The KLOE Experiment

E. De Lucia
LNF- INFN

DAϕNE the Italian ϕ-factory

- June 1990 the Istituto Italiano di Fisica Nucleare, INFN, approved the construction of an e+e– collider meant to operate around 1020 MeV, the mass of the ϕ-meson.

- The ϕ-meson decays mostly to kaons, neutral and charged, in pairs. Its production cross-section peaks at about 3μbarns.

- The collider, called a ϕ-factory, is christened DAΦNE and located at the Laboratori Nazionali di Frascati, LNF, INFN's high-energy physics laboratory near Rome.

- A ϕ-factory is thus a copious source of tagged and monochromatic kaons, both neutral and charged.

- September 1992 DAϕNE Physics Handbook

KLOE Timeline

A state-of-the-art detector is needed to collect data at DAΦNE

- Summer 1991, KLOE Collaboration was initiated proposing a detector and a physics program.

20 Marzo '92, P.F. 52

Est. '95:	Fasci in DAΦNE
Fine '92:	Progetto EMC centrale compl.
1 gen '93:	Inizio Produzione EMC centrale
31 dic '95:	Costruzione rivelatore è completa
1 gen '96:	Rivelatore si muove in sala DAΦNE
1 feb '96:	Inizio primo run a $\mathcal{L}\sim10^{32}$
1 giu '96:	4 mesi di dati raccolti a $\mathcal{L}\sim10^{32}$

Fig. 3
Cronologia per la costruzione di KLOE. Presentazione alla CSN I, 20 marzo 1992.

- The KLOE detector was not formally approved nor funded for another couple of years

- By mid Summer 1998, KLOE was designed, constructed, completely tested and, complete with all of its electronics for signal processing, event gathering and transmission, was practicing with cosmic rays.

- Christmas 1998 - 1999 New Year, KLOE was moved from its own assembly hall onto the DAΦNE's South Interaction Region.

1991-1997 Filippo is the INFN CSN1 President

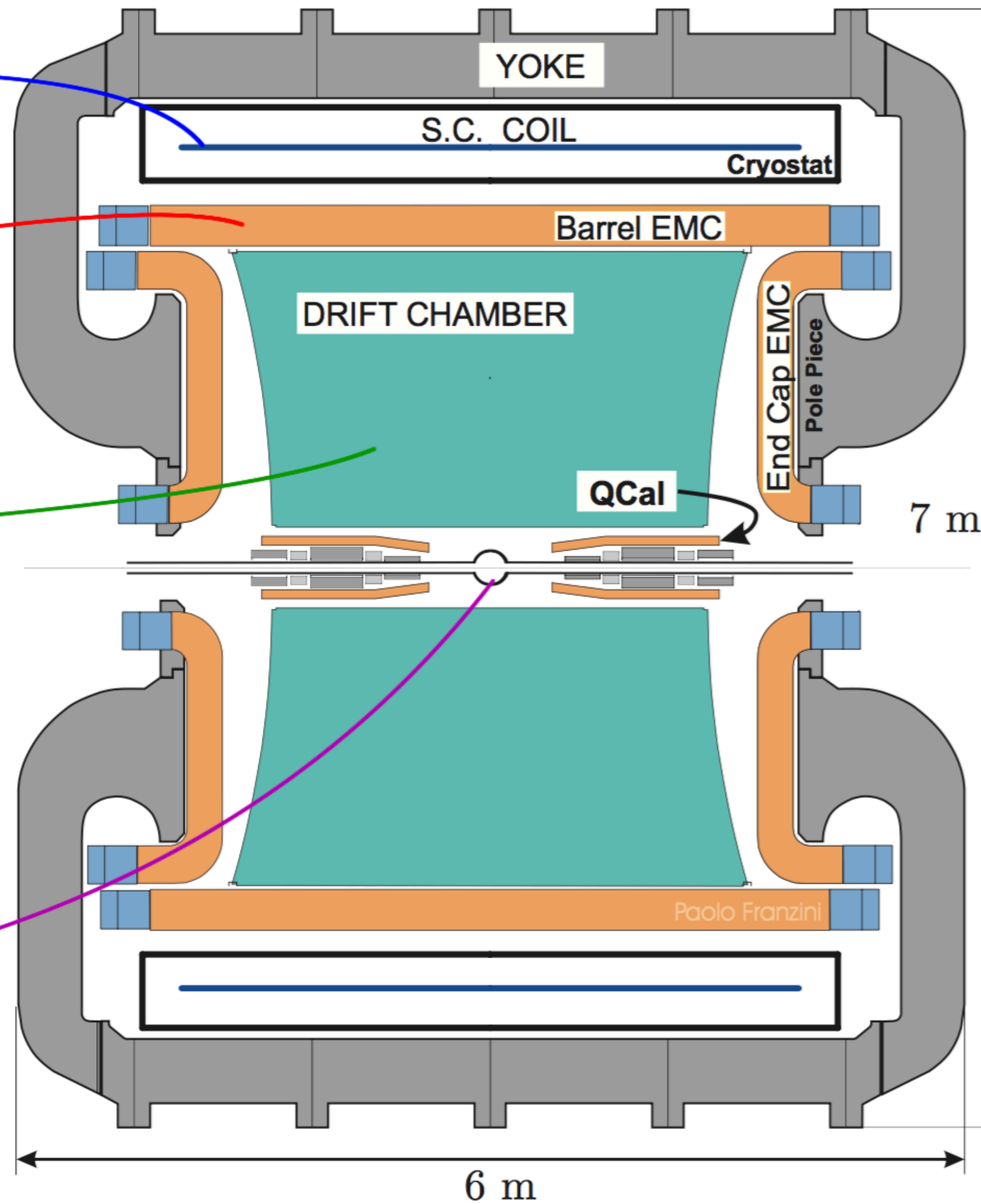
A state-of-the-art detector: KLOE

Magnet
SC Coil, B=0.6 T

EM Calor.
Pb–scint fiber
4880 pm, 2440 cells

Drift Ch.
12582 sense wires
52140 tot wires
Carbon fiber walls

Al-Be beam pipe
r=10 cm, 0.5 mm
thick



- State-of-the-art Trigger and DAQ (50 MB/s)
- With the Most Powerful Computational Facilities in INFN

A modern Giant: the KLOE Drift Chamber

- Large tracking volume ($\lambda_{KL} \cong 340$ cm)
  4 m ∅, 3.3 m length
- High and uniform reconstruction efficiency
  52000 wires Al + W - uniform cells structure
  $\sigma_{r\varphi} \sim 200\ \mu m$ $\sigma_z \sim 2$ mm
- Momentum resolution *$\sigma(p)/p \sim 0.4\%$ @ 0.6 T*

1994 Filippo joins KLOE Collaboration within the Drift Chamber Group

Several prototypes were built to study different drift cell solutions (Proto 0.1-0.2), full stero configuration+stringing strategy & tools (Proto 1)

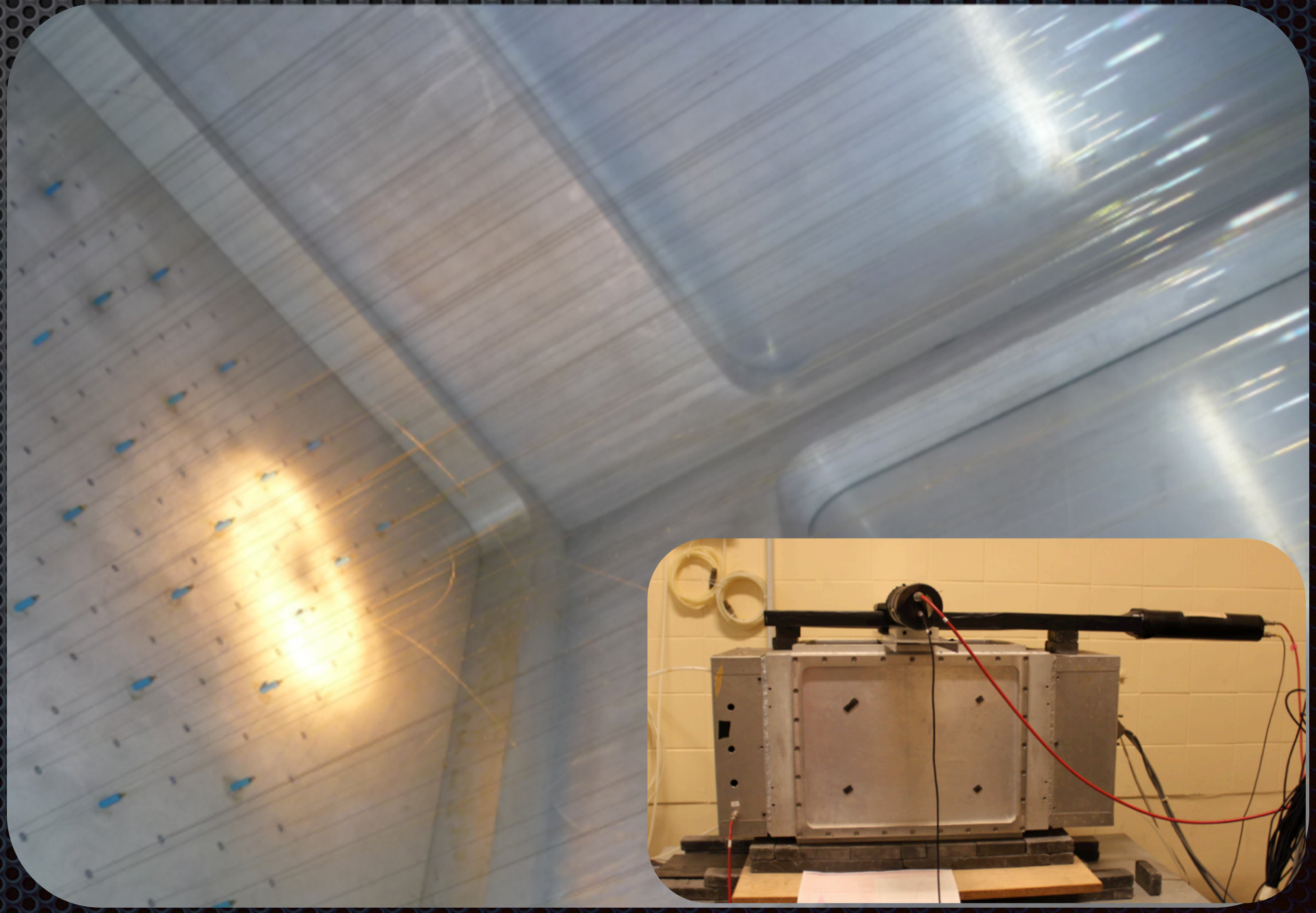
Proto 0.3 was designed & built in Rome
Reproduced a section of KLOE DC
Final cell structure 3xπ almost square
The only one tested in magnetic field
σ =120 μm @0.6 T
Primary ionization and drift velocity and dE/dx in a He-based gas mixture

- Transparency to reduce regeneration, multiple scattering and low energy photon conversion

light mechanical structure C-fiber

light drift medium:

He-10%iC_4H_{10} – 0.5% water
80 μm Al(Ag) field wires
25 μm W(Au) sense wires



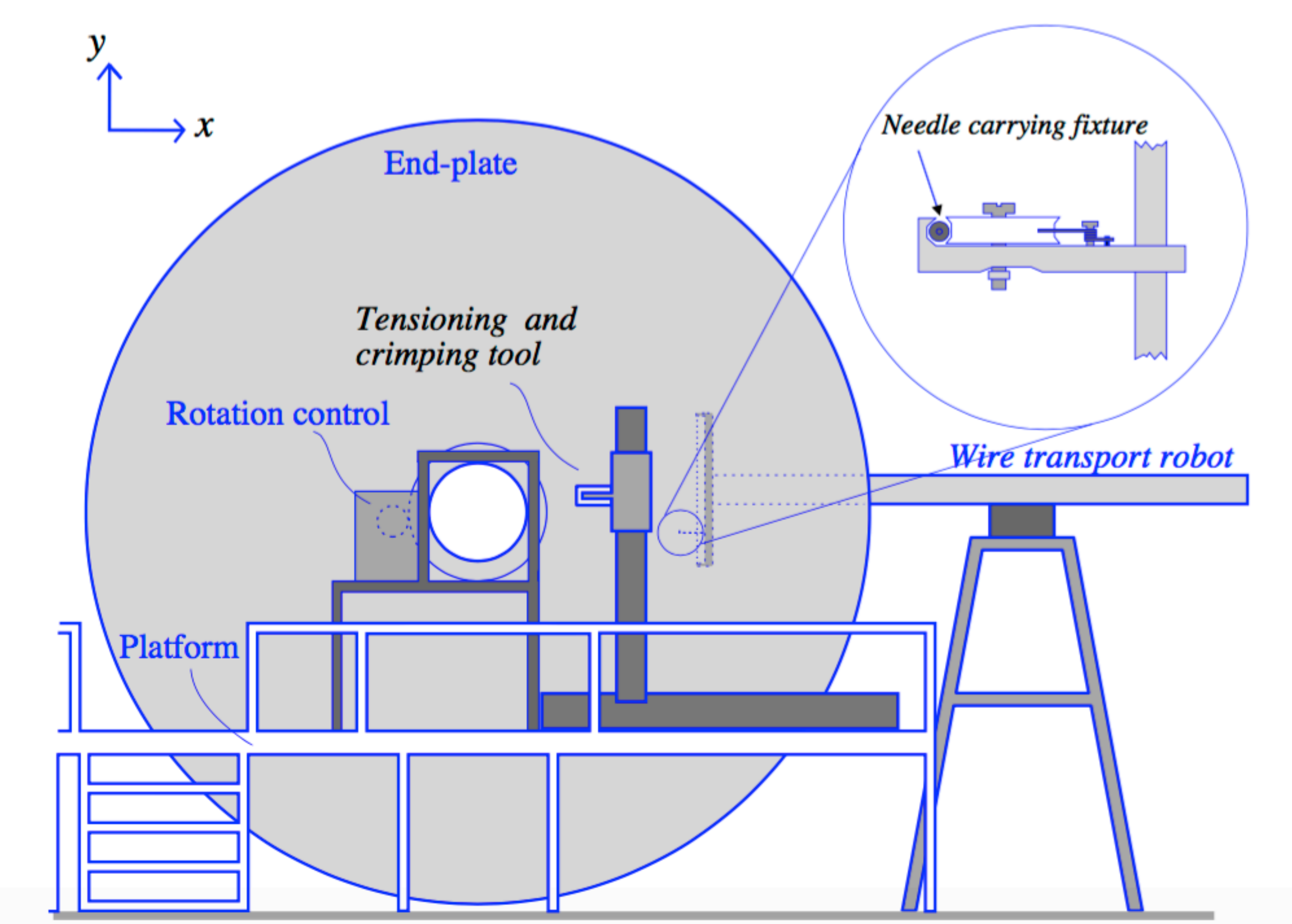
How to string thousands of wires?

New techniques were invented and later used also to build the BABAR Chamber

- A semi-automatic system to support and rotate the chamber structure, pull wi res between the holes in the end plates, stretch the wires to the appropriate mechanical tension and crimp the feedthroughs.

- Two operators manually in serted the wires into the fe edthroughs

- The wire transport from on e end plate to the other wa s performed by a robot



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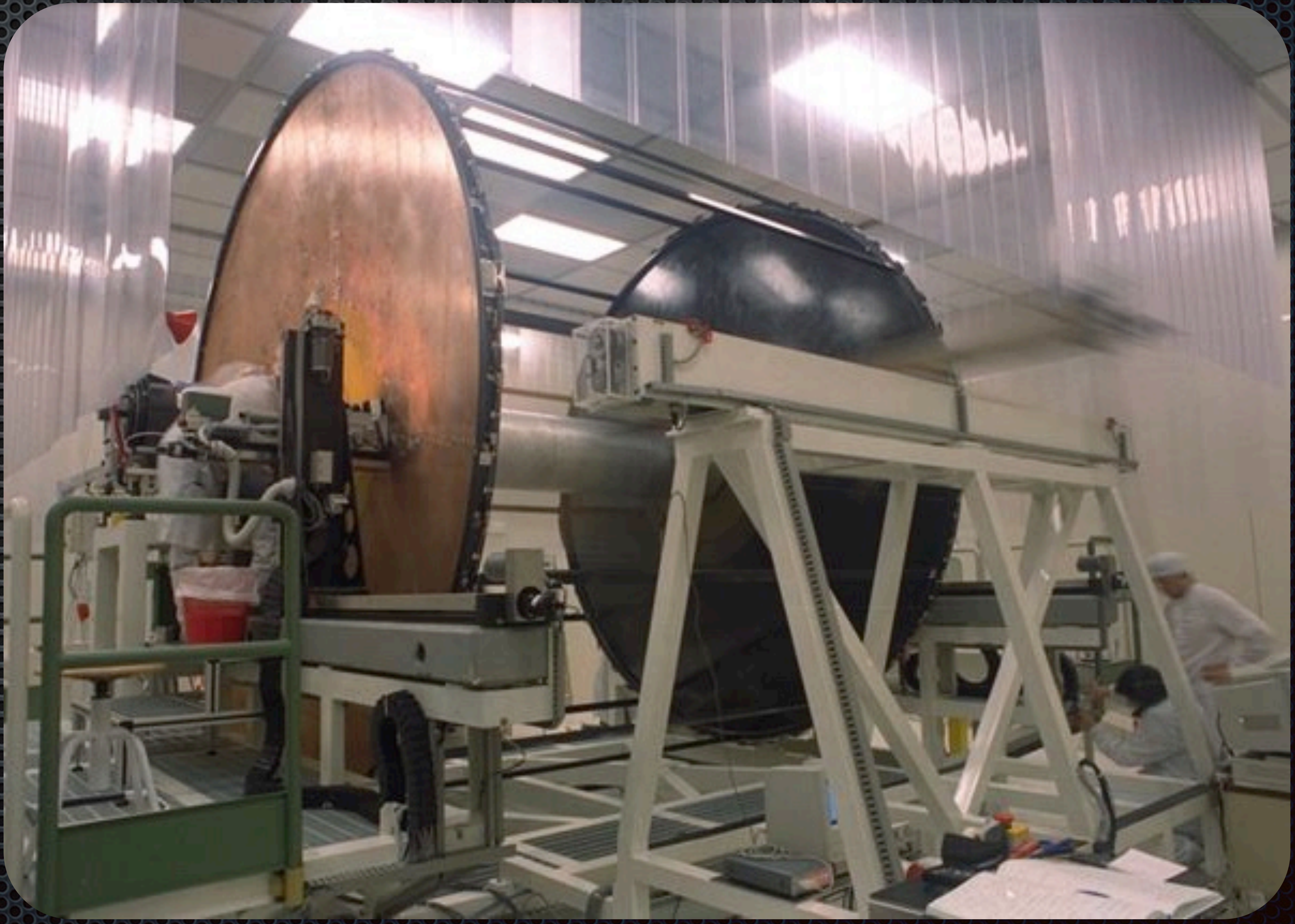

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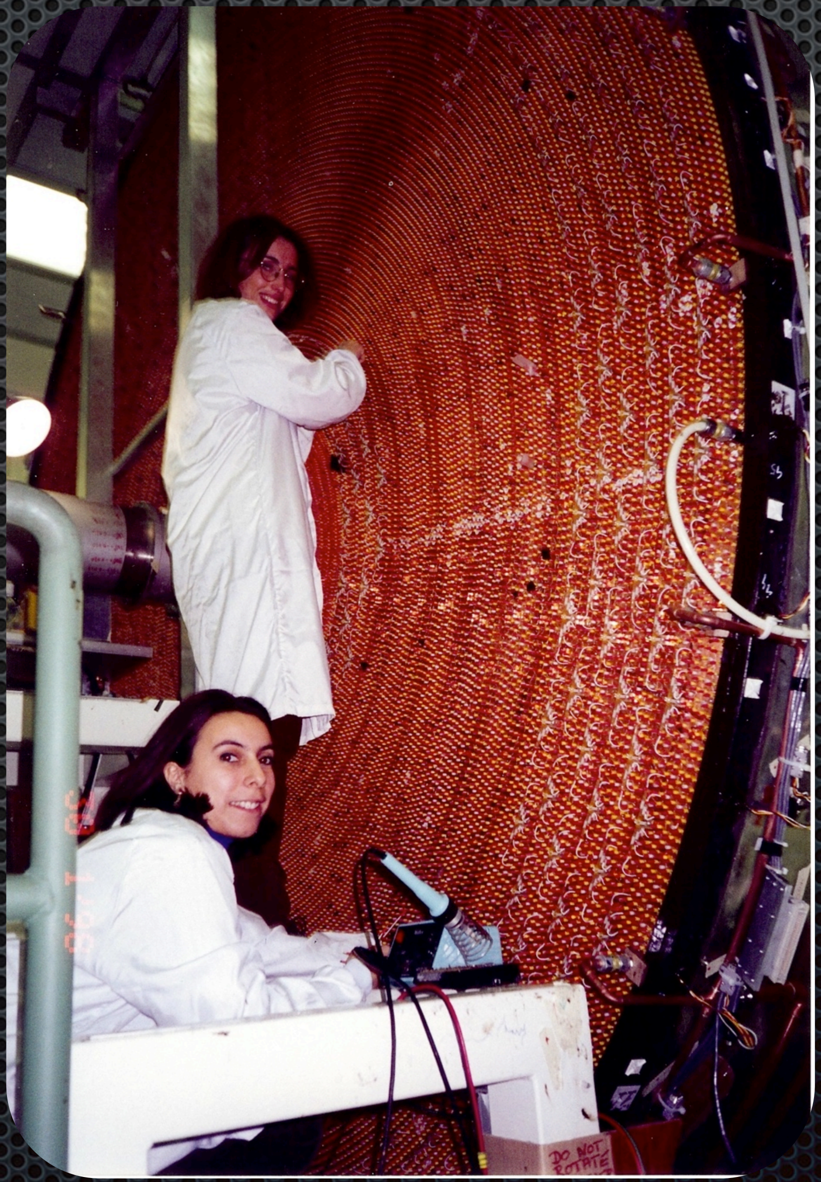
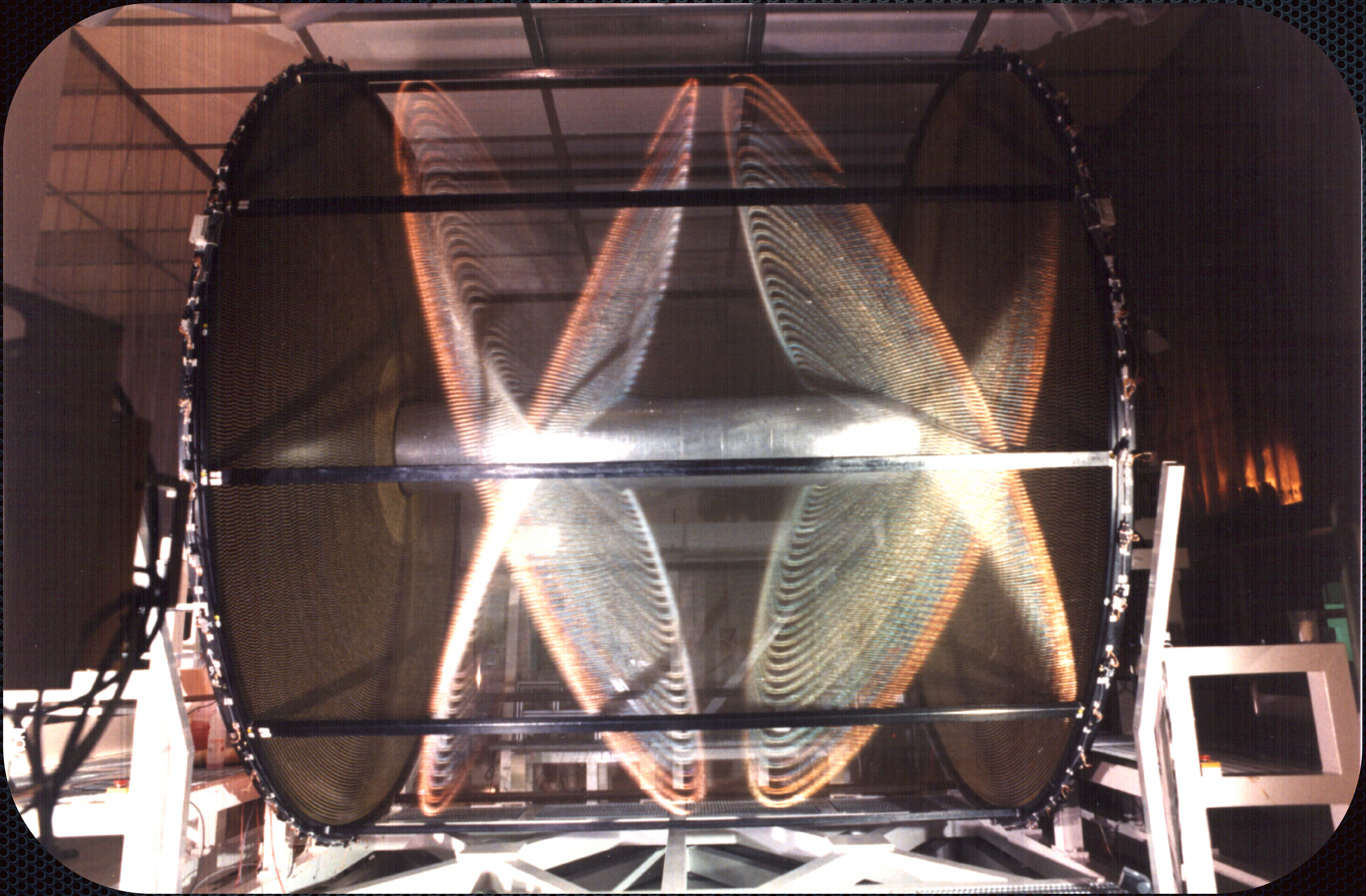
- A semi-automatic system to support and rotate the chamber structure, pull wi res between the holes in the end plates, stretch the wires to the appropriate mechanical tension and crimp the feedthroughs.

- Two operators manually in serted the wires into the fe edthroughs
- The wire transport from on e end plate to the other wa s performed by a robot
- Wire tension measured ele ctrostatically for quality co ntrols and deformations
- Spherical end-plates tensio ned while stringing



A Modern Giant, November '97



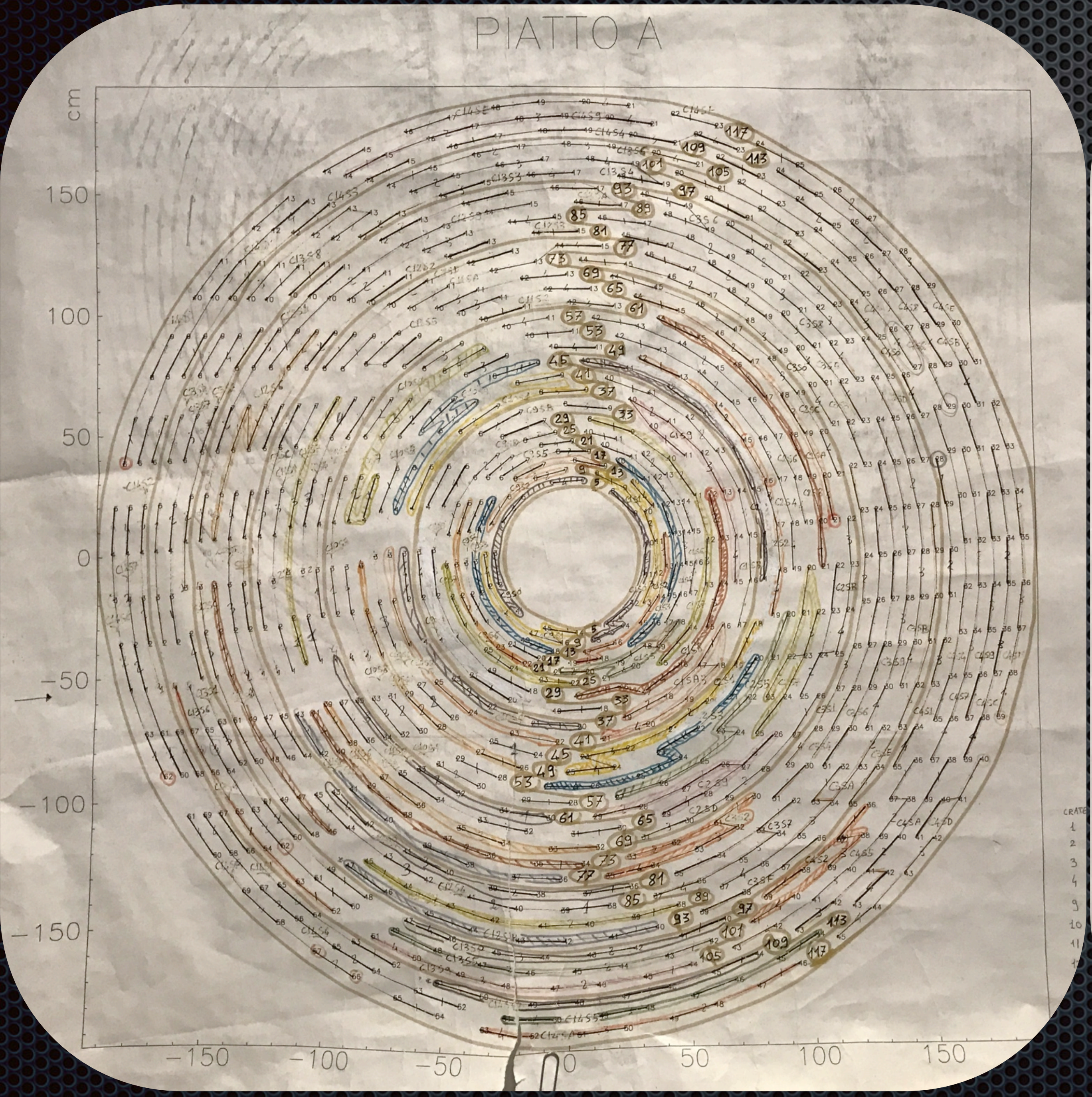
Getting ready for Signals

“Facciamo Piatto A & Piatto B”

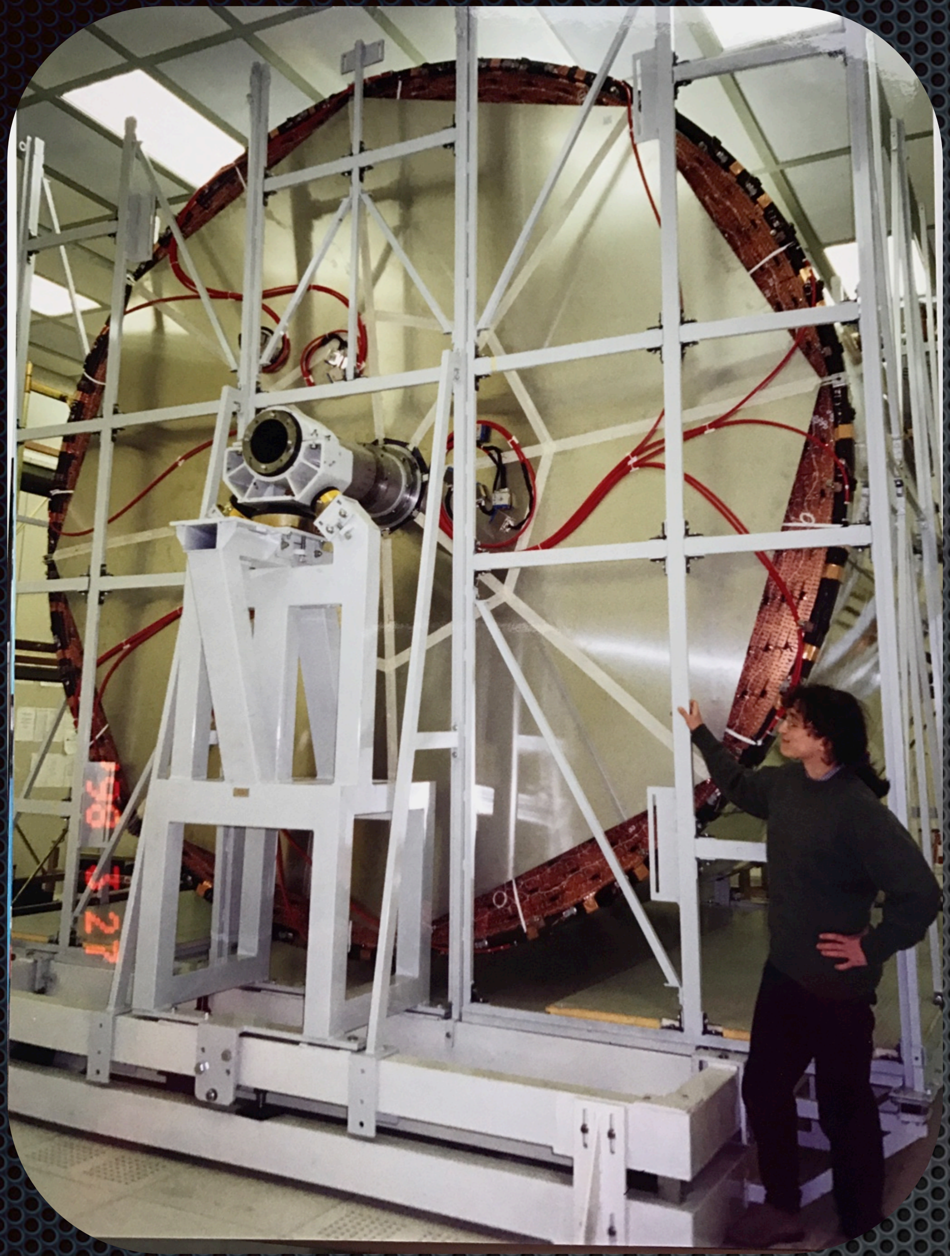
Drift Chamber High Voltage Cabling Scheme

High voltage cabling scheme of the drift chamber.

F. Ceradini
Università 'Roma Tre' e Sezione I.N.F.N. di Roma
E. De Lucia, C. Luisi
Università 'La Sapienza' e Sezione I.N.F.N. di Roma



Packing & Moving to the Assembly Hall



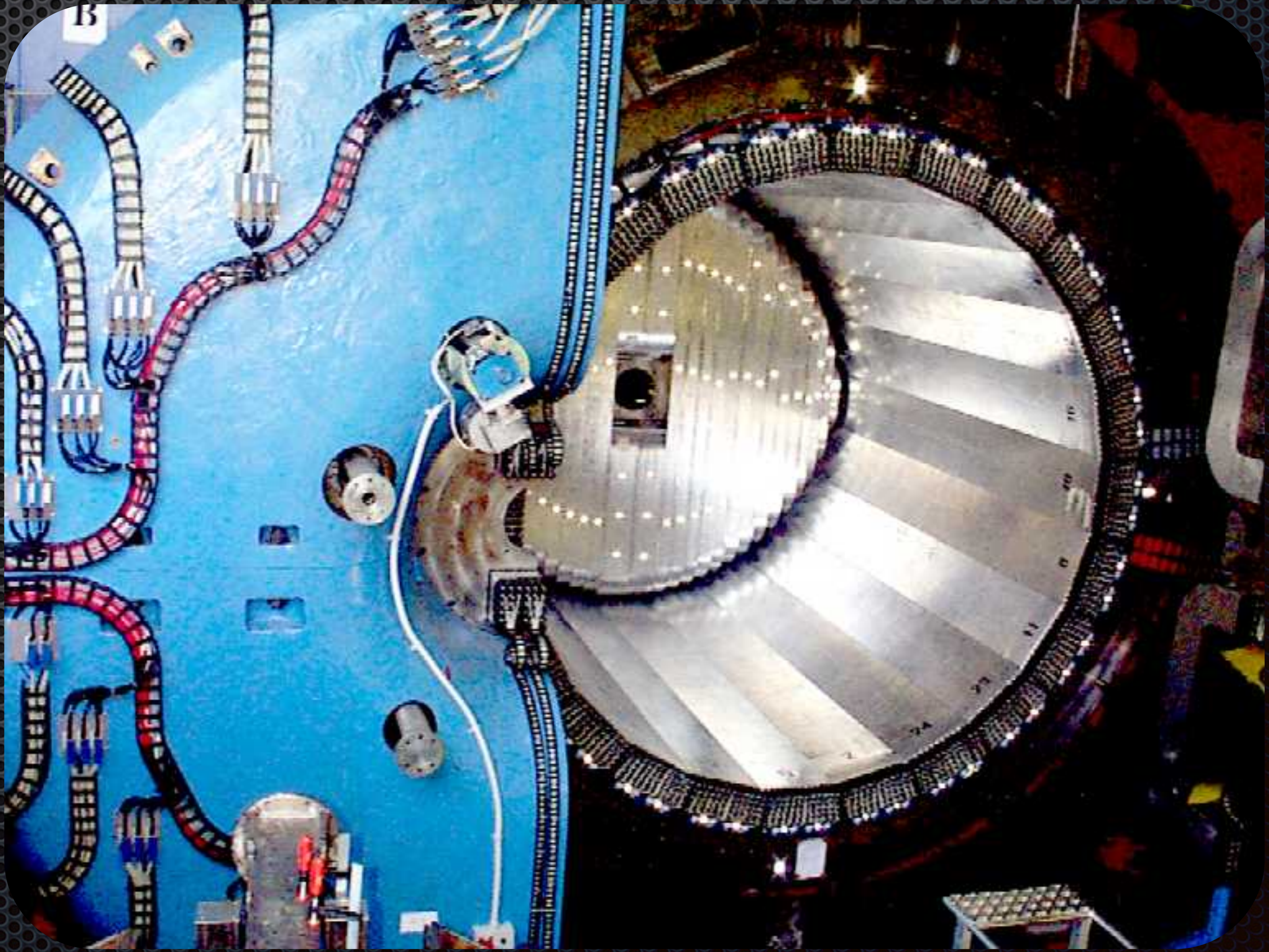
The Meanest and Fastest "Tempometro"

- Among first spaghetti calorimeters to be used at collider experiments
- Hermetic detection of low energy photons (20-500MeV) with high efficiency

  Lead/scintillating fiber (0.5/1 mm) - 98% coverage of solid angle -

  88 modules (barrel + end-caps) 4880 PMTs (two side read-out)
- Good energy resolution and excellent time resolution (KL neutral decays vtx)

$\sigma E/E = 5.7\% / \sqrt{E(GeV)}$ $\sigma t = 54\ ps / \sqrt{E(GeV)} \oplus 140\ ps$ $\sigma vtx(\gamma\gamma) \sim 1.5\ cm$



Superconducting magnet delivery

The world's largest commercially produced superconducting magnet from Oxford,England to INFN Frascati, Italy

Superconducting magnet delivery

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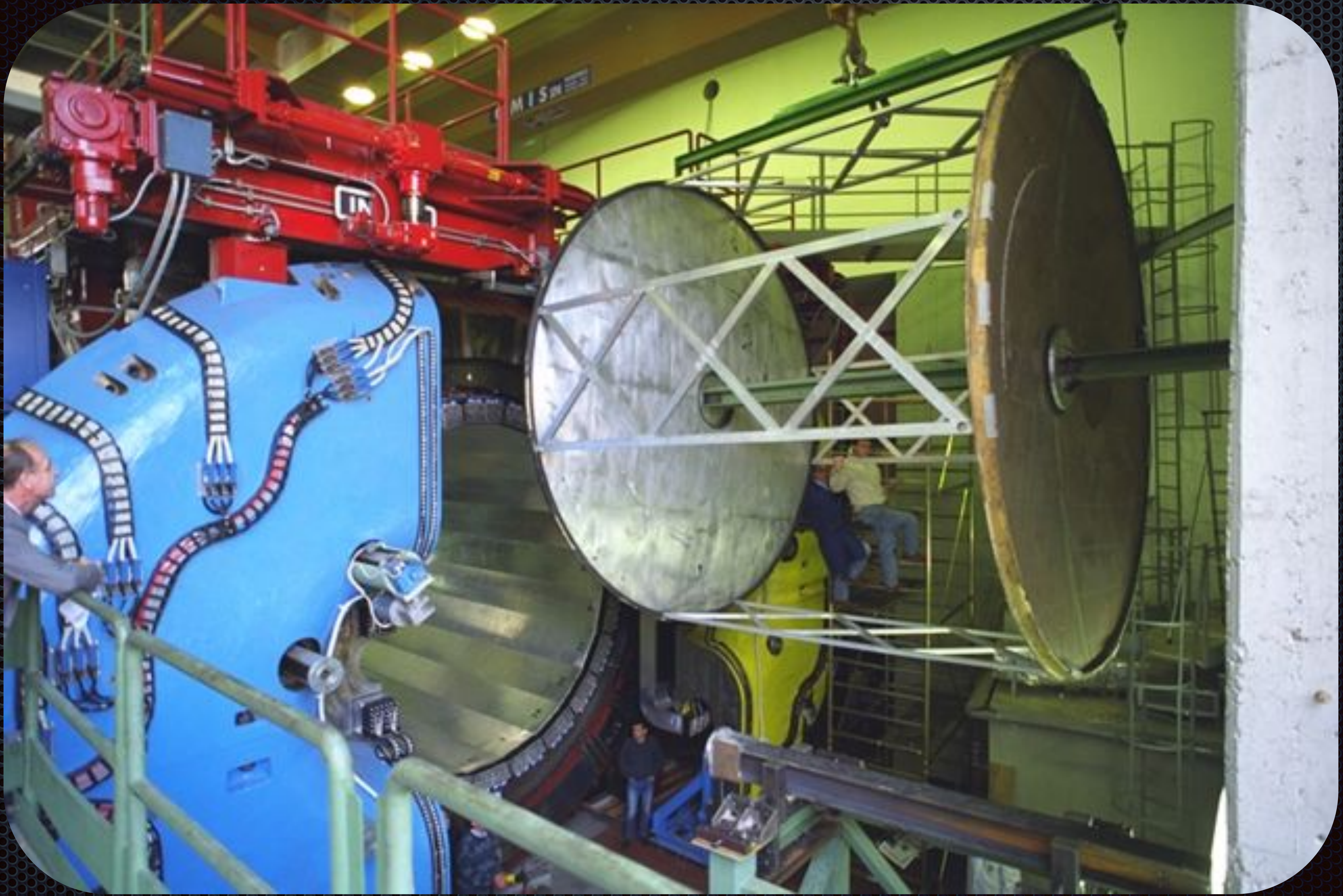
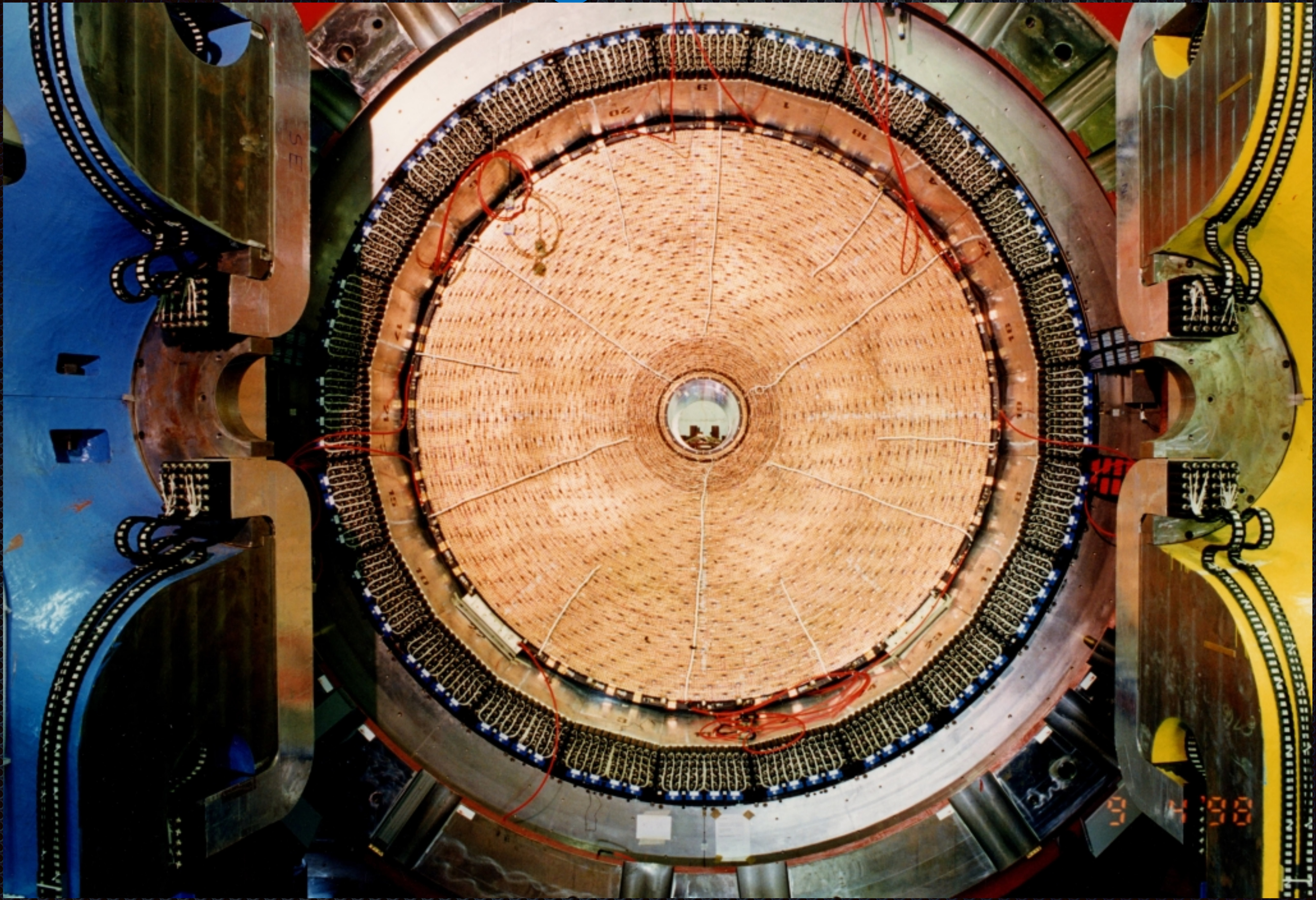
KLOE Superconducting magnet

Rehearsing Detector Integration



Detectors Integrated

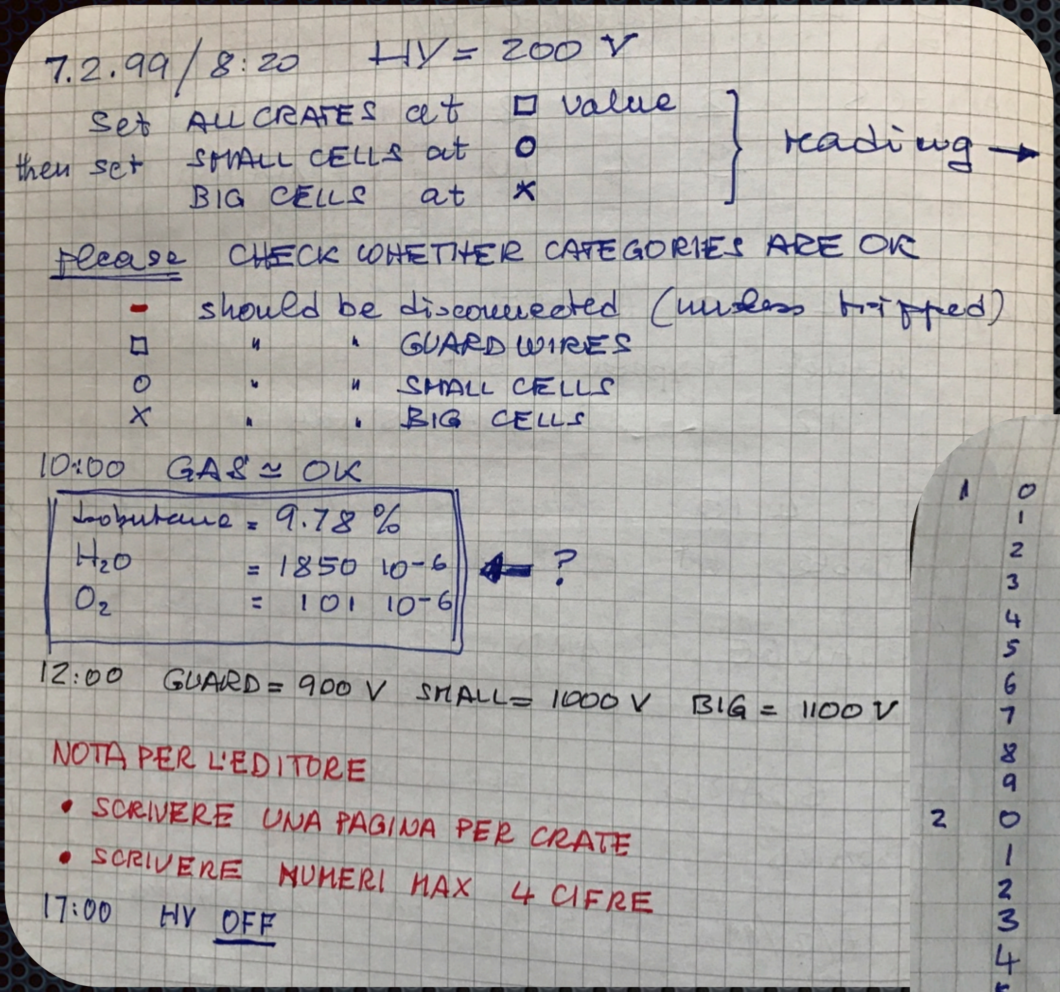


Metodo Scientifico & British

"Power On"

Drift Chamber High Voltage Settings
Practicing with cosmic rays

F. Ceradini on shift



7.2.99 / 8:20 HV = 200 V

Set ALL CRATES at □ value
then set SMALL CELLS at o
BIG CELLS at x
} reading →

Please CHECK WHETHER CATEGORIES ARE OK

- should be disconnected (unless tripped)
□ " " GUARD WIRES
o " " SMALL CELLS
x " " BIG CELLS

10:00 GAS ≃ OK

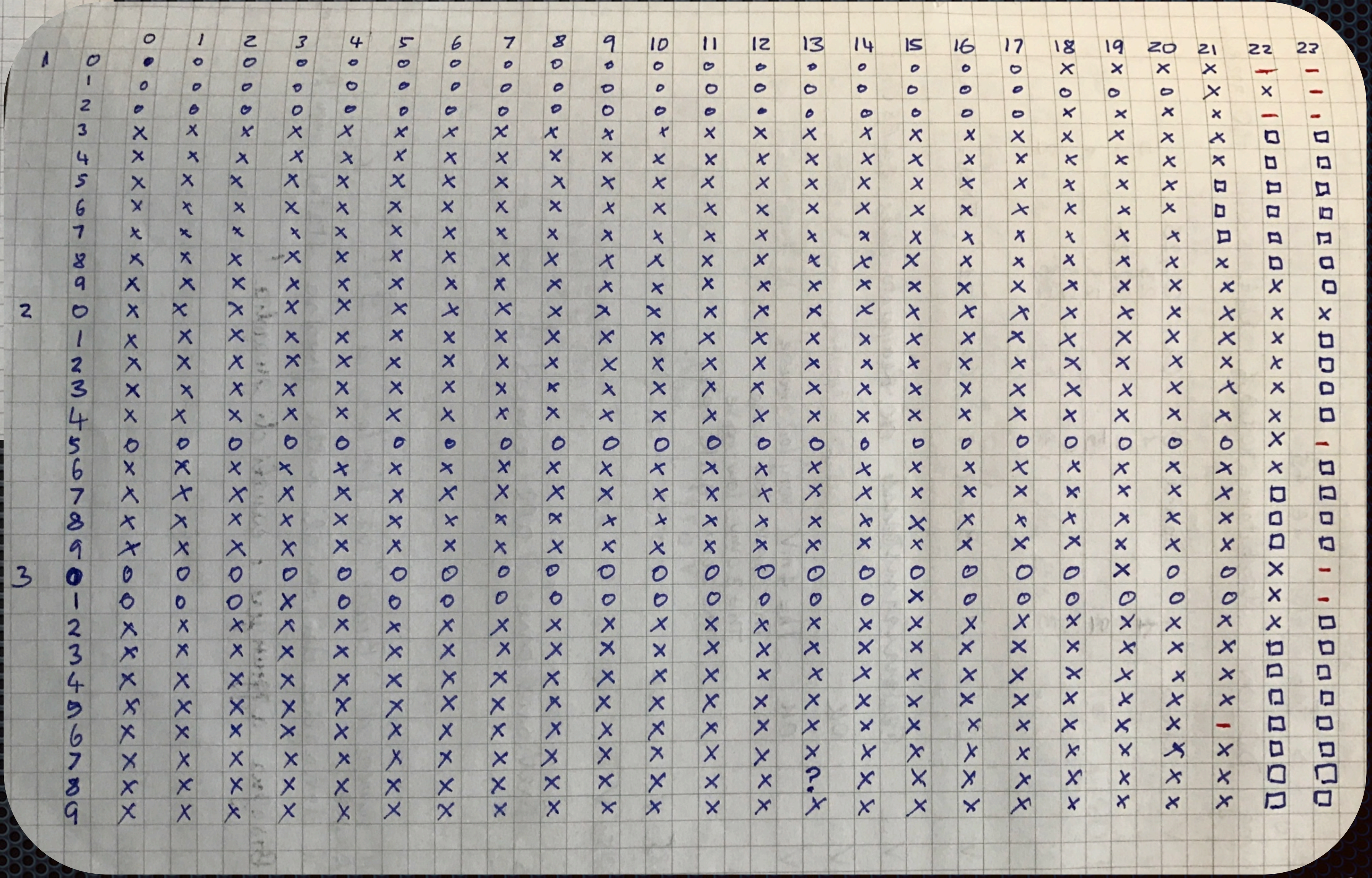
Isobutane = 9.78 %
H_2O = 1850 10^{-6}
O_2 = 101 10^{-6}
← ?

12:00 GUARD = 900 V SMALL = 1000 V BIG = 1100 V

NOTA PER L'EDITORE

- SCRIVERE UNA PAGINA PER CRATE
- SCRIVERE NUMERI MAX 4 CIFRE

17:00 HV OFF



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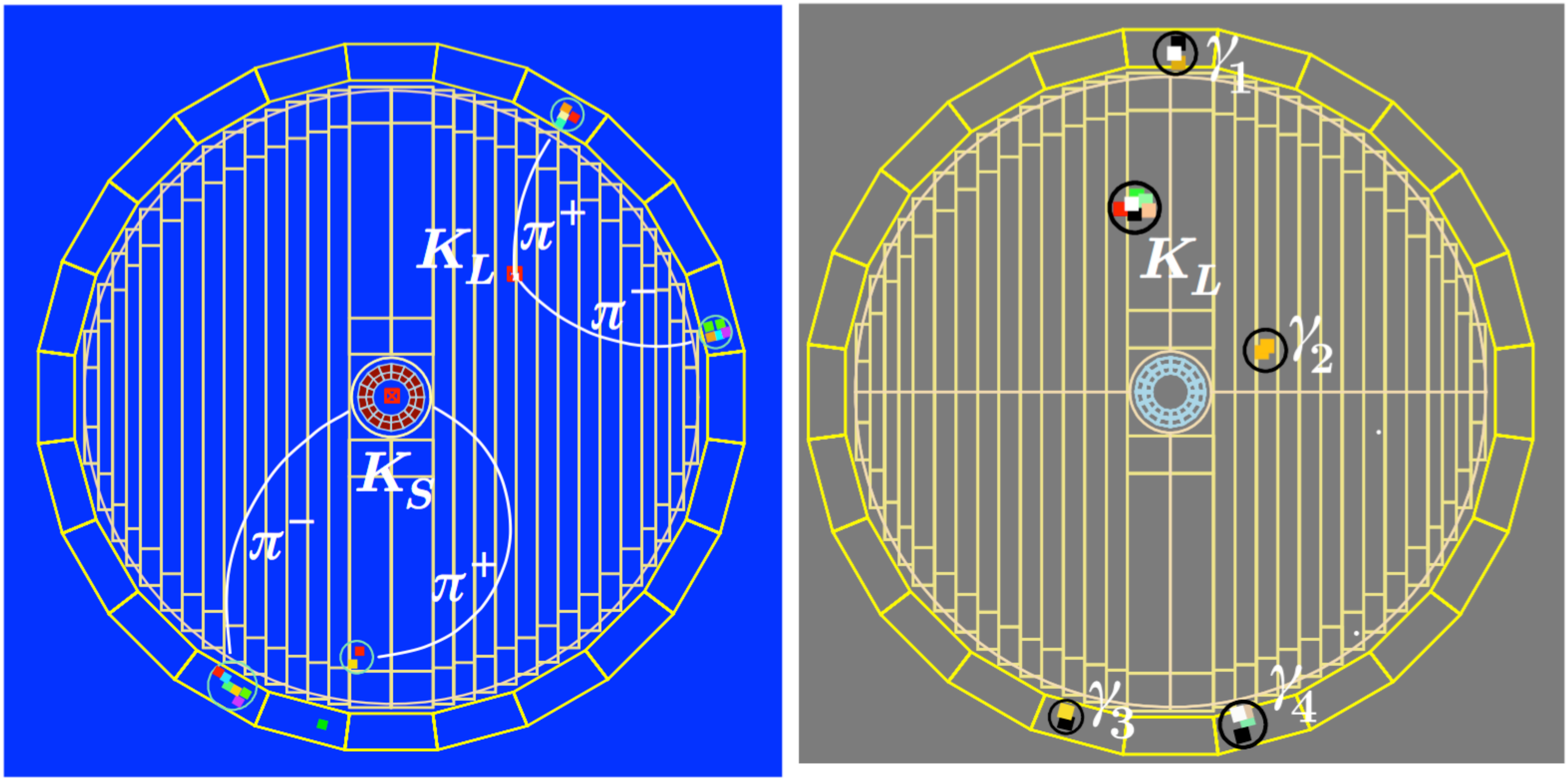
	9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	□	□

The First events, April '99

Between Christmas 1998 and 1999 New Year, KLOE was moved from its own assembly hall onto the DAΦNE's South Interaction Region.

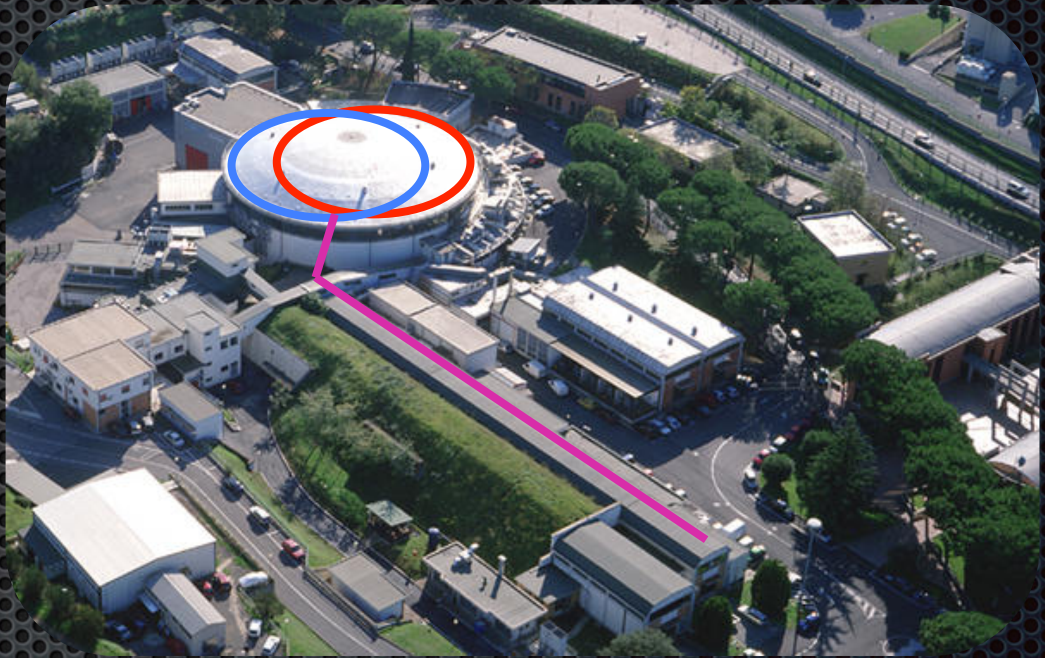


$K_S \to \pi^+\pi^-$, $K_L \to \pi^+\pi^-$ $\quad$ $K_S \to \pi^0\pi^0$, K_L interacts in ECal

DAΦNE & KLOE

- DAΦNE Frascati φ-factory: an e^+e^- collider @ $\sqrt{s}$ =1019.4 MeV = M_ϕ

  Best performance in 2005:
  - L_{peak} = 1.4 × 10^{32} $cm^{-2}s^{-1}$
  - $\int Ldt$ = 8.5 pb^{-1}/day

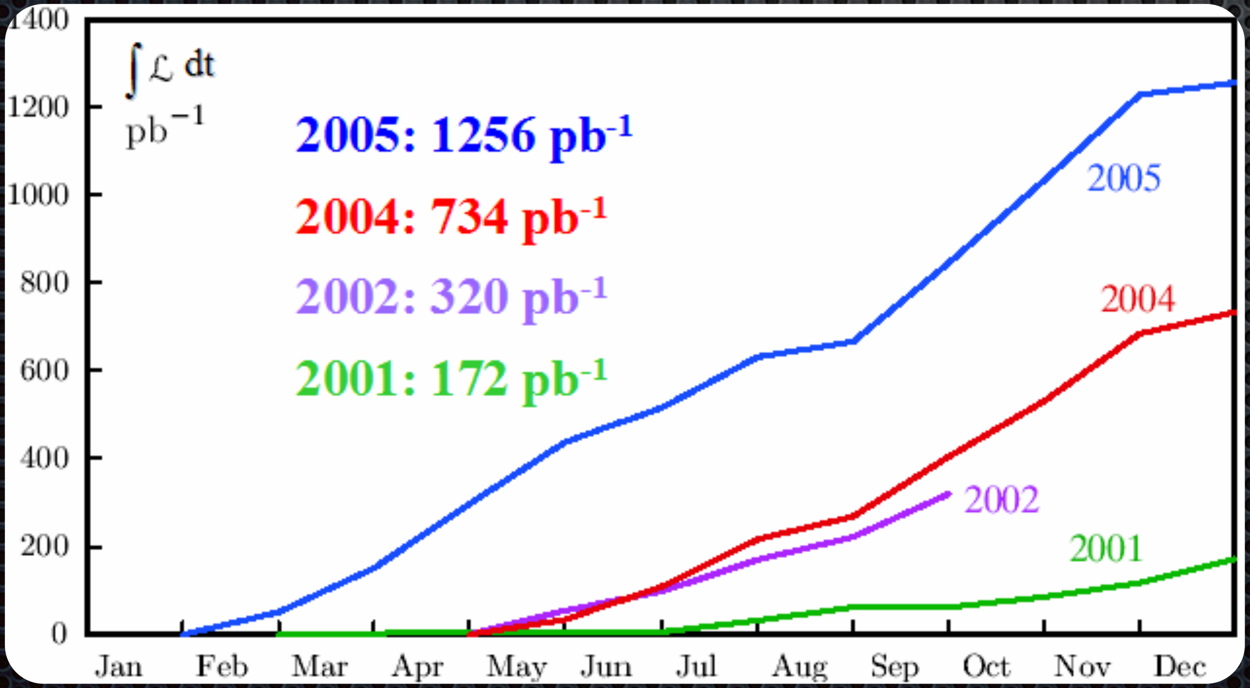


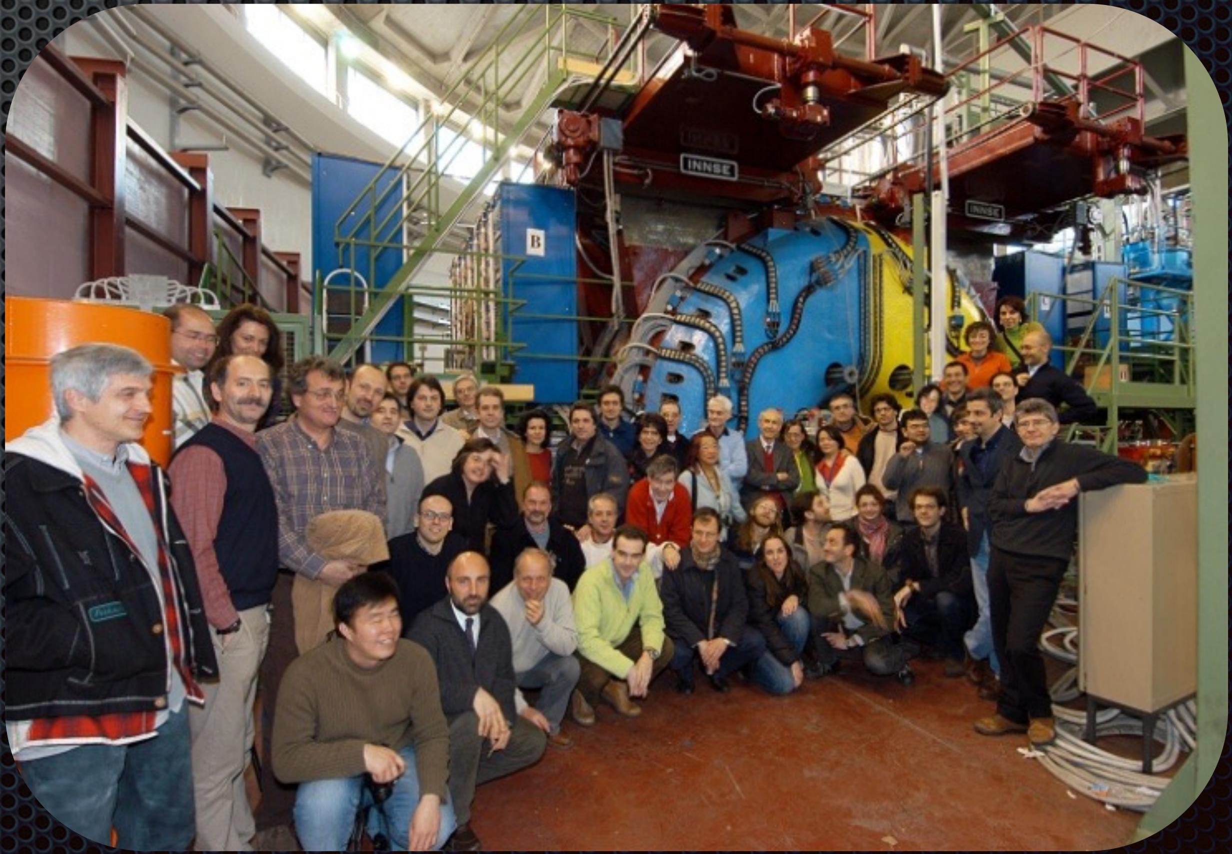
- KLOE has acquired 2.5 fb^{-1} @ $\sqrt{s}=M_\phi$ (2001-05)

+ 250 pb^{-1} off-peak @ $\sqrt{s}$=1 GeV

Precision Kaon and Hadron Physics with KLOE

[Rivista del Nuovo Cimento Vol.31, N.10 (2008)]



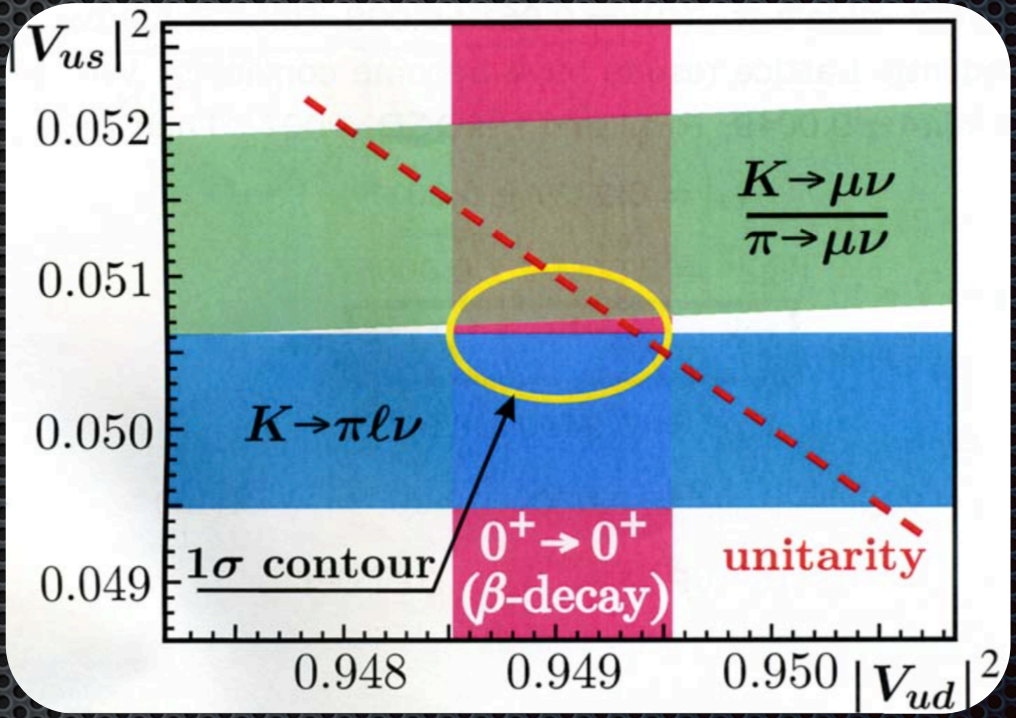


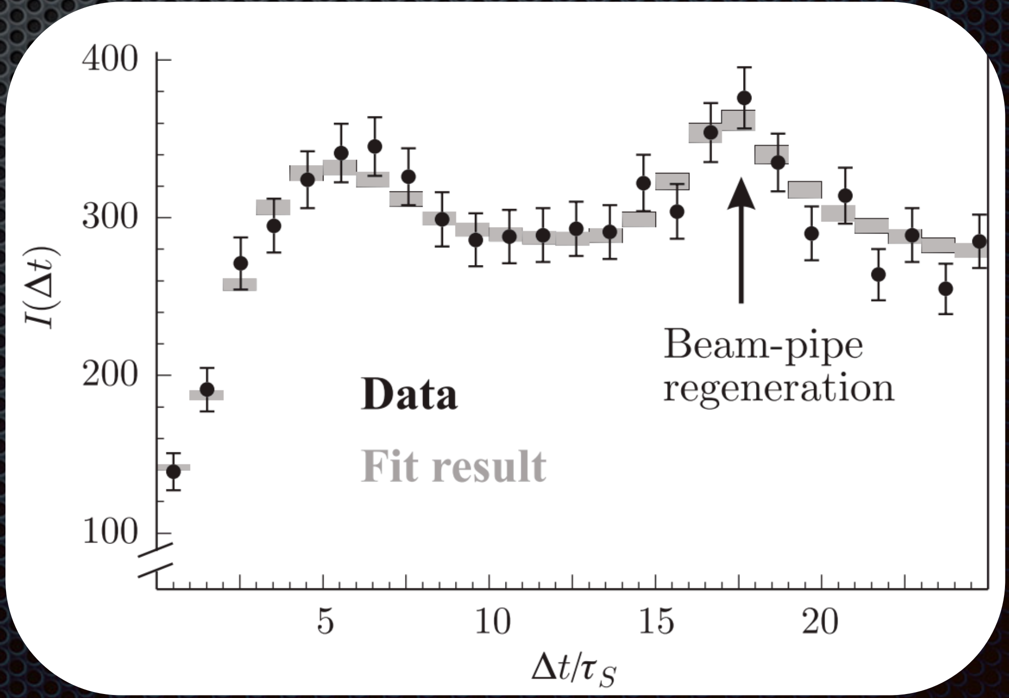
KLOE Physics (I)

"Siamo andati sul libro"

"After beginning with a trickle of beam, by 2006 KLOE had produced data of such precision that the kaon, the first fundamental particle to introduce the concept of "flavor" into our current way of thinking, got its definitive 21st century portrait re-mapped with high precision, 60 years after its discovery" [Rivista del Nuovo Cimento Vol.31, N.10 (2008)]

- At a ϕ-factory unique availability of pure K_S, K_L, $K^\pm$ beams *Absolute BRs*
- Measured all significant BRs of all kaon species, the K_L,K_S and K± lifetimes and form factors. We verified the validity of CKM matrix unitarity $1-V_{ud}^{\ 2}-V_{us}^{\ 2} = 4(7)\times10^{-4}$ @0.6σ and lepton universality. KLOE is the only experiment which measured all relevant inputs.
  Bounds on new physics in mass(H^+) vs tanβ plane complementary to B mesons
- Quantum interferometry, CPT and Lorenz symmetry invariance. First Observation of quantum interference in $\phi\rightarrow K_S K_L\rightarrow\pi^+\pi^-\pi^+\pi^-$



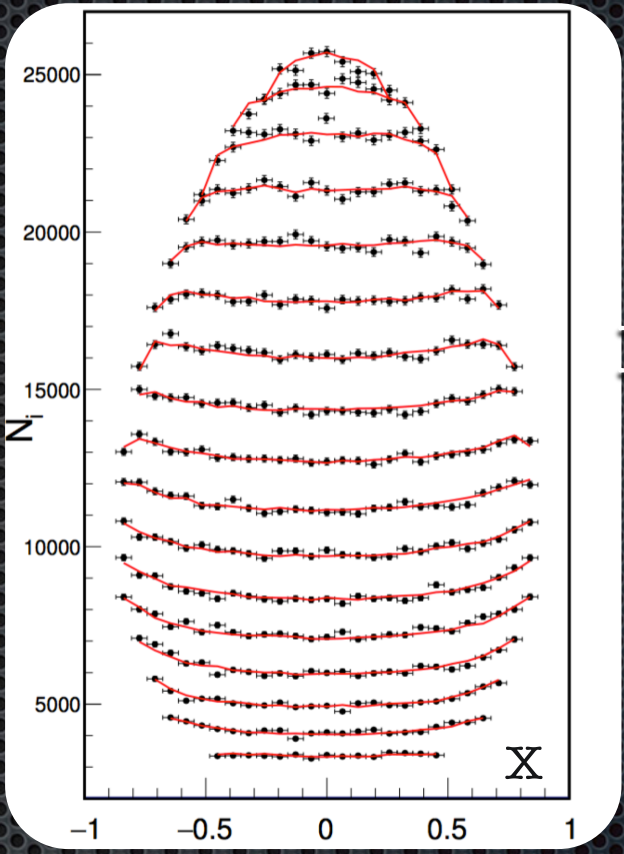


KLOE Physics (II)

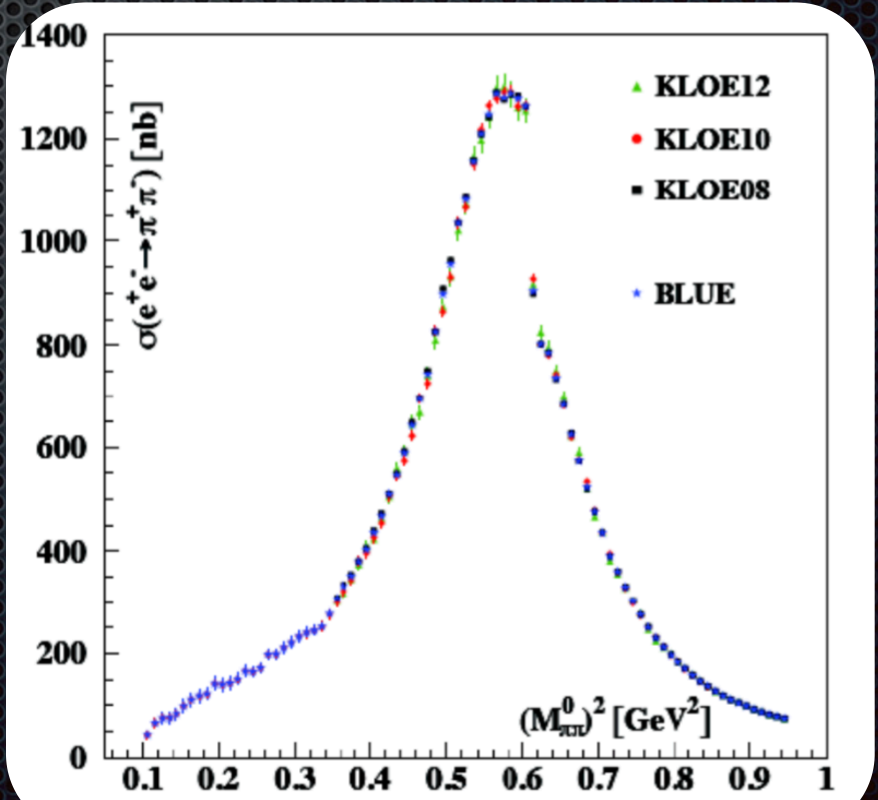
"Siamo andati sul libro"

Investigation at a ϕ–factory can shed light on several debated issues

- Radiative ϕ-meson decays to probe meson quark structure: η-η' mixing angle, gluonium f0-a0 composition.
  Studied properties of light scalar and pseudoscalar mesons with unprecedented accuracy. First limit ever on BR($\phi \to K_S K_S \gamma$)
- η-meson factory BR($\phi \to \eta\gamma$) = 1.3% searches for extremely rare or forbidden decays. Best limits to date on $\eta \to \pi^+\pi^-$ CPV and $\eta \to 3\gamma$ CV. $\eta \to \pi^+\pi^-\pi^0$ Dalitz Plot - world's largest sample
- Dark Photons @ GeV: $\phi \to \eta U$, $e^+e^- \to U\gamma$, $e^+e^- \to Uh$'
- Dipion cross-section, $\sigma_{\pi\pi}$, to evaluate a_μ-hadronic contribution to a^{SM}_μ pioneering the Radiative Return Method exploiting ISR.
  Three different measurements with different systematics confirm theo-exp 3σ discrepancy on g-2 ($\sqrt{s}$ = Mϕ, $\sqrt{s}$ =1 GeV, $\pi\pi\gamma/\mu\mu\gamma$)
  KLOE covers ~70% of total a_μ^{HLO} @ 1.0%



$\eta \to \pi^+\pi^-\pi^0$ Dalitz Plot
Light quark masses constraint



Filippo's Mentoring: Master & PhD thesis

"Non c'è bisogno di ricordarsi tutto, basta ricordarsi dove andare a guardare"

- Detector related
  - Drift Chamber prototypes
  - Drift Chamber Construction & Commissioning, Calibration
  - Trigger Design & Optimization
- Kaon Physics
  - CP, CPT symmetries
  - Neutral Kaon form factors, lifetime
  - Regeneration
  - Charged Kaon branching ratios
  - K_S rare decays
- Hadron Physics
  - $\eta \to \pi^0 \gamma\gamma$ ChPT golden mode
  - $e^+ e^- \to$ hadrons cross-section using radiative return technique
  - η-meson production in $\gamma\gamma$ interactions
  - scalar meson production in $\gamma\gamma$ interactions

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Scientific Writing Advices

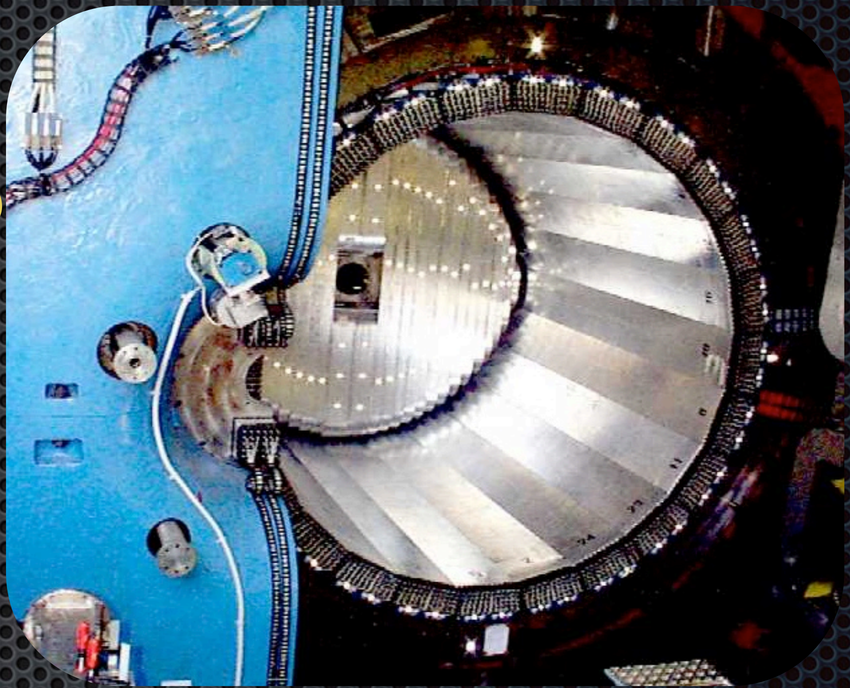
1. "Sciacquare I panni in Avon"
2. "Non vessare il povero lettore"
3. Sintesi & Precisione

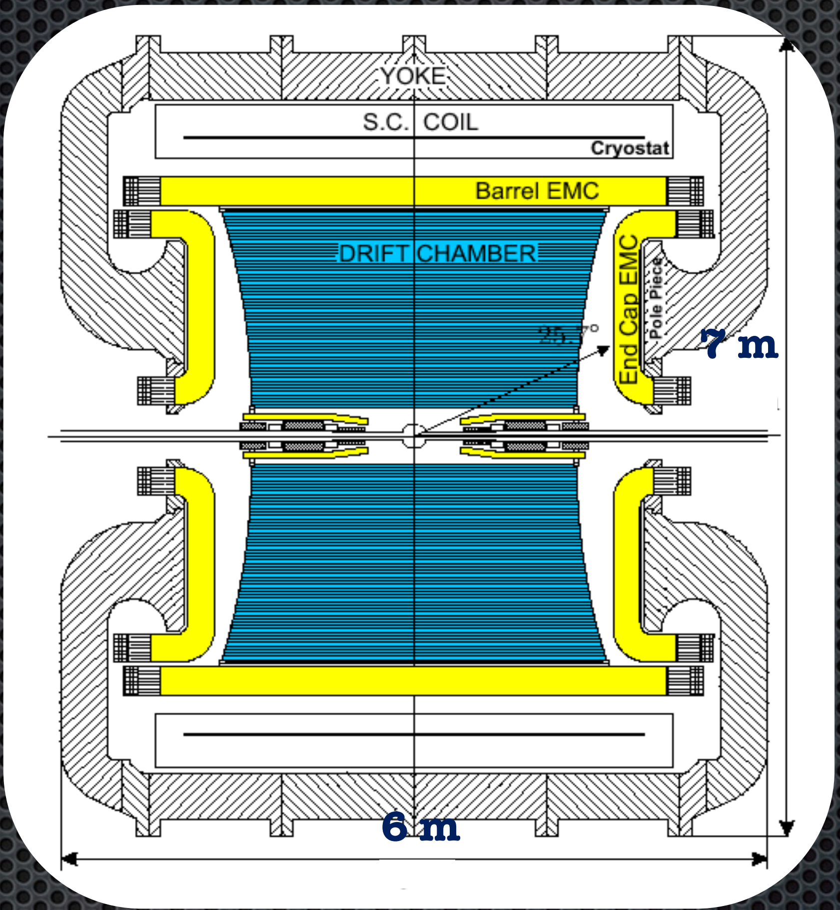
Sometimes with Side Effects

KLOE-2 at DAφNE: the new challenge

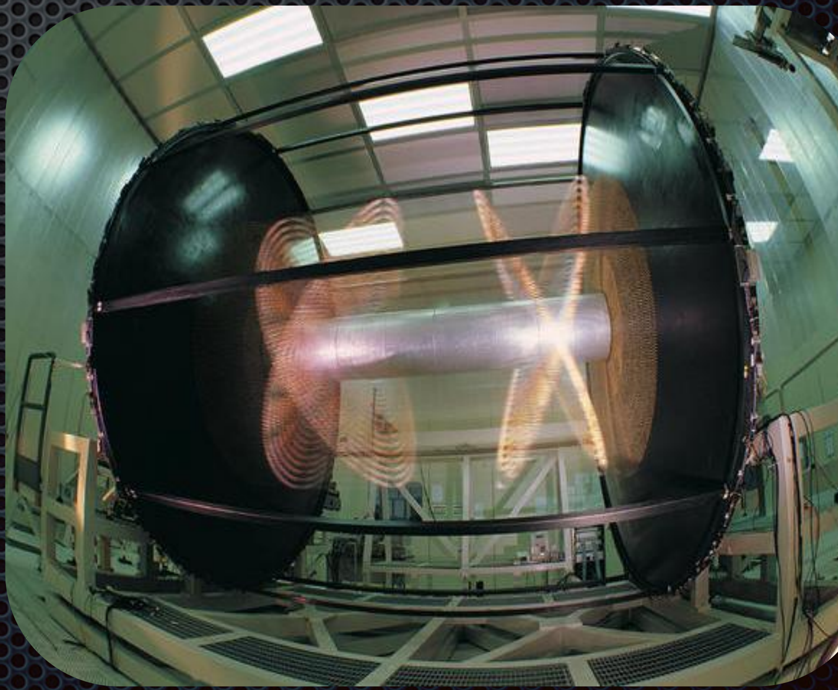
- Calorimeter System
  - EMC – Lead / Scintillating Fibers w PMT

$\sigma E/E = 5.7\% / \sqrt{E(GeV)}$
$\sigma t = 54\ ps / \sqrt{E(GeV)} \oplus 140\ ps$
$\sigma vtx(\gamma\gamma) \sim 1.5$ cm (vertex reso)





- Tracking System
  - DC – He-Iso 90-10 3.7m x 4m Drift Chamber

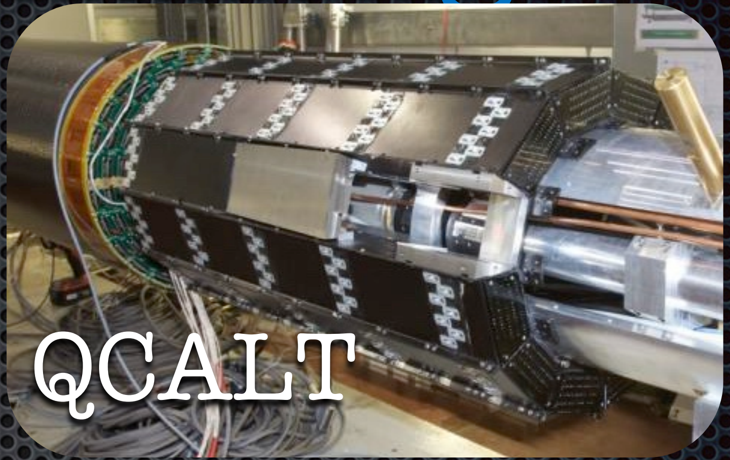


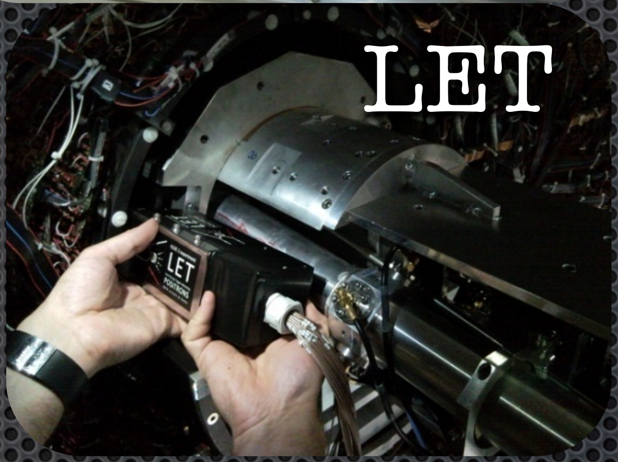
- Superconductive Magnet
  - 0.52 T solenoidal field
- DAFNE φ-factory
  - $e^+ e^-$ at 1020 MeV

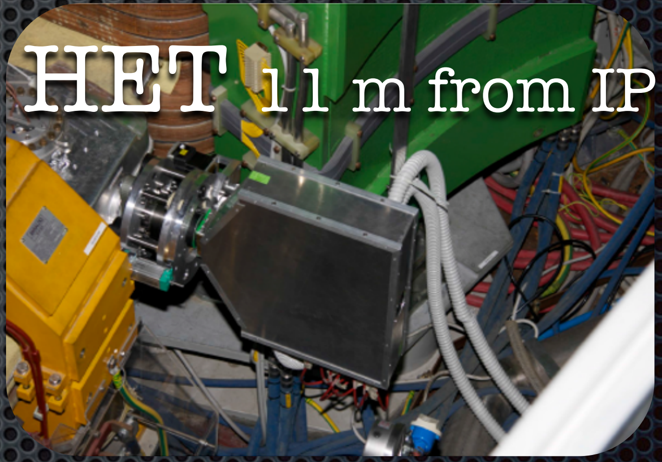
$\sigma p/p = 0.4\ \%$ ($\theta track > 45°$)
$\sigma hit = 150\ \mu m$ (xy), 2 mm (z)
$\sigma vertex \sim 3$ mm

KLOE-2 at DAϕNE: the new challenge

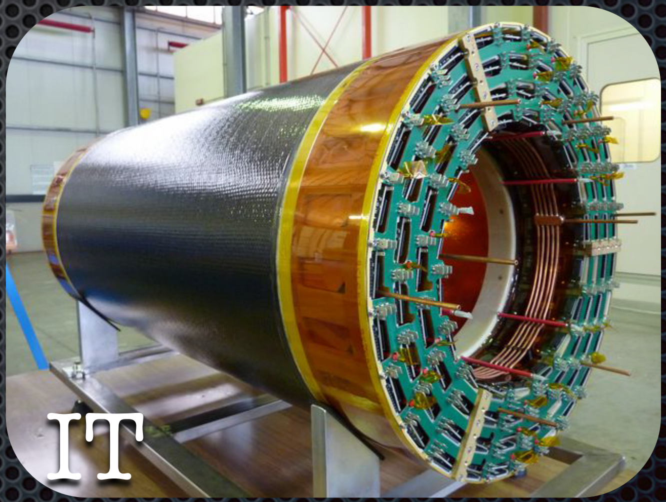
- Calorimeter System
  - EMC – Lead / Scintillating Fibers w PMT Barrel and Endcaps
  - CCALT – LYSO Crystal w SiPM – Low- beta
  - QCALT – Tungsten / Scintillating Tiles w SiPM - Quadrupole Instrumentation
  - LET / LYSO+SiPMs
  - HET / Scint+PMTs







- Tracking System
  - DC – He-Iso 90-10
    3.7m x 4m Drift Chamber
  - Inner Tracker – 4 Cylindrical GEM detectors

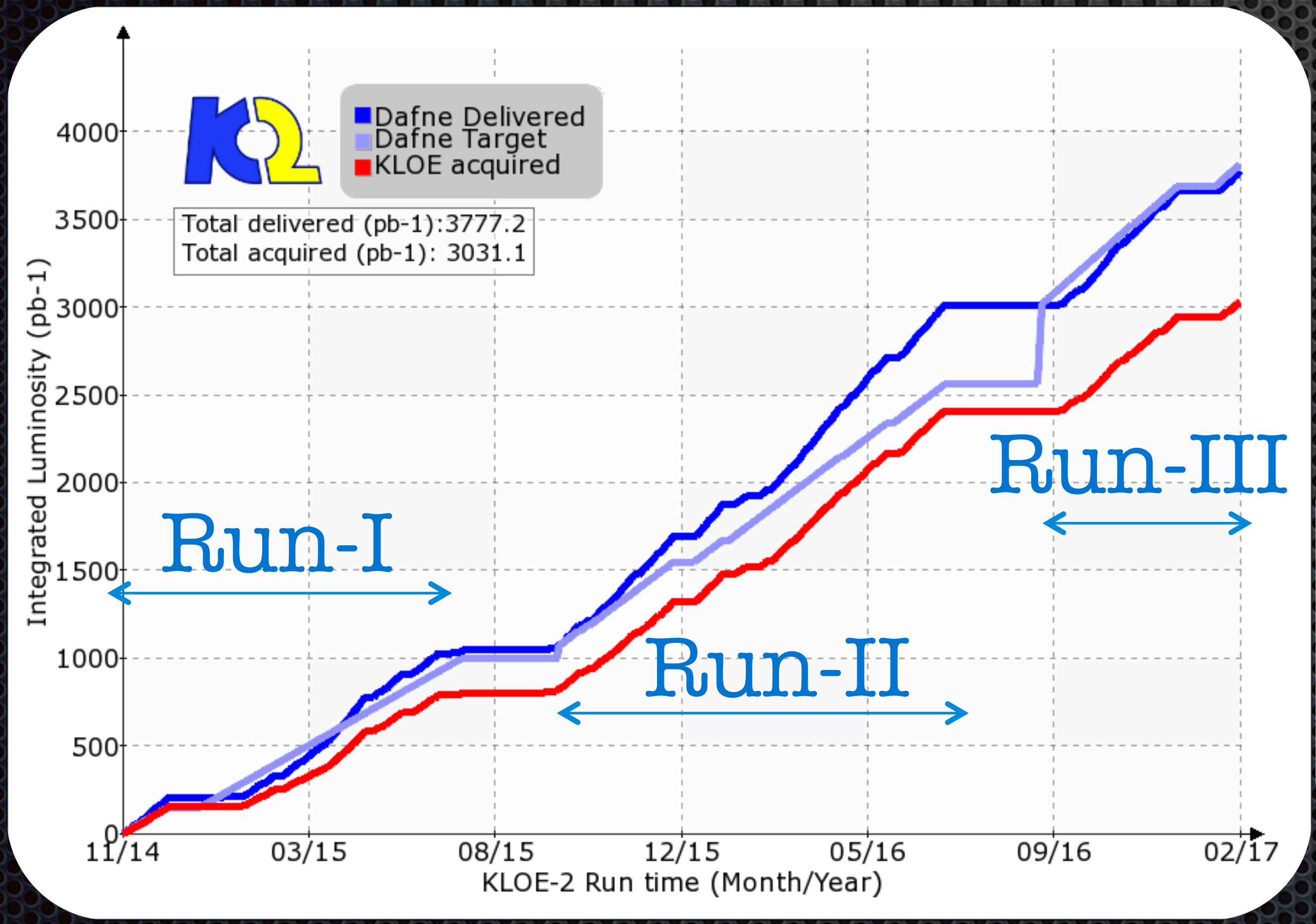


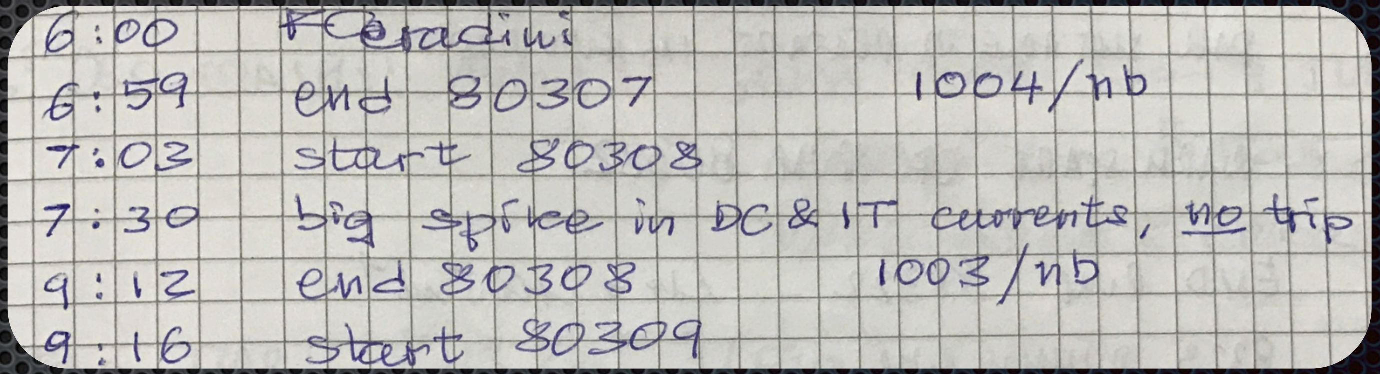
- Superconductive Magnet
  - 0.52 T solenoidal field
- DAFNE φ-factory
  - $e^+ e^-$ at 1020 MeV

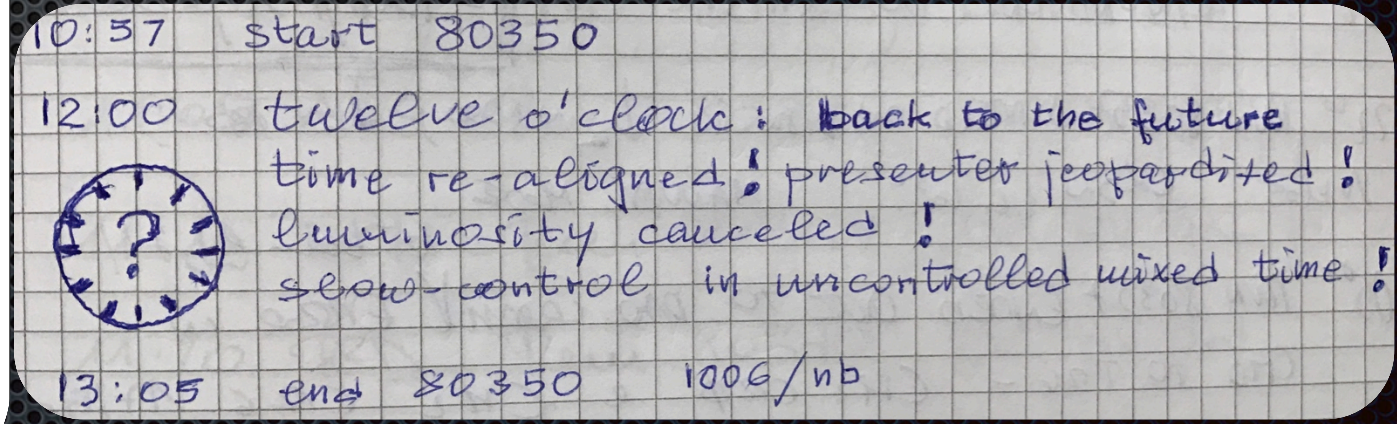
- Physics program [EPJC 68 (2010)]
  - Ks, η, η_S rare decays
  - Quantum Interferometry
  - Dark photon search

KLOE-2 Run: sempre sul pezzo!

- KLOE-2 Run started in November 2014
  Daily record 16/04/2016: 13 (11.0) pb^{-1} delivered (acquired)
  Peak Luminosity: $2.2 \times 10^{32}\ cm^{-2}\ s^{-1}$
- 3.0 (2.4) fb^{-1} delivered (acquired) Run-I + Run-II
- Run-III started September 2016 – Target >= 5 fb-1 by March '18







F. Ceradini on shift

KLOE-2 Run: sempre sul pezzo!

- KLOE-2 Run started in November 2014
  Daily record 16/04/2016: 13 (11.0) pb^{-1} delivered (acquired)
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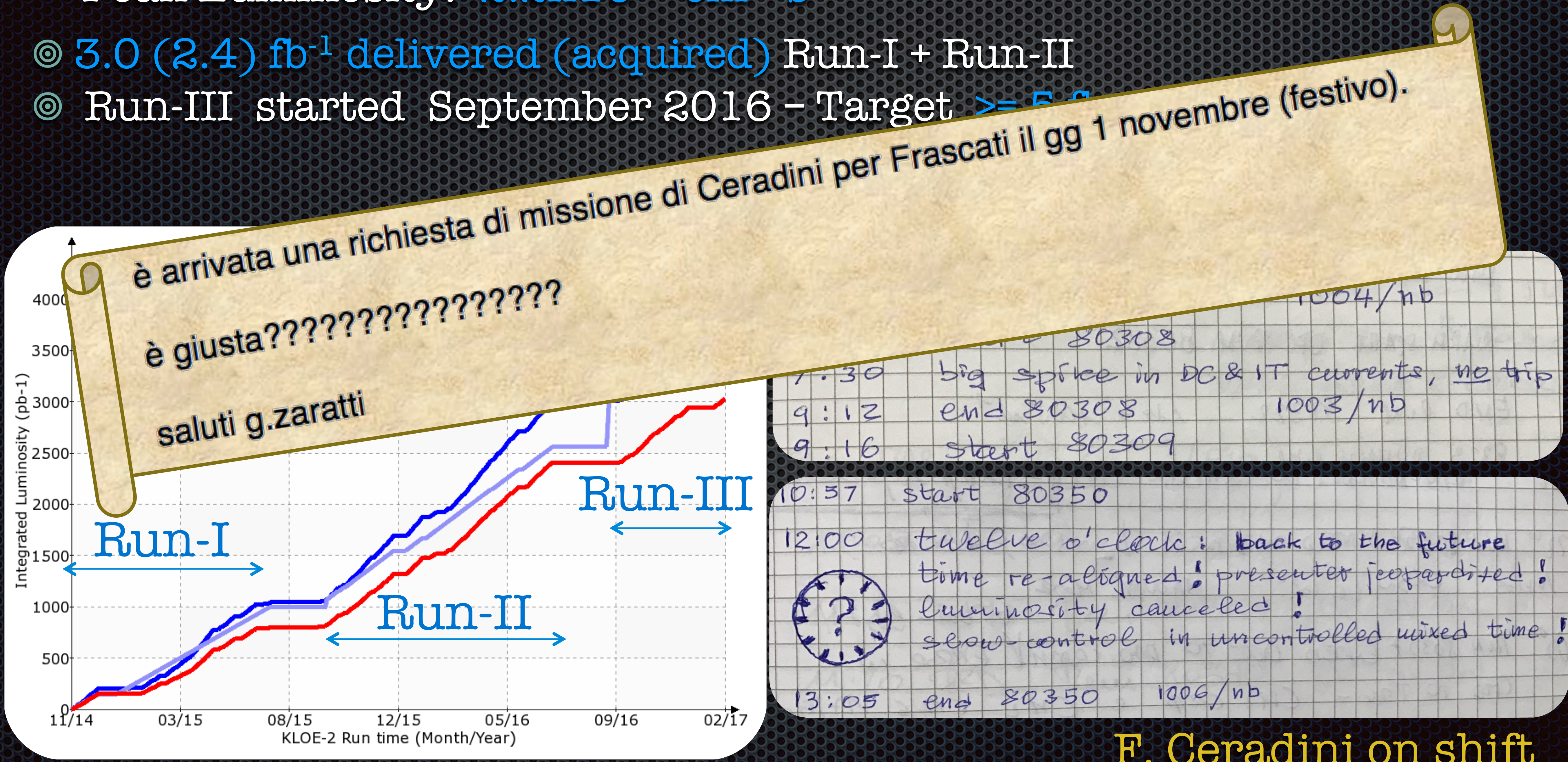
- Run-III started September 2016 – Target >= 5 f



F. Ceradini on shift

Filippo's Legacy


G. Lanfranchi


E. De Lucia


B. Sciascia


A. Ferrari


M. Palutan


F. Bellini


F. Nguyen


B. Di Micco


S. Bocchetta


D. Capriotti


L. Aperio Bella


C. Taccini


I. Prado Longhi


S. Loffredo


A. Di Cicco


A. Selce


curiosity
sagace
persistent
preciso
meditativo
imperscrutabile
physics-lover
inesorabile
inflessibile
saggio
sornione
smiling
pignolo
rigore
competent
competente
prudente
affidabile
autorevole
accademico
concreto
saggio
preciso
meditativo
rigore
persistent
sagace
autorevole
curiosity
sornione
inesorabile
imperscrutabile
pignolo
competent
smiling
prudente