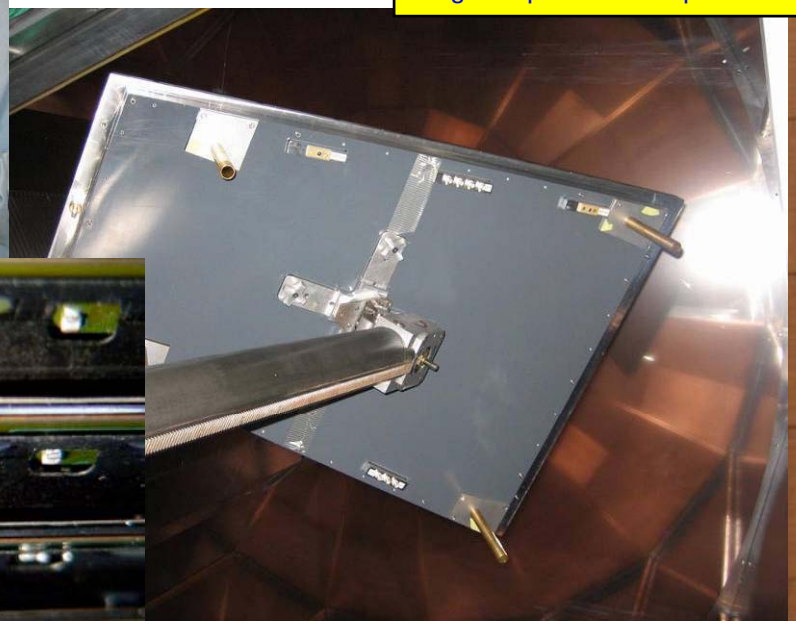
2006: SPD is feeling the heat…

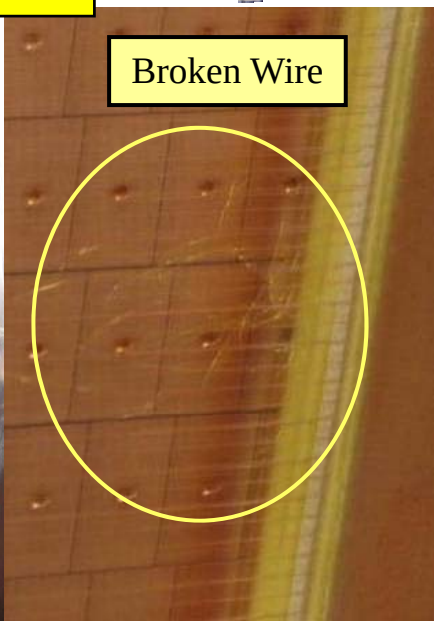
March: Fire in SPD production clean room

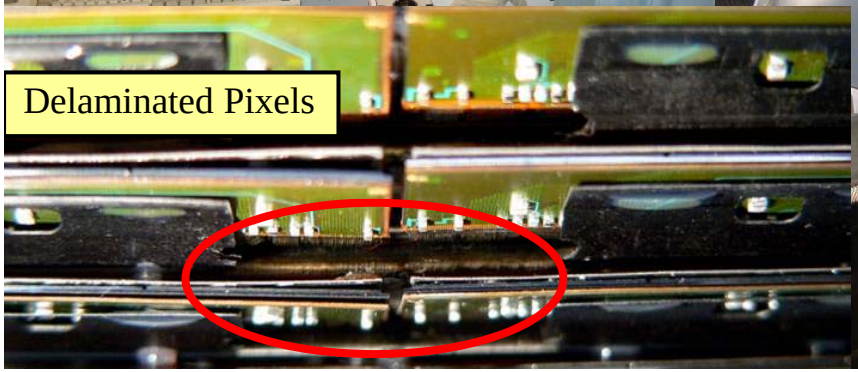
May: delamination of sector by overheating

2006: Broken wire in TPC

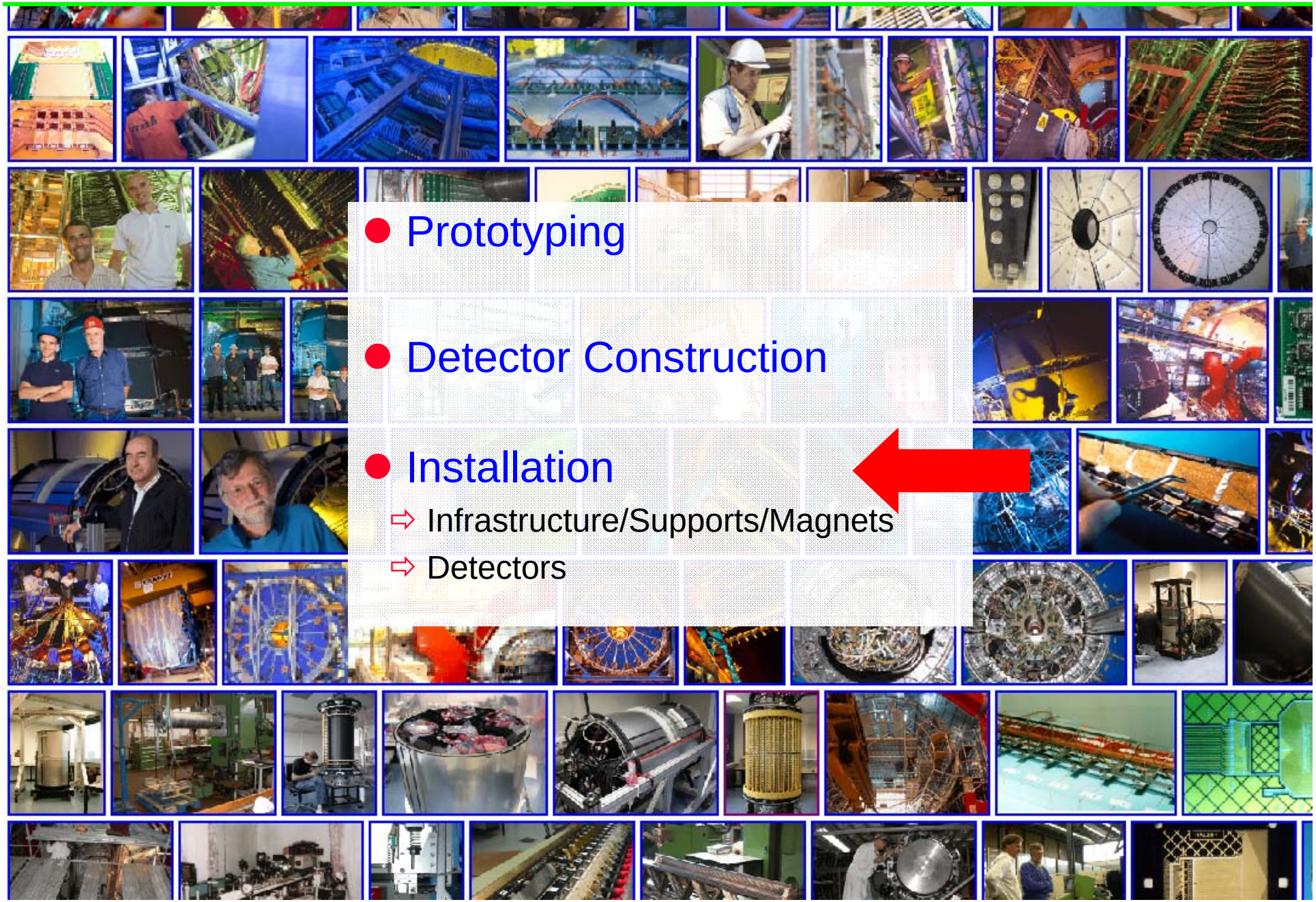
surgical operation to replace chamber







ALICE in Pictures



- Prototyping
- Detector Construction
- Installation
  - ⇨ Infrastructure/Supports/Magnets
  - ⇨ Detectors

Spring Cleaning in 2001


The ALICE
magnet end 2001:
ready for the experiment to move in!

Installation of Large Structures

2002: Modifying L3 doors

Nov 2007: EMCAL support

Installation of Large Structures


29 Nov 2007: Descent of the last big structure

Transport & Heavy Handling

movement of multi-ton objects with millimeter precision

March 2004: Permanent closure of back doors

now blocked by muon spectrometer

Muon Magnet Coils

and barely over L3 …

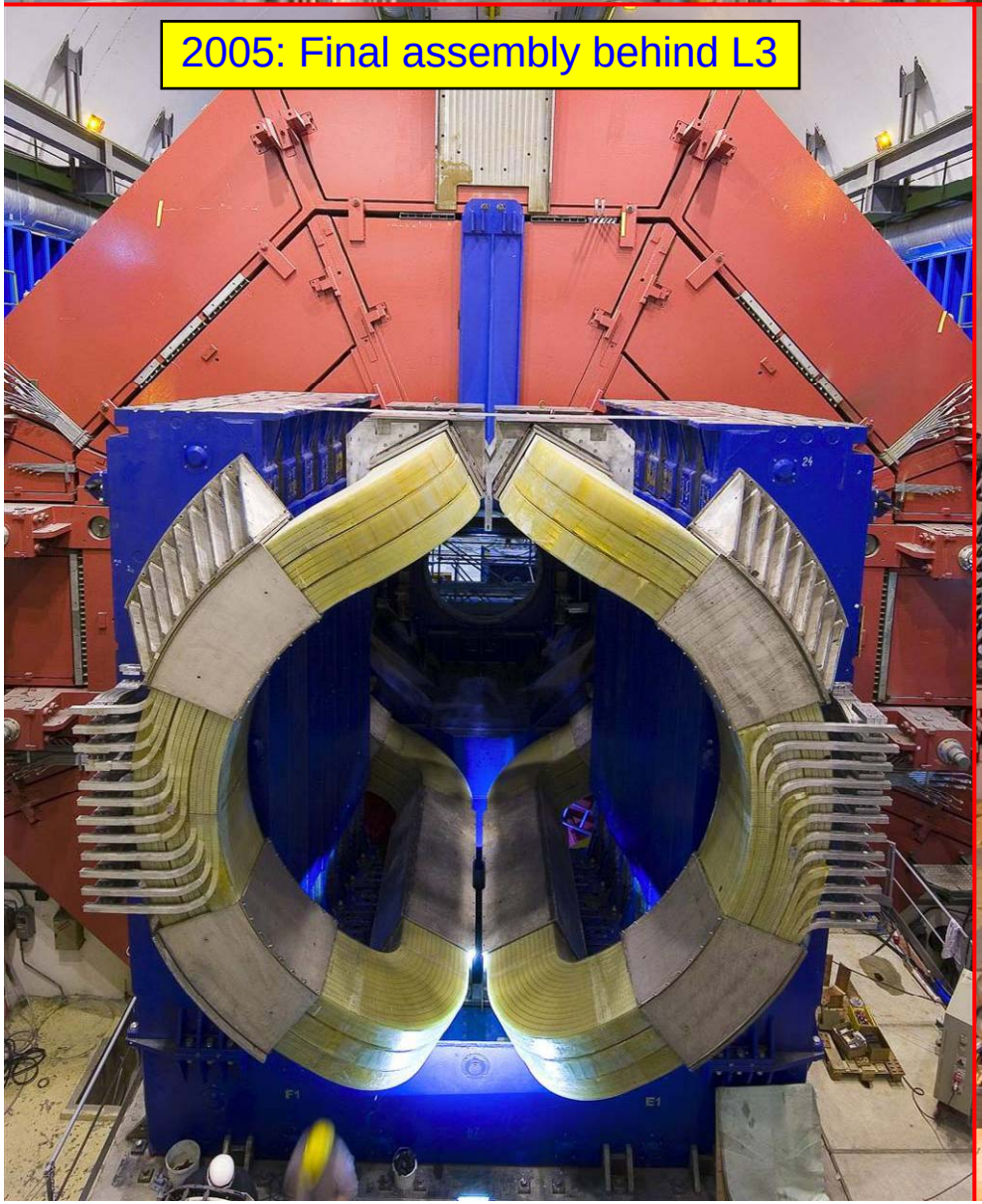
fitting barely under the bridge..

Sept 2003: Arrival of Dipole Coils after ‘Tour de France’

Muon Magnet

2002: Yoke assembly in Dubna

2005: Final assembly behind L3

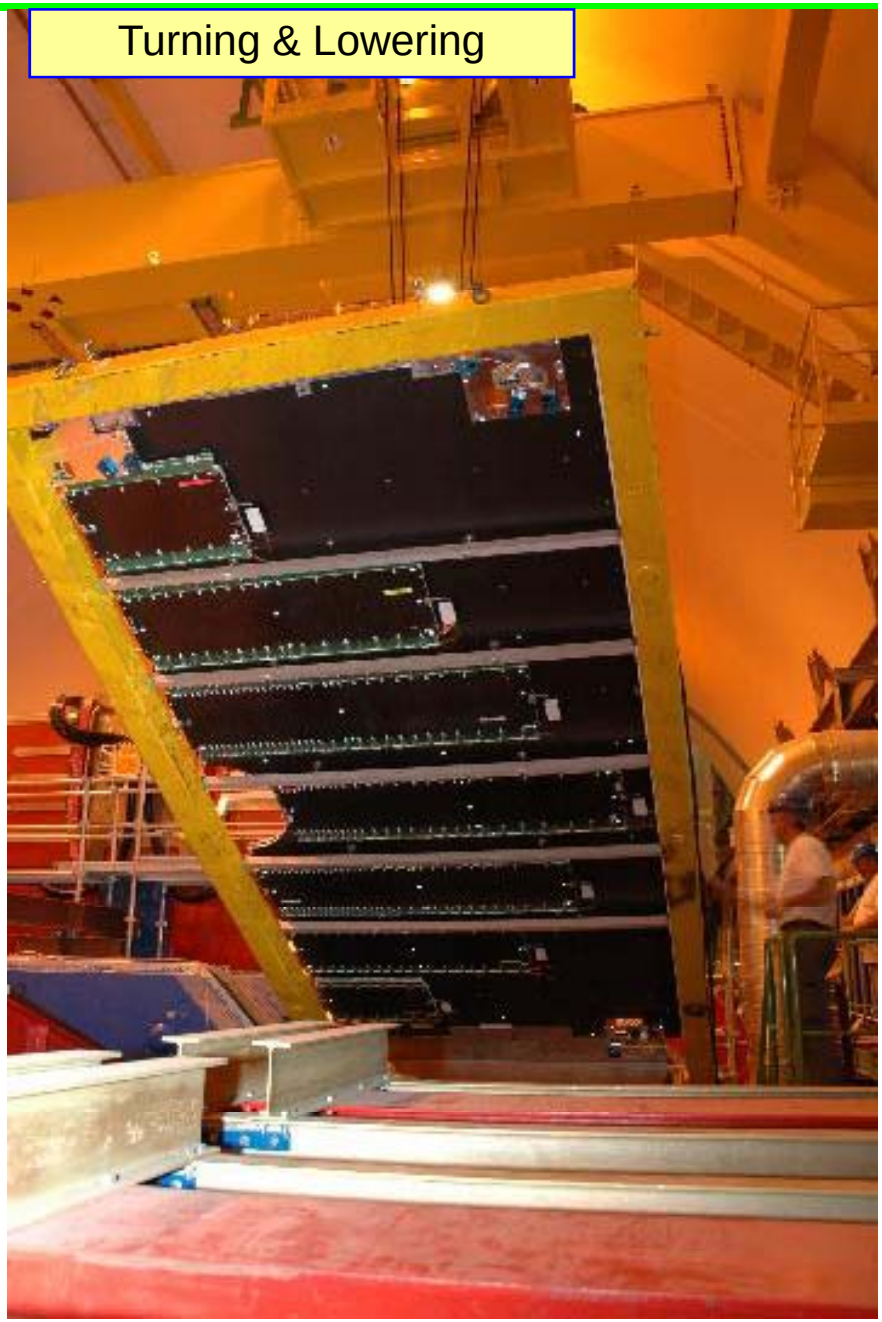


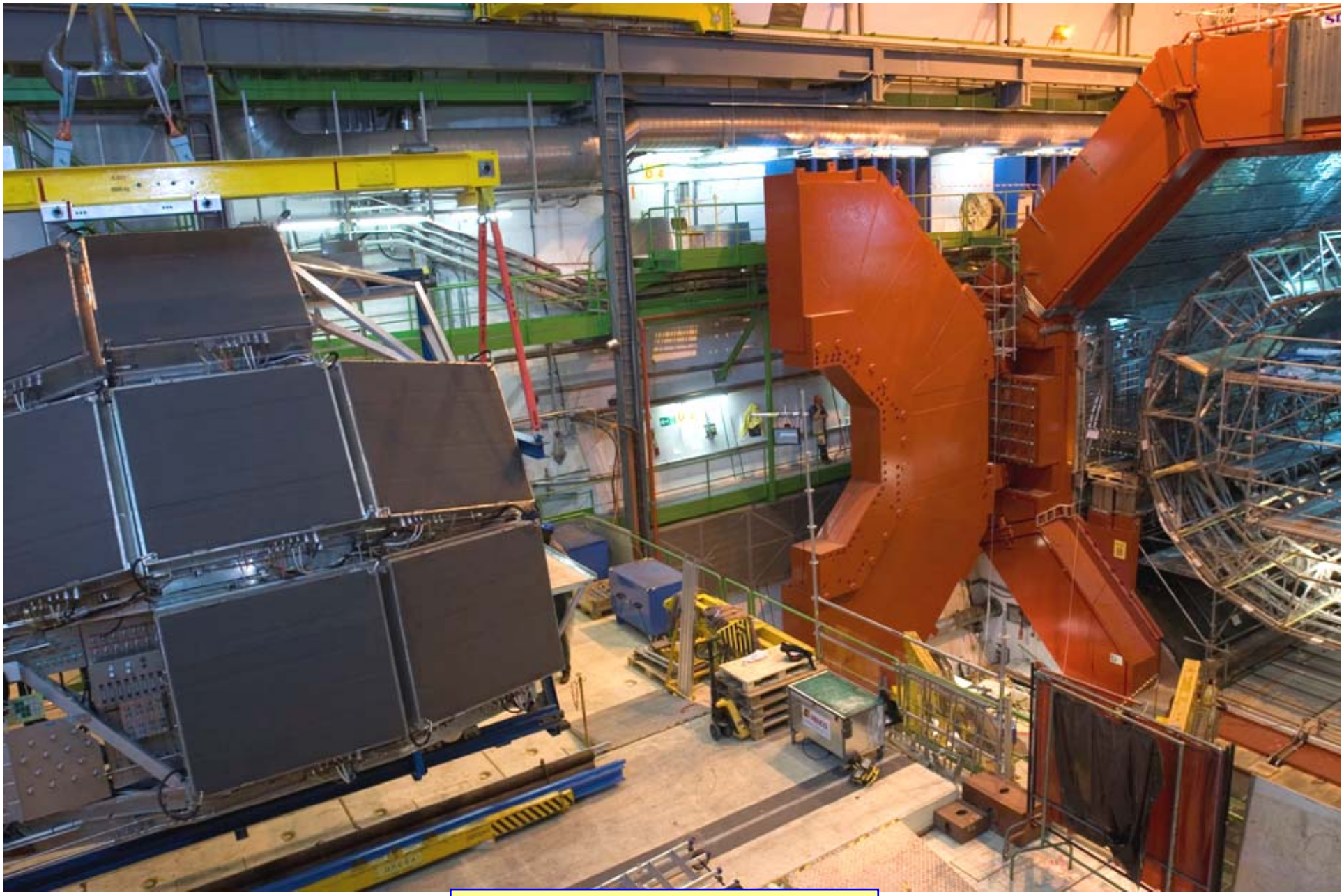
2004: Test assembly in front of L3

Muon Tracking Chambers (July 06)

Transport across L3 magnet

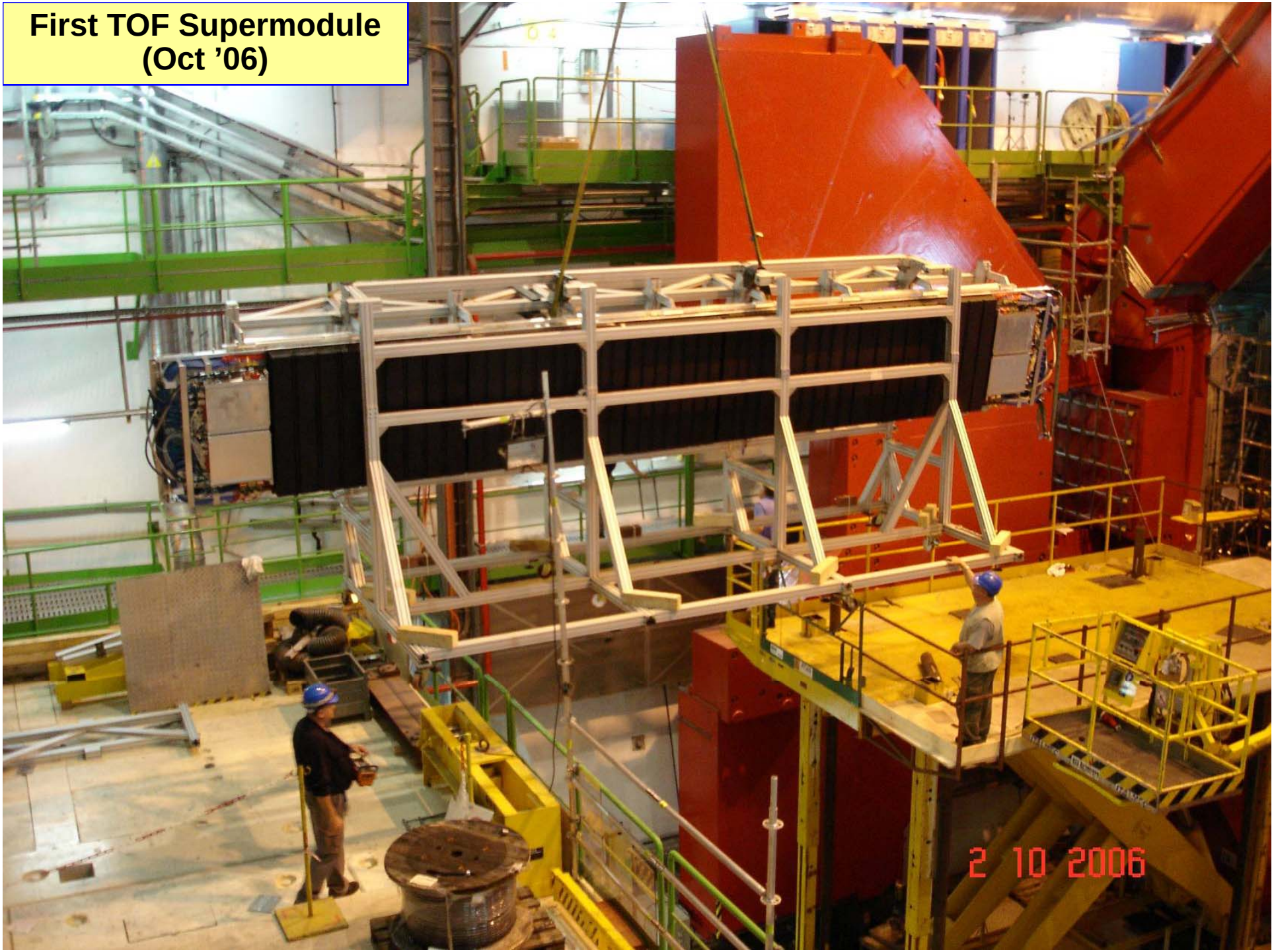
Turning & Lowering

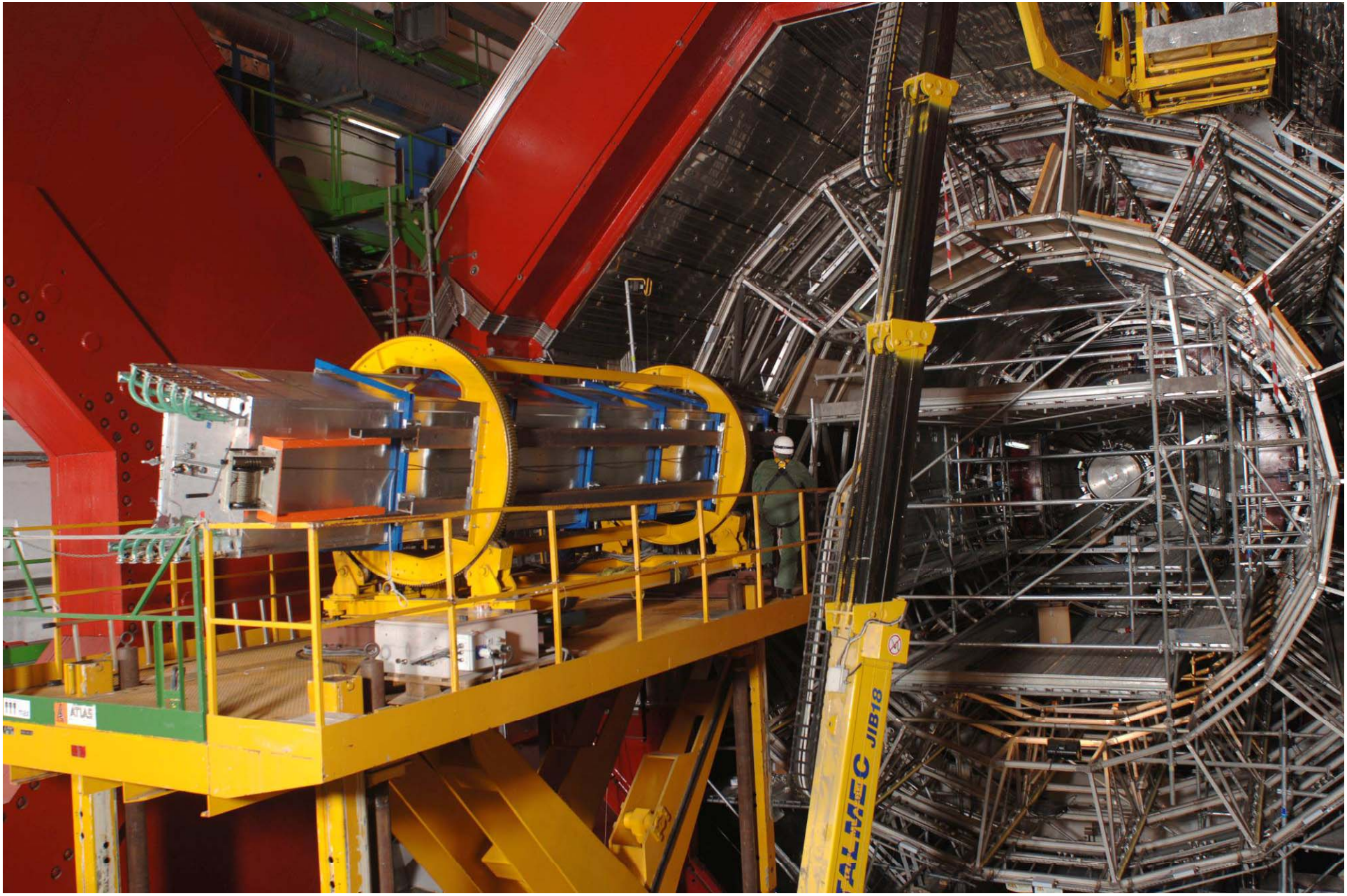




HMPID (Sept ’06)

First TOF Supermodule (Oct '06)

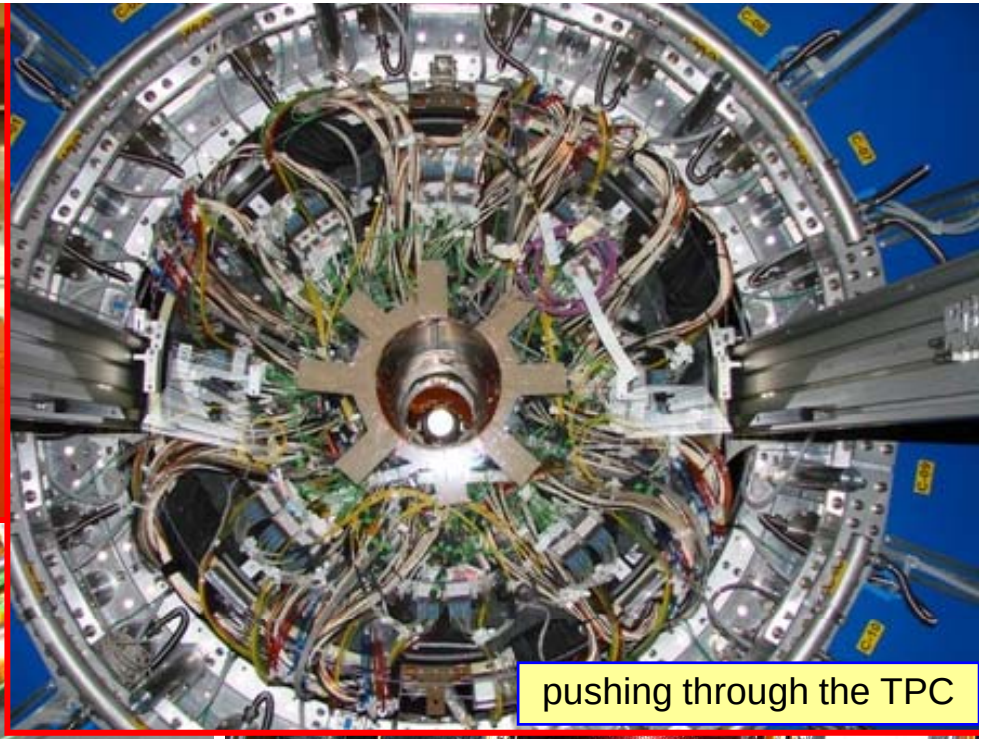




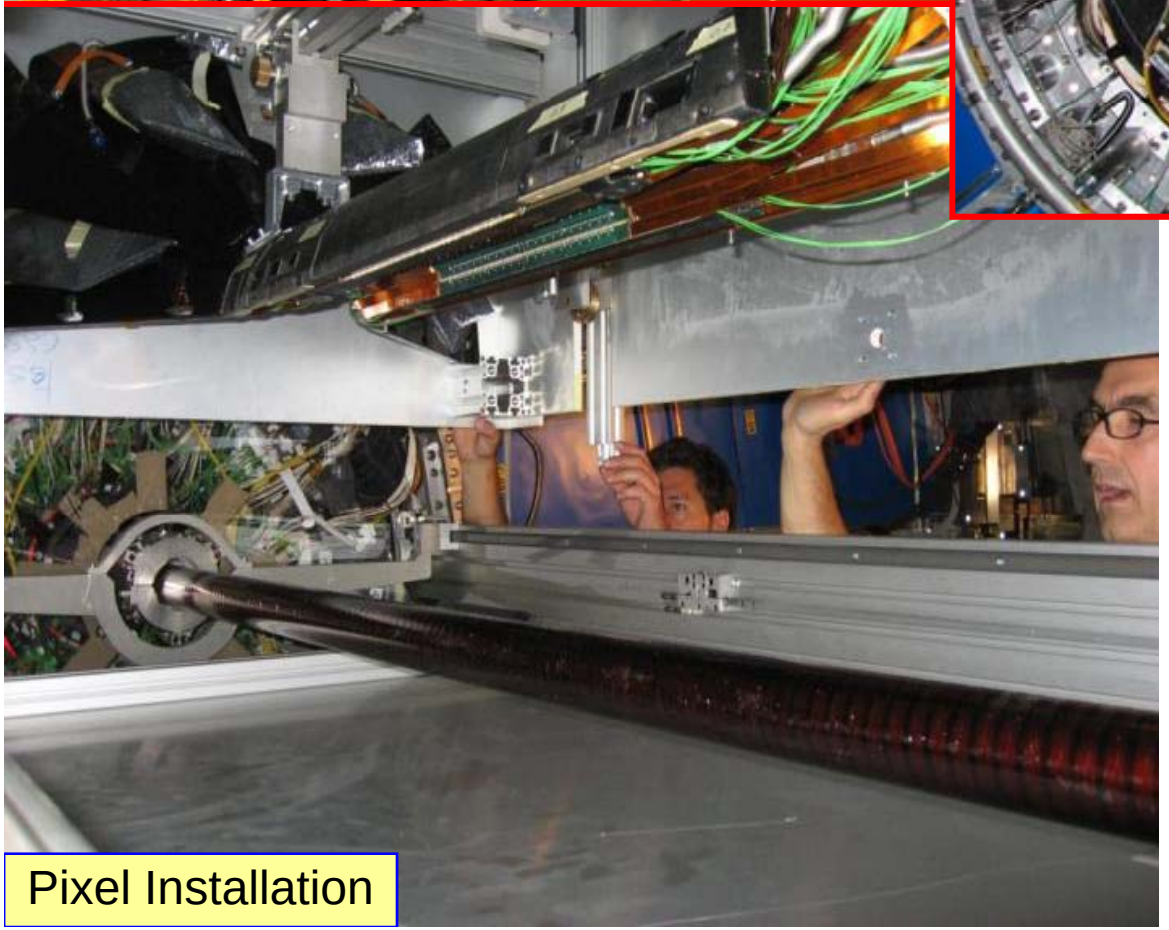
First TRD supermodule
(Oct ’06)


TPC transport
(January 2007)
Position Monitor
< 100 m horizontal, < 100 m vertical in 2 days
<v> = 4 m/hour

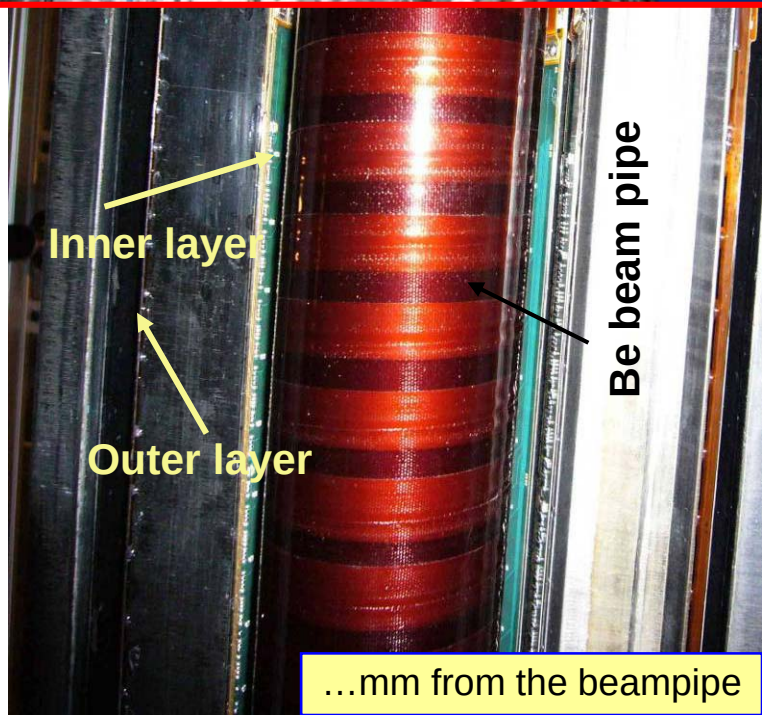
ITS transport March 07



pushing through the TPC

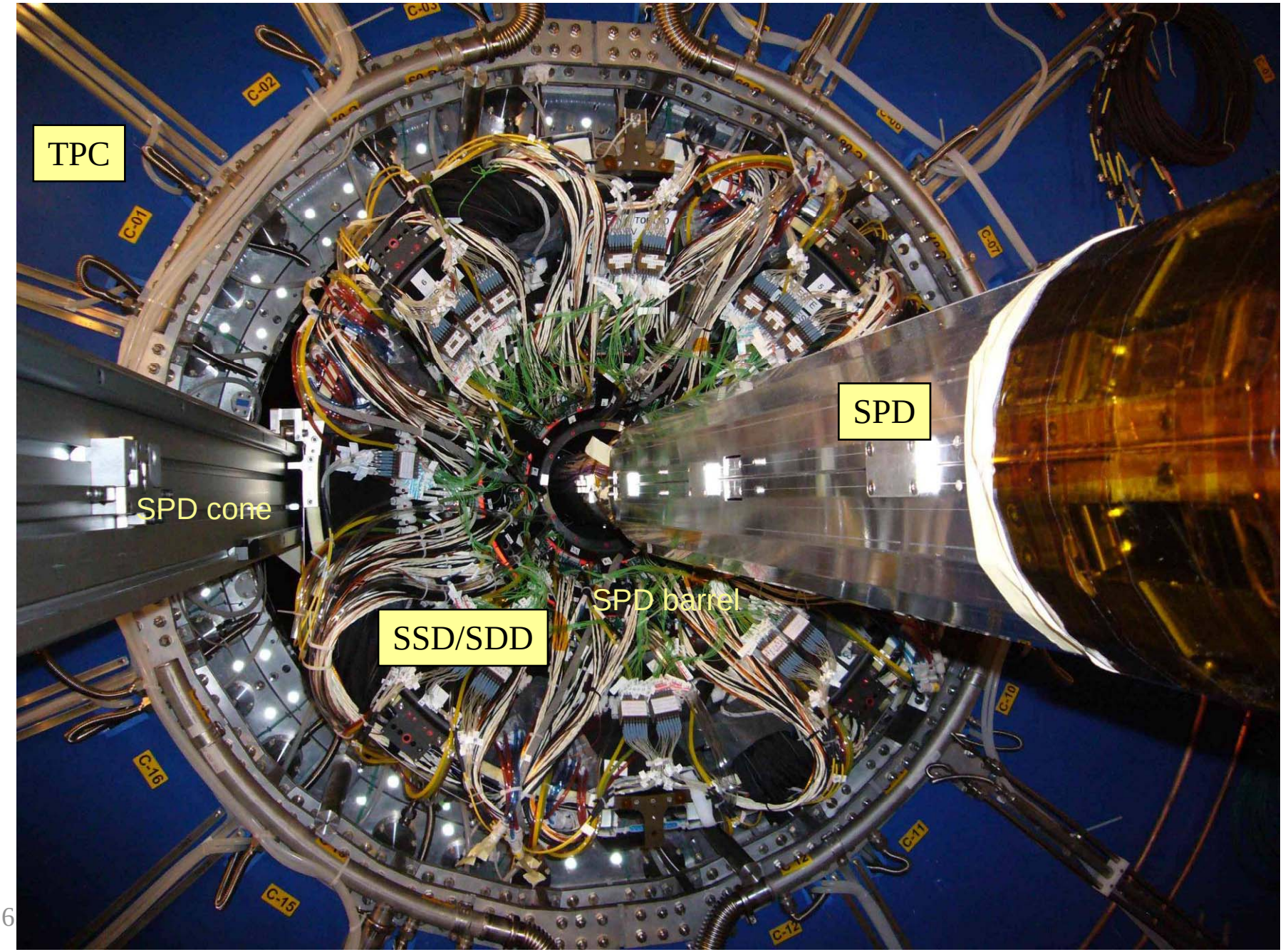


Pixel Installation

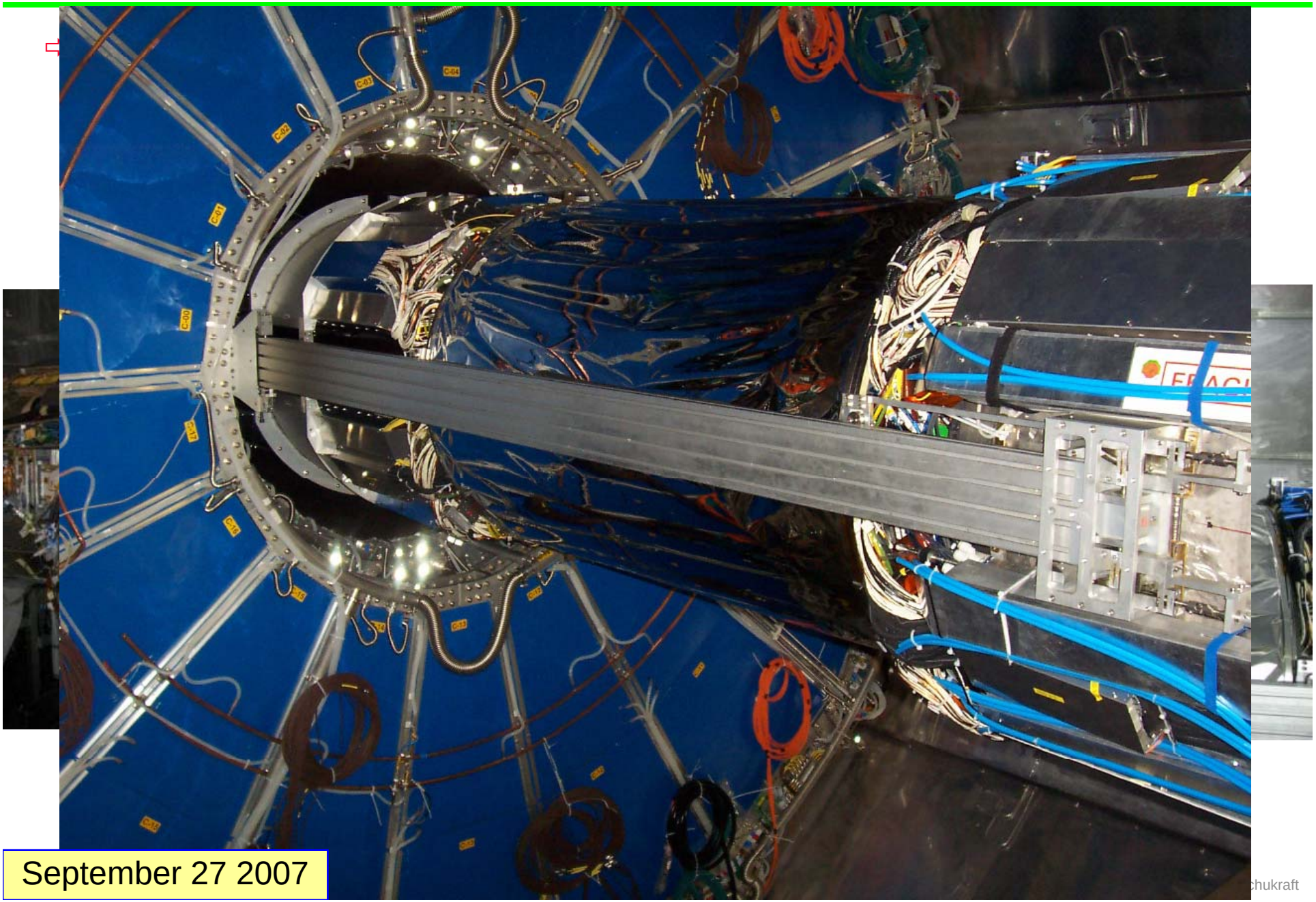


…mm from the beampipe

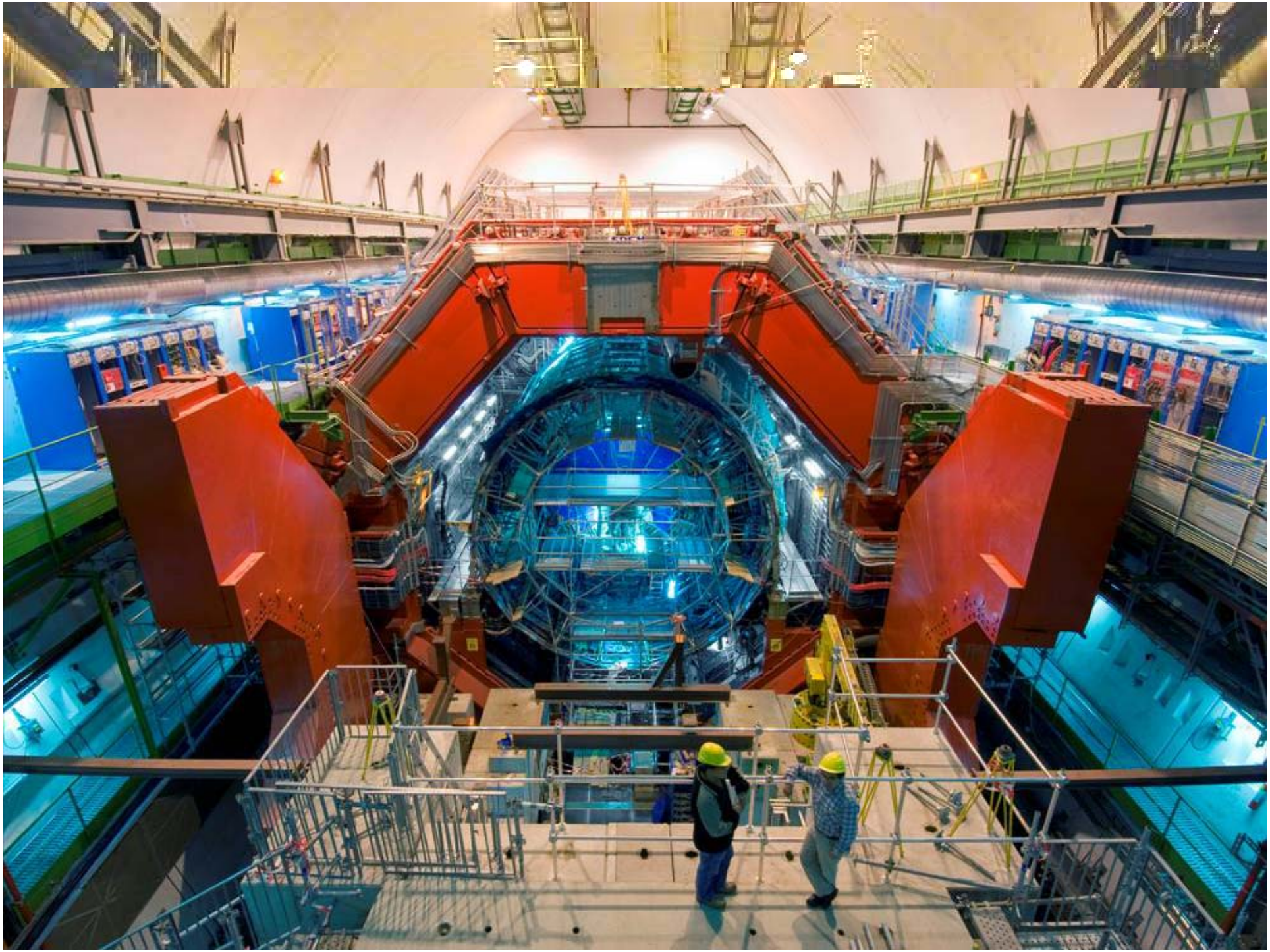
Russian Dolls I: Moving of the ITS over the SPD



Russian Dolls II: Moving of theTPC over ITS/ SPD

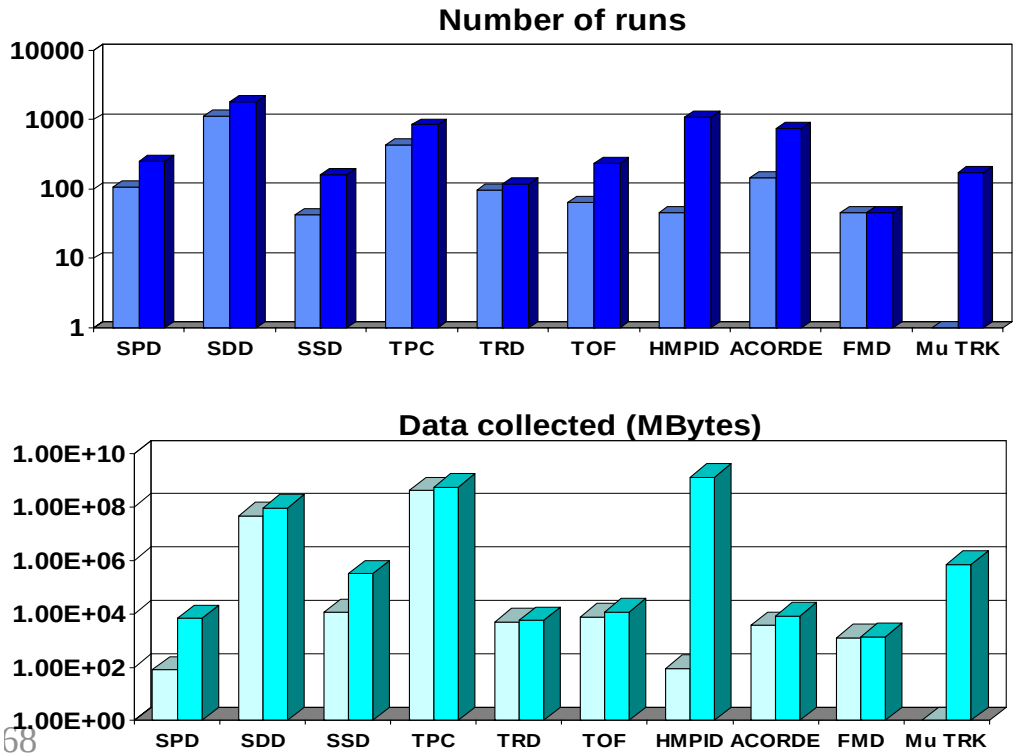


September 27 2007



Commissioning

- individual (groups of) detectors ‘in situ’ from the ACR
  - 1) individual detector operation (LV, HV, gas, cooling, FEE)
  - 2) integration with online systems **(DAQ/HLT/Trigger/DCS/ECS)**
  - 3) operation of several detectors together
- ‘global commissioning’ with cosmics
  - ⇨ 10-21 Dec, 4 weeks in February, April -> first beam
    - includes detector calibration and alignment



Alice Control Room

Looking Forward to Physics

- expected start-up configuration mid 2008
  - **complete**: ITS, TPC, TOF, HMPID, muons, PMD, V0, T0, ZDC, Acorde,..
  - **partially complete**: TRD (25%), EMCAL (0%), DAQ/HLT (30%), PHOS(60%)

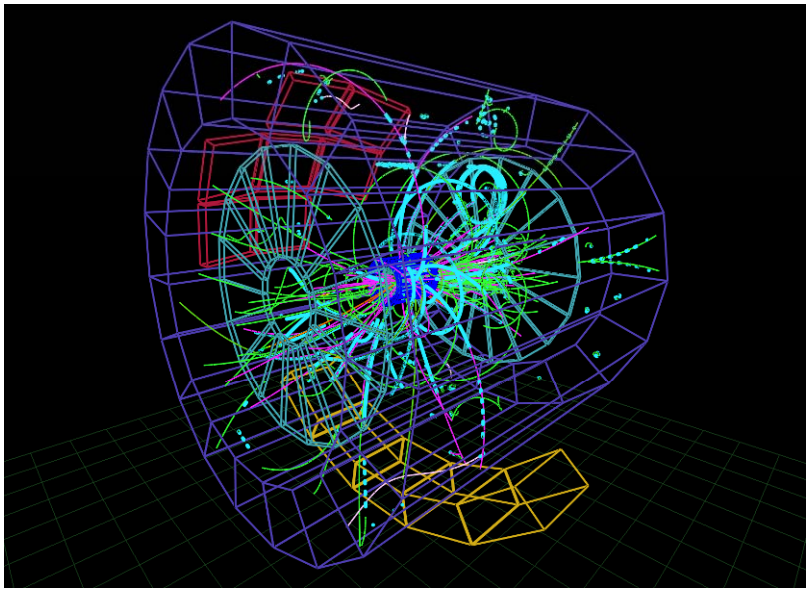
  ⇨ complete ALICE: **TRD (2009), DAQ/HLT(2009), PHOS** (2010), **EMCAL (2010/11)**

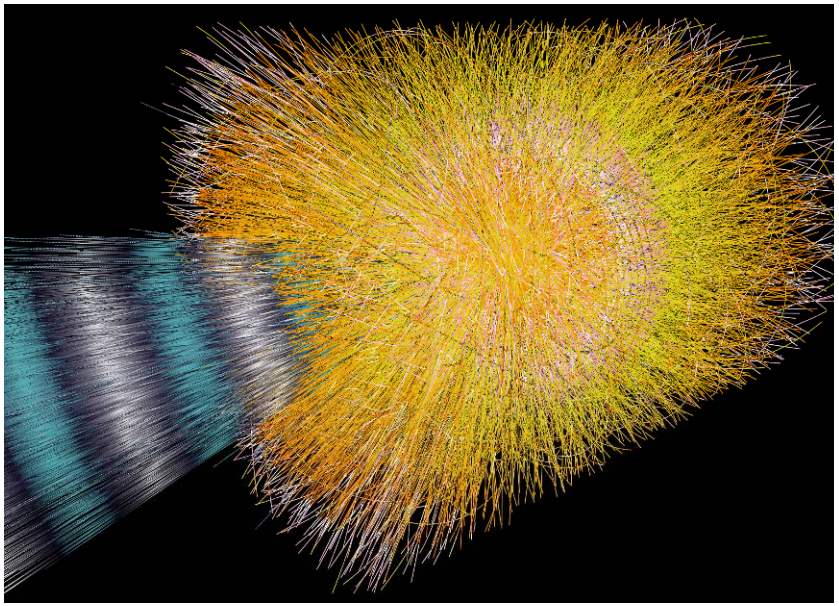
- Physics of the first 'year'…

  ⇨ 'day 1' physics in 2008 with pp: **global event properties** (**0.9/14 TeV**)
  - requiring only subset of detectors, few 10,000 events

  ⇨' early pp physics' 2008/2009: **detailed studies** of pp

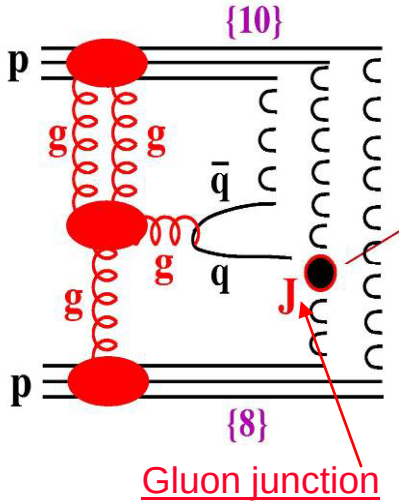
  ⇨ first heavy ion run 'at the end of the first long pp run'



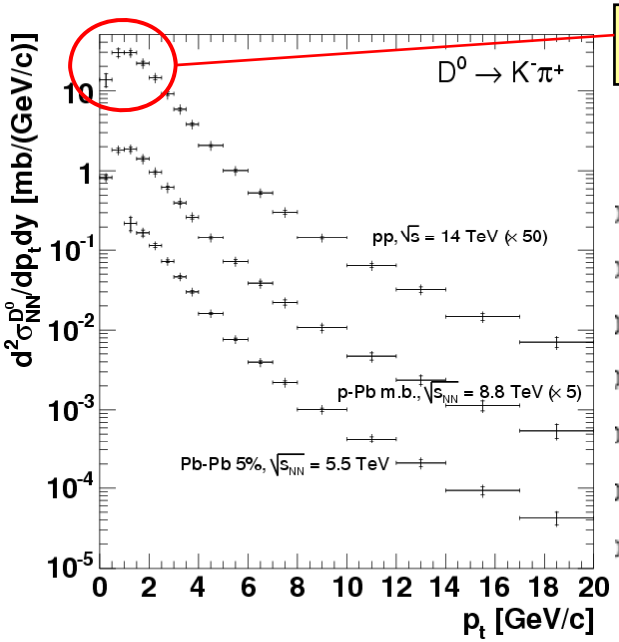


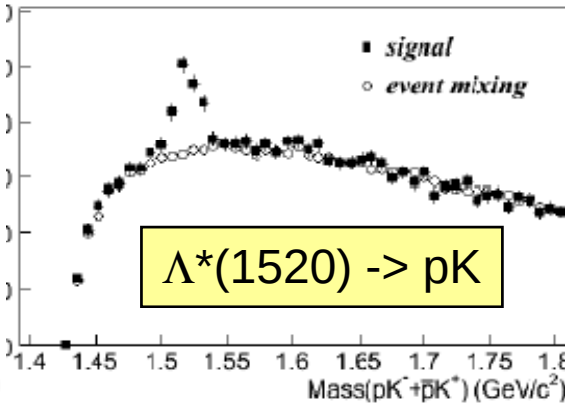
QCD at 14 TeV

- ALICE physics with pp
  - ⇨ Taking 'comparison data' for the heavy ion program
    - ✪ eg: J/Ψ suppression in AA requires measuring J/Ψ production in pp
  - ⇨ Survey and characterization of typical ('Minimum Bias') events
    - ✪ multiplicity, p_t distribution, particle composition, ….
    - ✪ => **tuning** of Monte Carlo generators (which differ widely)
    - ✪ => **evaluate background** & detect. performance
  - ⇨ Specific QCD measurements for which ALICE is particularly well suited
    - ✪ signals involving **PID** eg 'baryon transport: how are the beam protons decelerated'
    - ✪ **low x-physics**, **charm & beauty** production at **low p_t** ,…

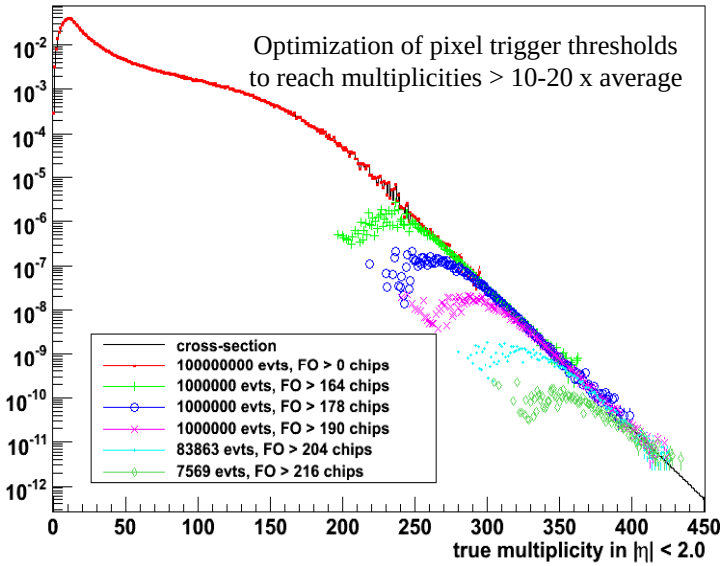


acceptance down to 0 p_t





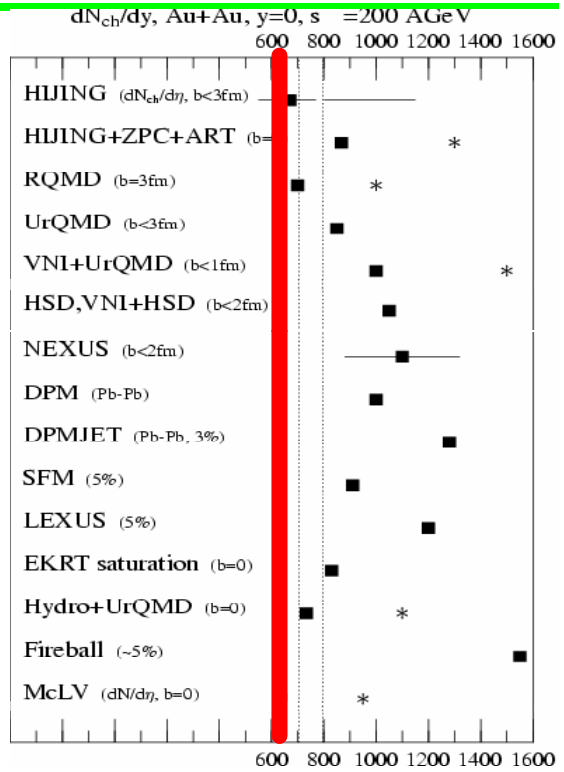
Λ*(1520) -> pK

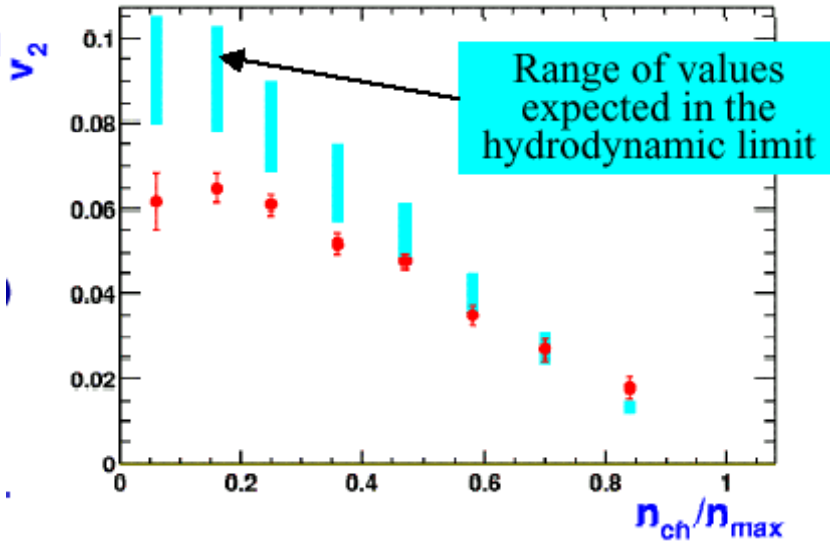


Heavy Ions: 'The First 3 Minutes'

- Minimum Statistics needed:
  - ⇨ **6366 MB (382 central) events**
  - ⇨ **few seconds at 1% design L**
- **RHIC in 2000:** first collisions June 12
  - ⇨ 1st paper July 19, dNch/dη, excluding 90% of predictions
    - ✪ 2nd: Aug 24, 22k MB events, **flow surprise** (v_2)
  - ⇨ ~ 3 weeks run, very low L, > 10 PRL's within < 1 year
    - ✪ RHIC was commissioned with HI !
- **SPS in 1986**
  - ⇨ first spectrum 1 week **before** start of HI run !
- **LHC:** first short run at very low Lum
  - ⇨ global properties & hadronic observables

    particle ratios & spectra, HBT, flow, ….
    - ✪ Thermodynamics & Hydrodynamics

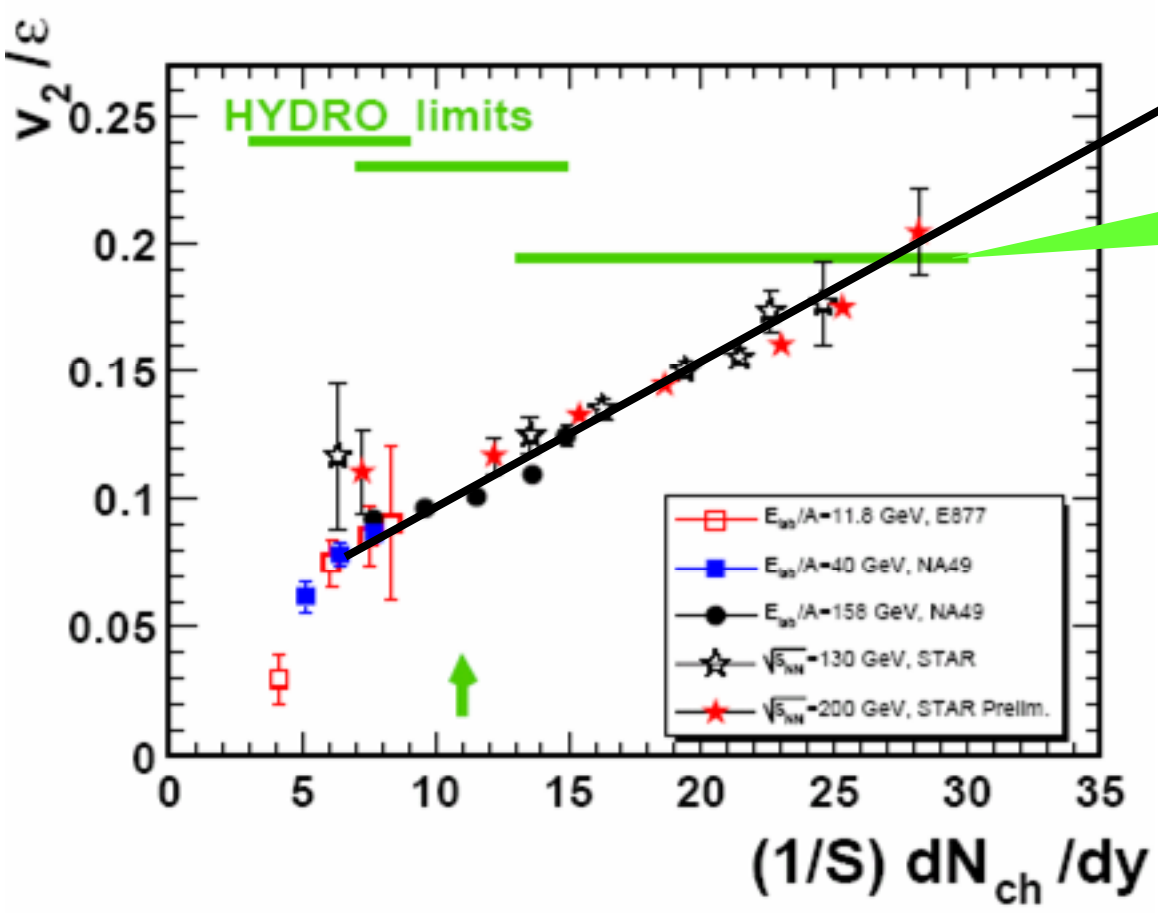


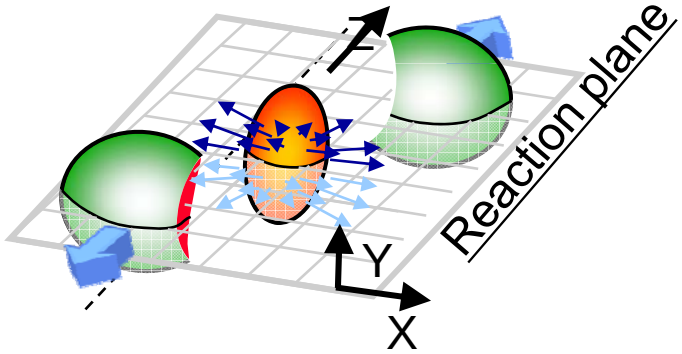


Is the QGP an ideal fluid ?

- one of the first 'expected' answers from LHC
  - ⇨ Hydrodynamics: modest rise (Depending on EoS, viscosity, speed of sound)
  - ⇨ experimental trend & scaling predicts large increase of flow

LHC ?





BNL Press release, April 18, 2005:

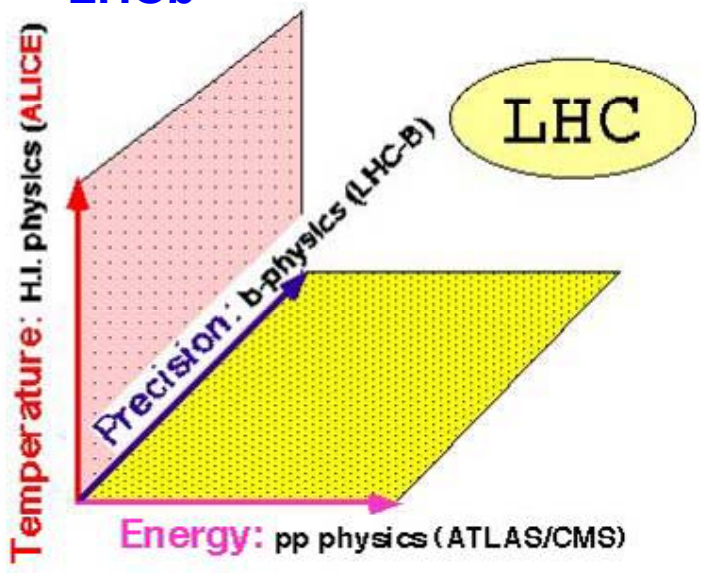
RHIC Scientists Serve Up "Perfect" Liquid

New state of matter more remarkable than predicted – raising many new questions

Physics at the LHC

- Common Questions
  - ⇨ generation of mass
    - ✪ **elementary** particles => Higgs => **Atlas/CMS**
    - ✪ **composite** particles => QGP => **Alice**
  - ⇨ broken symmetries
    - ✪ **SuperSymmetry**: matter <=> forces => **Atlas/CMS**
    - ✪ **ChiralSymmetry**: matter <=> QCD vacuum => **Alice**
    - ✪ **CP Symmetry:** matter <=> antimatter => **LHCb**

- Different Approaches
  - ⇨ **'Concentrated Energy'**
    => new high mass particles
  - ⇨ **'Distributed Energy'**
    => heat and melt matter
  - ⇨ **'Borrowed Energy'**
    => indirect effects of virtual high mass particles



Summary

- LHC is the ultimate machine for Heavy Ion Collisions
  - ⇨ very **significant step** beyond RHIC
  - ⇨ excellent conditions for **experiment & theory** (QCD)

- ALICE is getting ready
  - ⇨ first truly **general purpose** HI experiment
    - ✪ addresses most relevant observables: from super-soft to ultra-hard
  - ⇨ many **evolutionary** developments
    - ✪ SSD, SDD, TPC, em cal, …
  - ⇨ some **big advances** in technology
    - ✪ electronics, pixels, TOF, computing

ALICE is looking forward to exploit this unique combination .. In 2008 !!