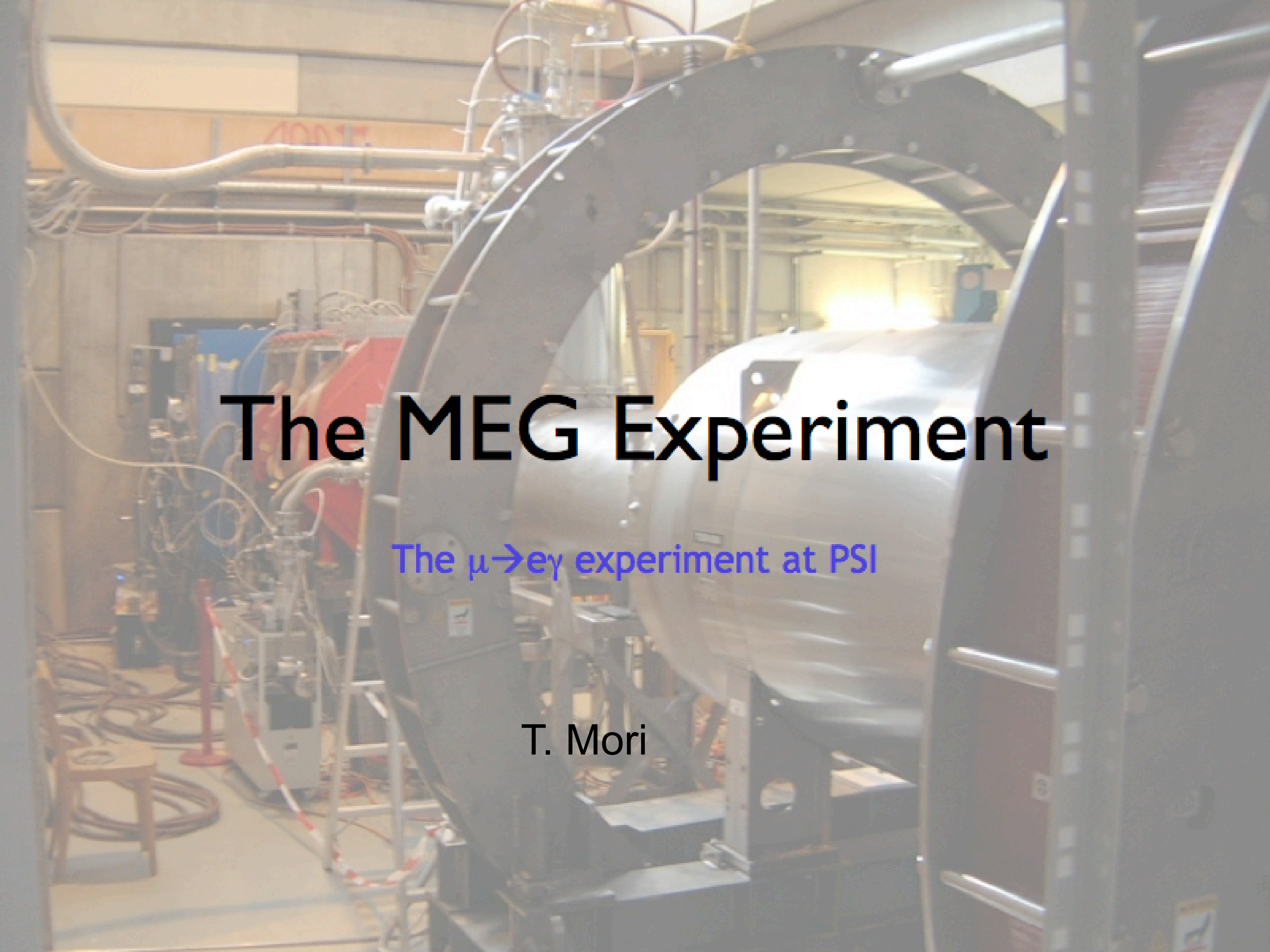


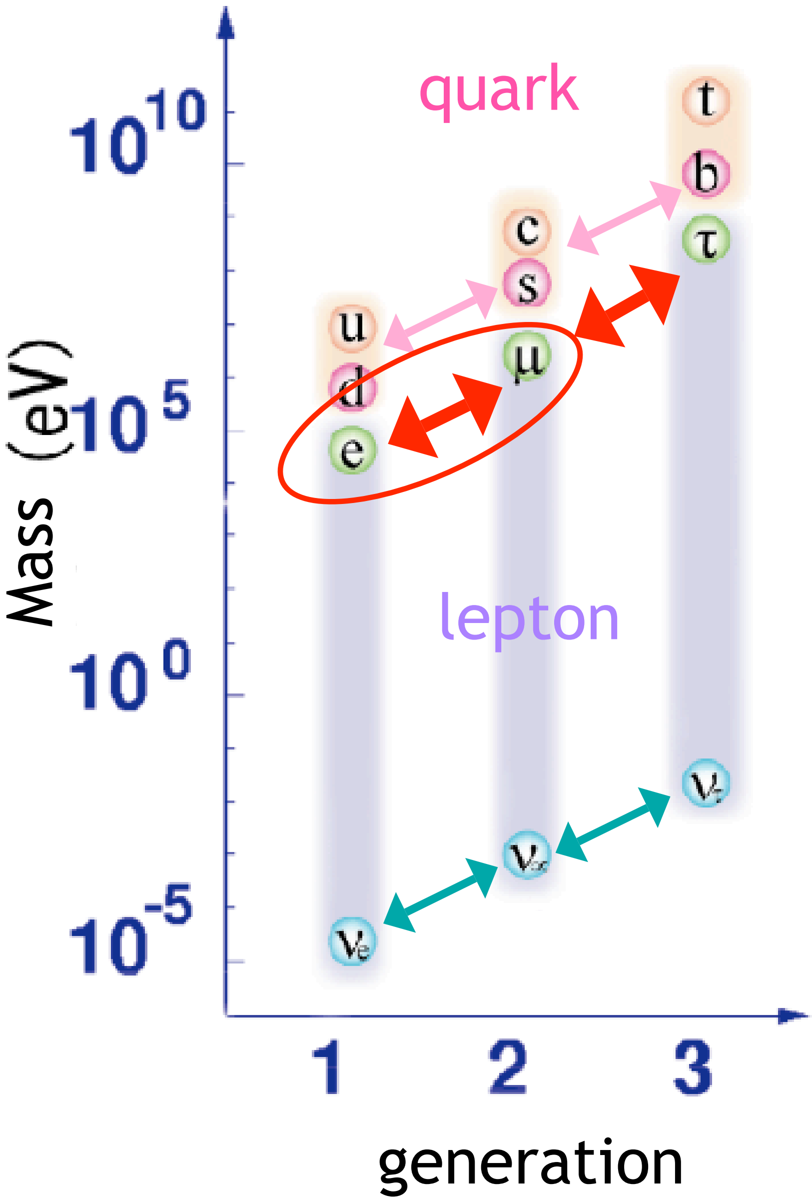
# The MEG Experiment

## The $\mu \rightarrow e\gamma$ experiment at PSI

T. Mori

What is MEG going to do?

What is $\mu \rightarrow e$ ?




Quark Mixing : B factories etc

Unification of quarks and leptons (GUT)

**Charged Lepton Must Also Mix!**

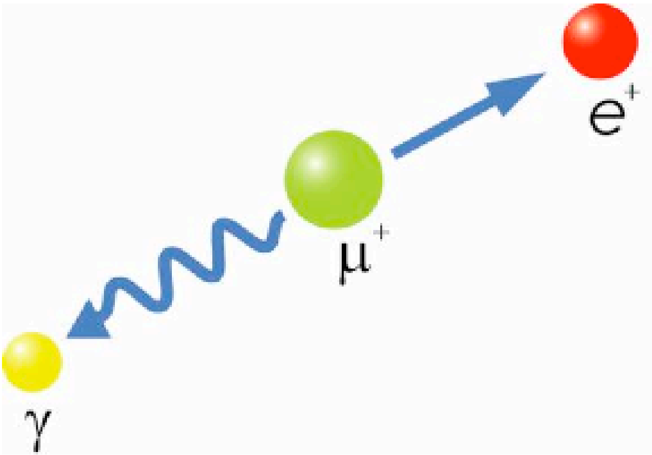
**$\mu \rightarrow e$ : most sensitive**

Seesaw mechanism to make neutrinos light

Neutrino Oscillation : SuperK etc

Explores GUT/seesaw via SUSY

# $\mu \to e\gamma$




Good detector system
Is essential

Clear 2-body kinematics

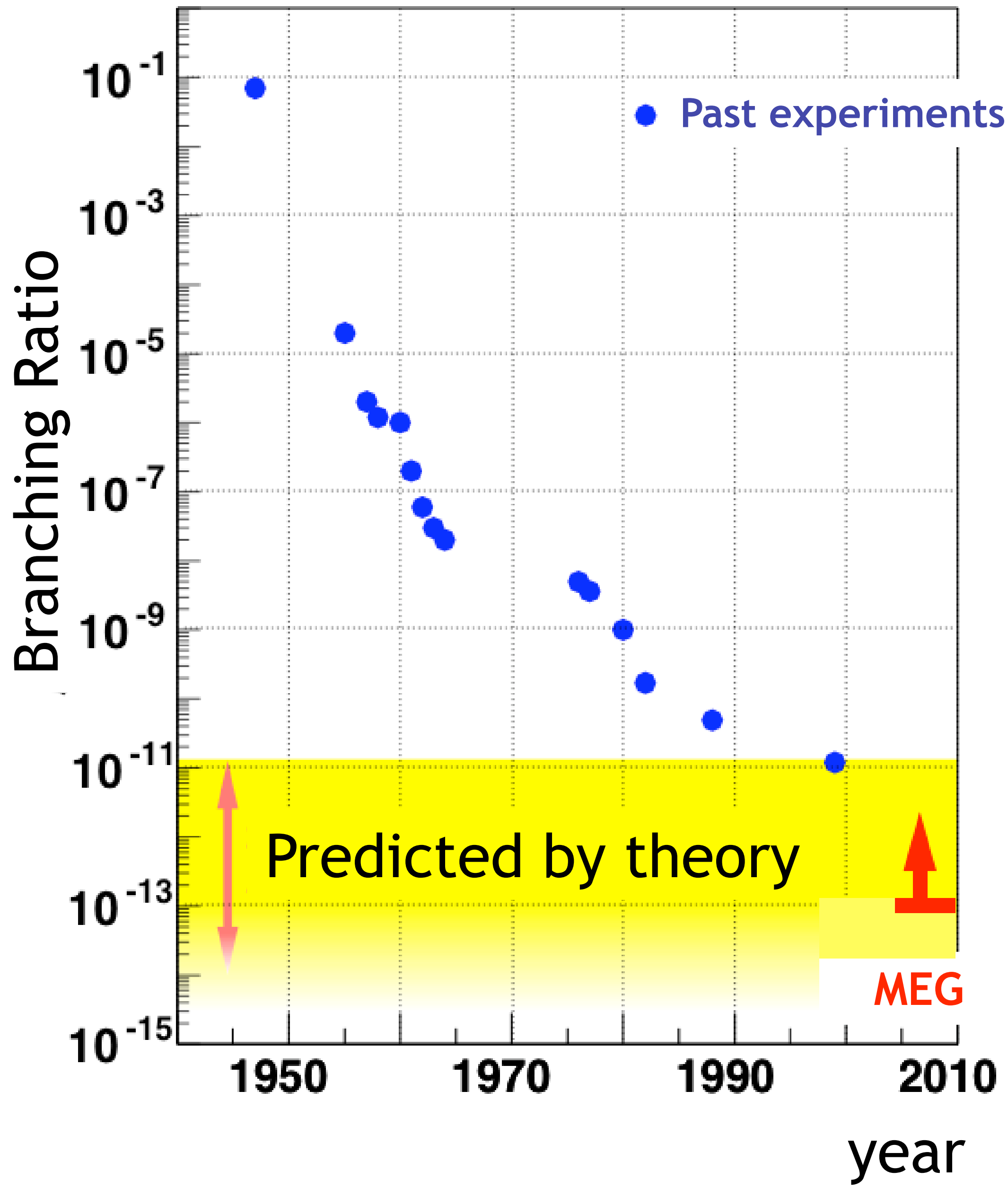
Use $\mu^+$ to avoid capture
inside stopping target

Background dominated by
Accidental coincidence

→ lower $\mu$ rate is better

→ DC $\mu$ beam is best

"surface muon beam":
100% polarized




Aiming at
BR of $10^{-13}$

~$10^7$ muons /sec

very high rate
experiment

# The MEG Collaboration

Japan, Italy, Switzerland, Russia, USA

NEW

Spokespersons: T.Mori, A.Baldini

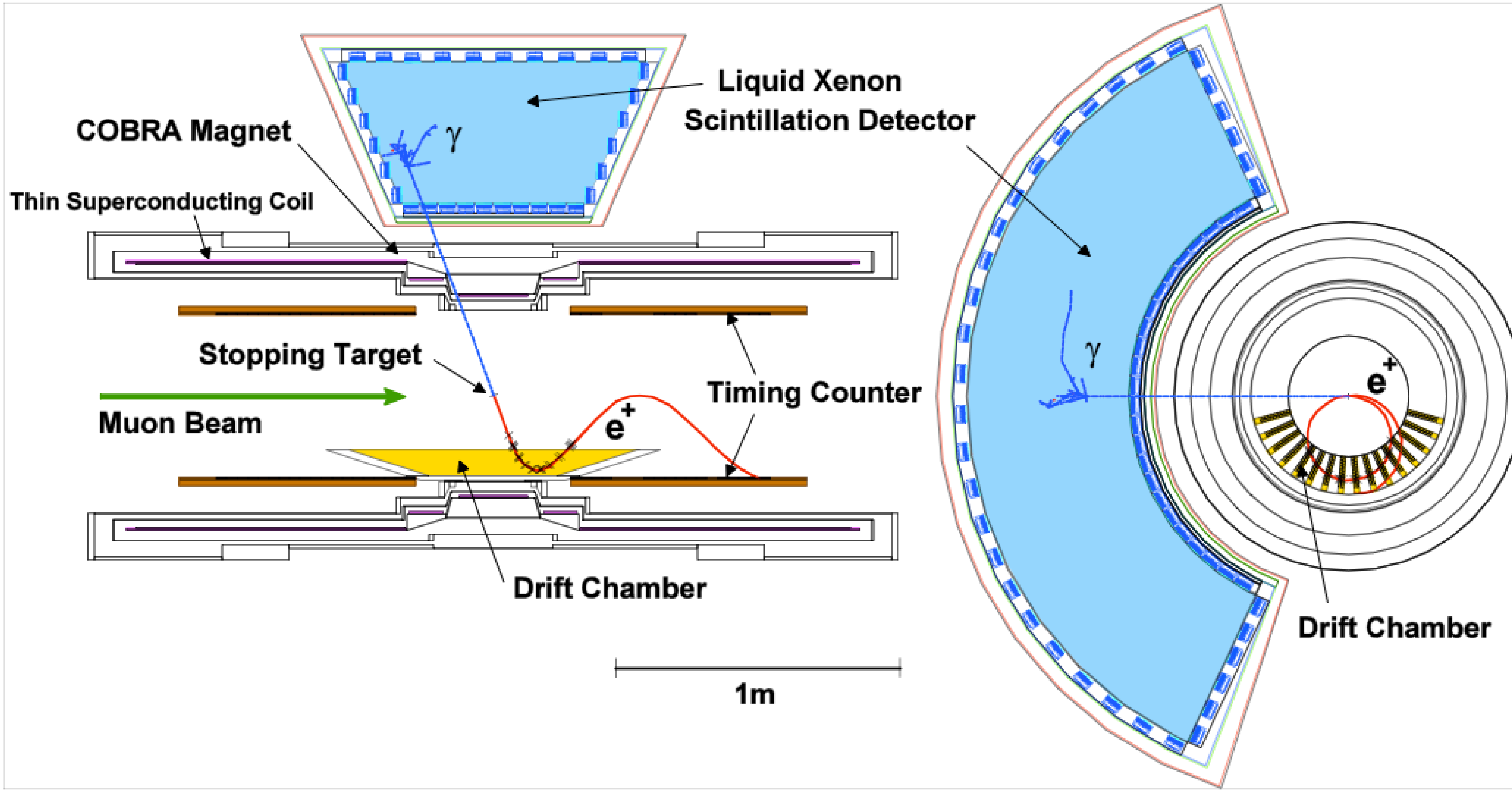
Technical Coordinator: S.Ritt

Detectors:

| | | |
|---|---|---|
| • Beam line: | PSI | P.-R.Kettle |
| • COBRA: | KEK/Tokyo | W.Ootani |
| • Drift Chamber: | PSI | J.Egger |
| • Timing Counter: | Genova/Pavia/Roma | G. Cecchet |
| • Photon Detector: | Tokyo/Pisa/KEK | S.Mihara |
| • Trigger: | Pisa | M.Grassi |
| • DAQ/Elec.: | PSI | S.Ritt |
| • Offline: | S.Yamada/F.Cei/R.Sawada/M.Schneebeli | |

NEW

# The MEG Detector




Beam: intensive focused DC muon beam ($10^8$,~2cm$\phi$)

$e^+$: COBRA(gradient B) + DC ($p,\phi,\theta$) + TC(t)

Gamma: LXe scintillation detector

# Background and Sensitivity

| | Jan 2004 | Jan 2005 |
|---|---|---|
| Gamma Energy (%) | 4.5-5.0* | |
| e+ Timing (nsec) | 0.1* | |
| Gamma Timing | <0.23* | ~0.15** |
| Gamma Position (mm) | 4.5-9.0* | |
| Gamma acceptance | >0.4* | |
| Muon rate ($10^8$/sec) | 0.2-0.3 | 0.25-0.35 |
| Running Time ($10^7$sec) | 4.0 | |
| Accidental Rate ($10^{-14}$) | 2.3-3.5 | 1.9-3.0 |
| # Accidental Events | 0.6 | 0.6 |
| 90% CL Limit ($10^{-13}$) | 1.2-1.7 | 0.9-1.4 |

* Measured **w/ new PMTs

More detailed calculations are coming!
(Physics Meeting in Tokyo, this March)

## People getting more & more serious about MEG:

A number of theoretical studies under way

a year long workshop:

**"Flavour in the Era of the LHC"**

interplay of flavour and collider physics

e.g. SUSY benchmark point study w/ MEG & LHC,

Extra D theory w/ neutrino oscillation (LFV)

MEG's importance emphasized at
Open Symposium on
European Strategy
for Particle Physics Research
by CERN Council Strategy Group

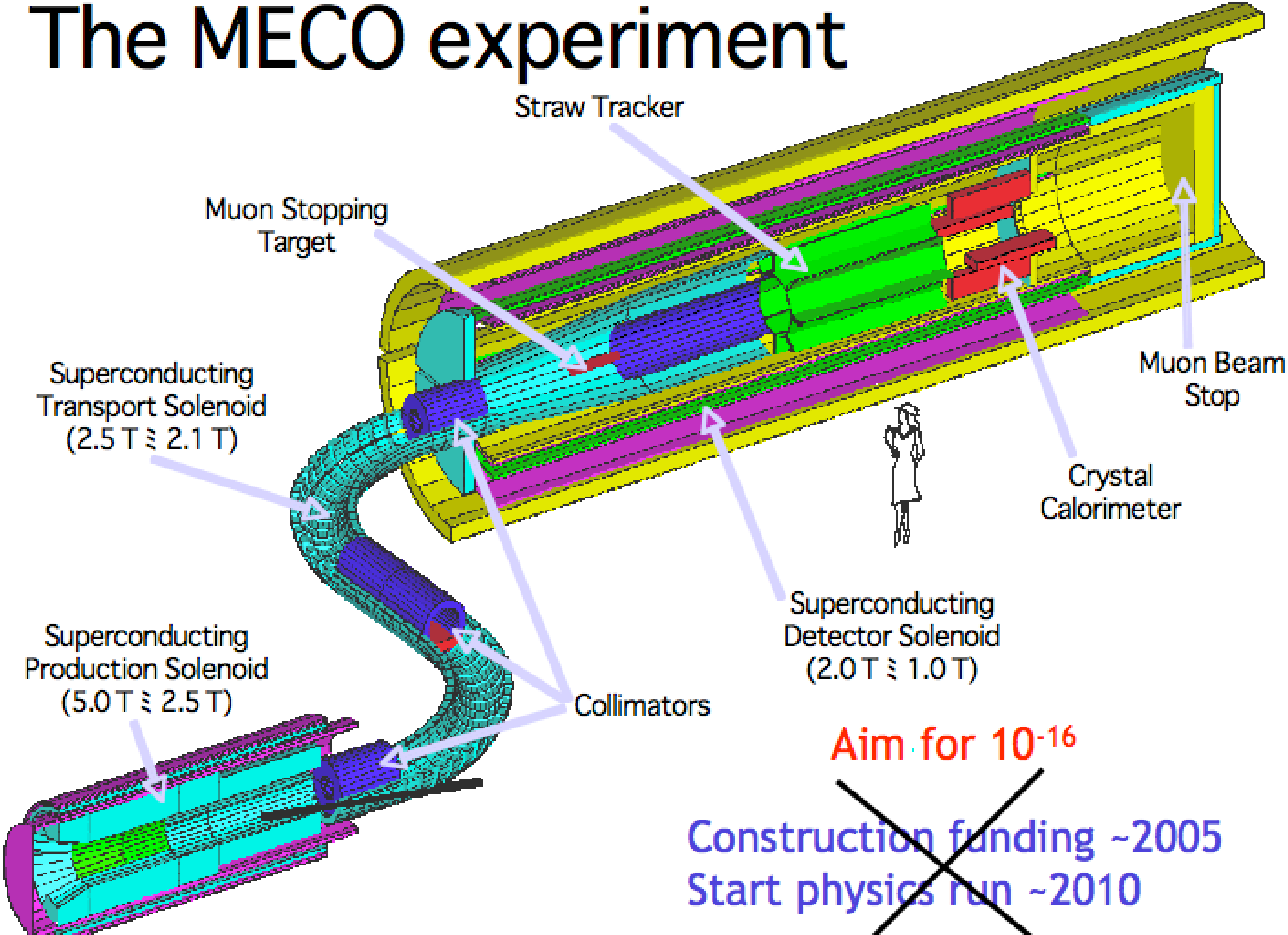
MEG is now
CERN's "Recognized Experiment" RE12

# Summary of my talk

- What have happened since the last BVR

- Steps to take toward $\mu \rightarrow$ **e** discovery

# The MECO experiment




Aim for $10^{-16}$

~~Construction funding ~2005~~
~~Start physics run ~2010~~

CANCELLED

# Highlights during the last one year

## Beamline:

Muon beam successfully tuned down to the target region

## COBRA magnet:

All problems about the fringing field have been solved

## LXe Detector:

More than 800 phototubes have been tested; more to come

Cryostat & PMT support are being (slowly) constructed

## Drift Chamber:

The first chamber has been assembled for various tests

## Timing Counter:

Production getting underway

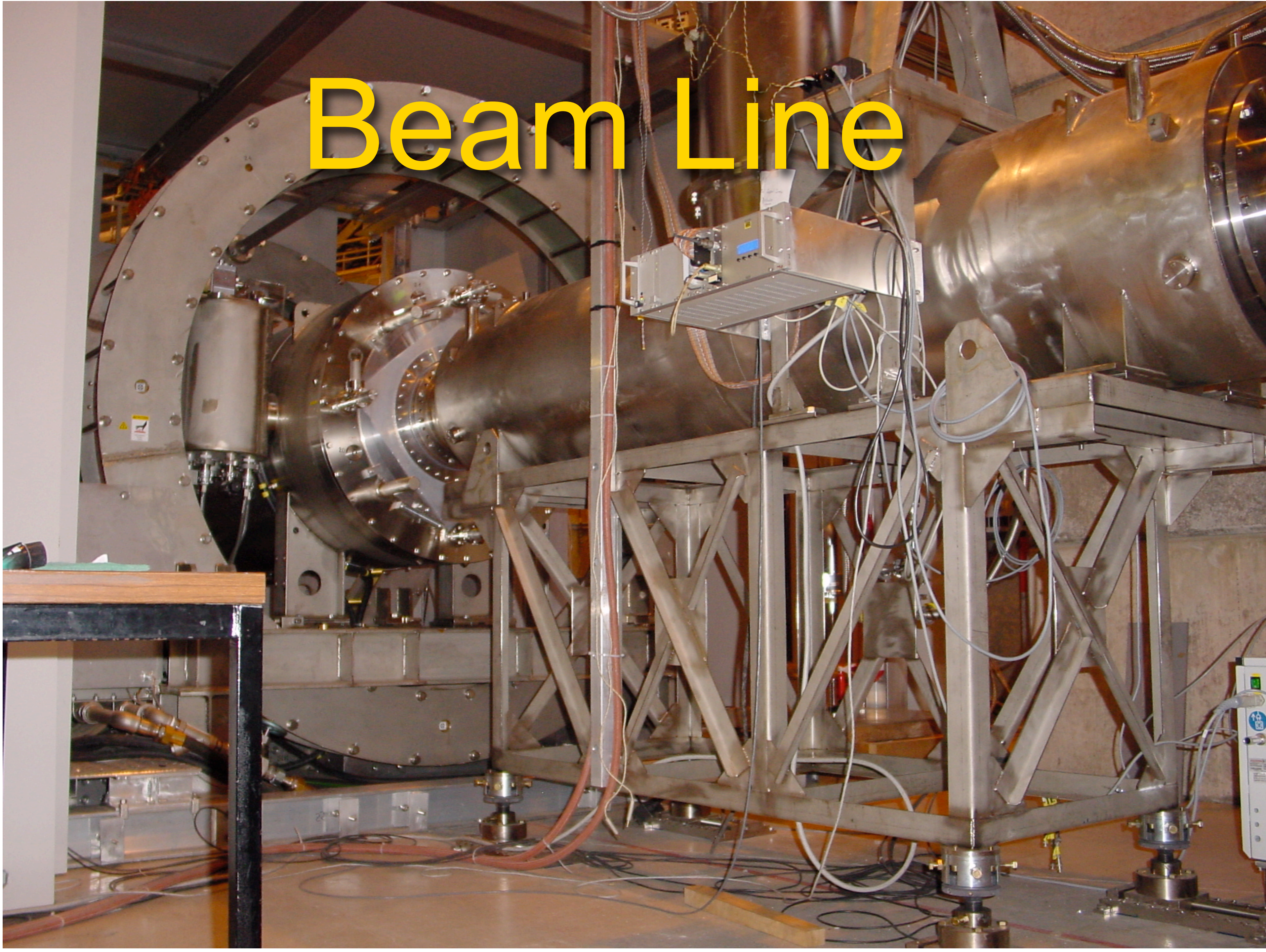
## DAQ & Electronics:

Prototypes successfully tested; getting into production soon

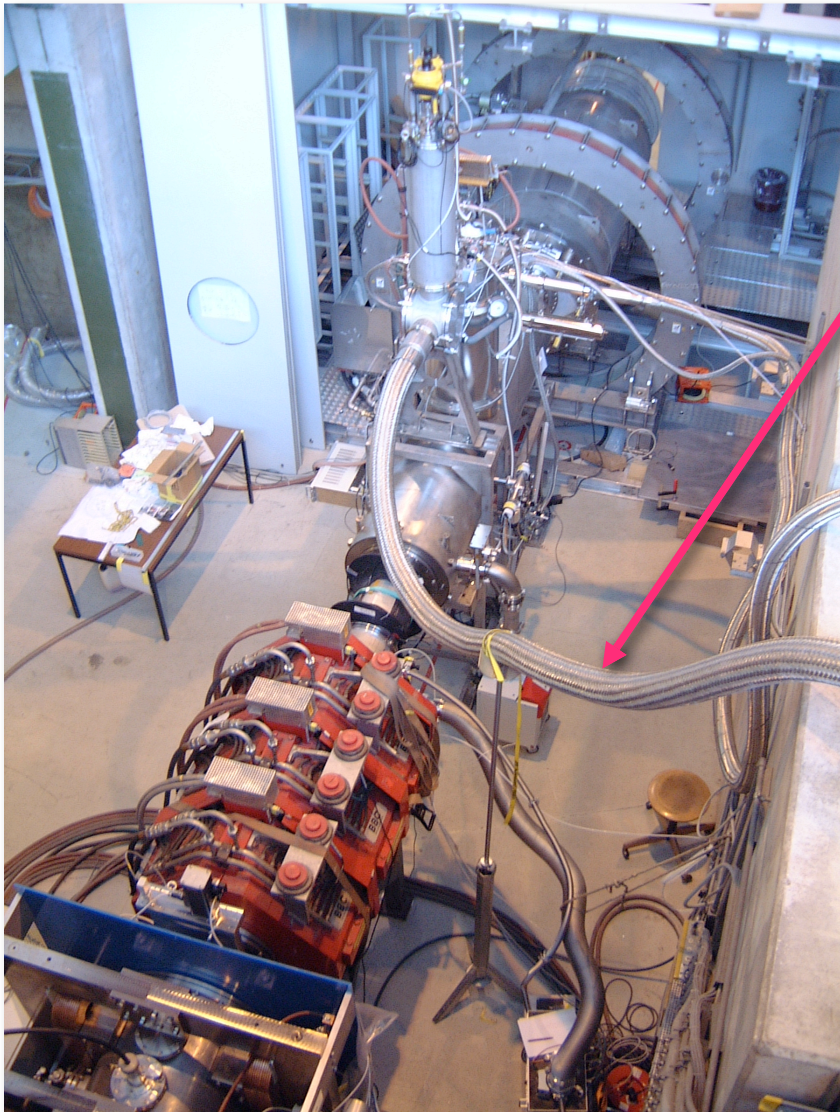
## Offilne:

Framework & new organization established

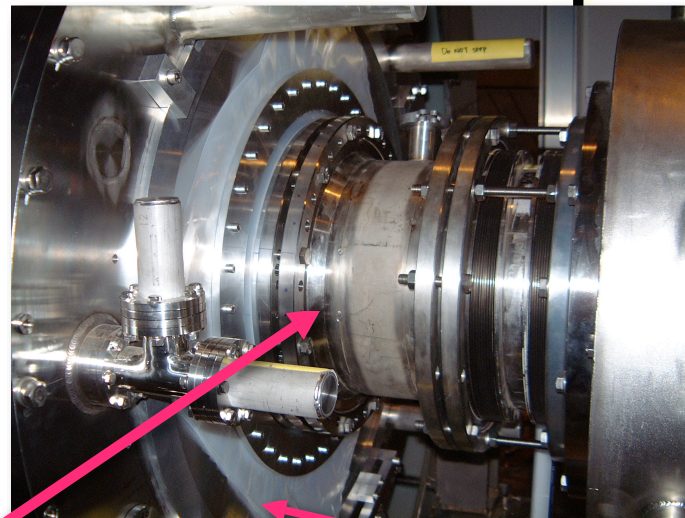
# Beam Line



# COBRA Injection Test Setup

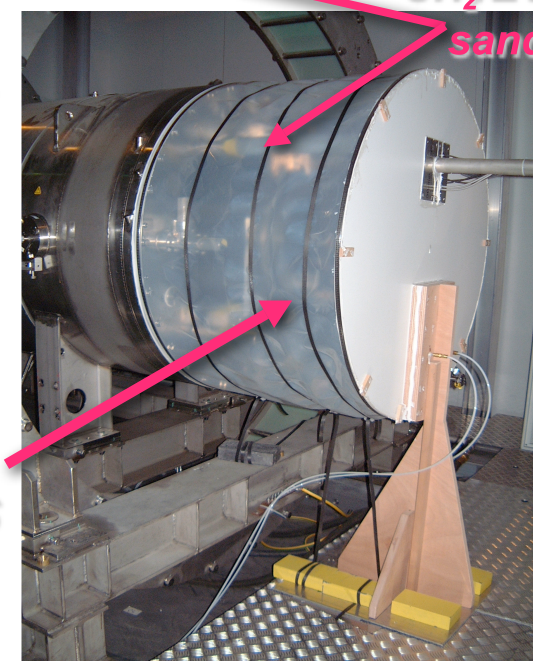


LHe From Cryo. Plant



BTS-COBRA Improvised Connection +He-Bag US

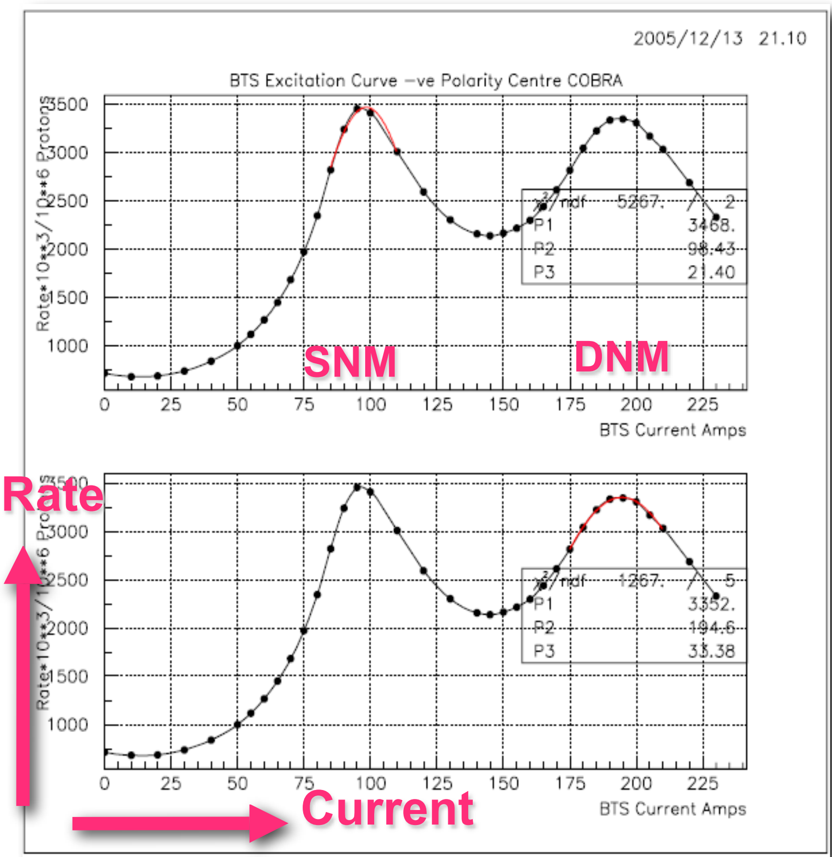
$CH_2$/EVAL/$CH_2$ sandwich

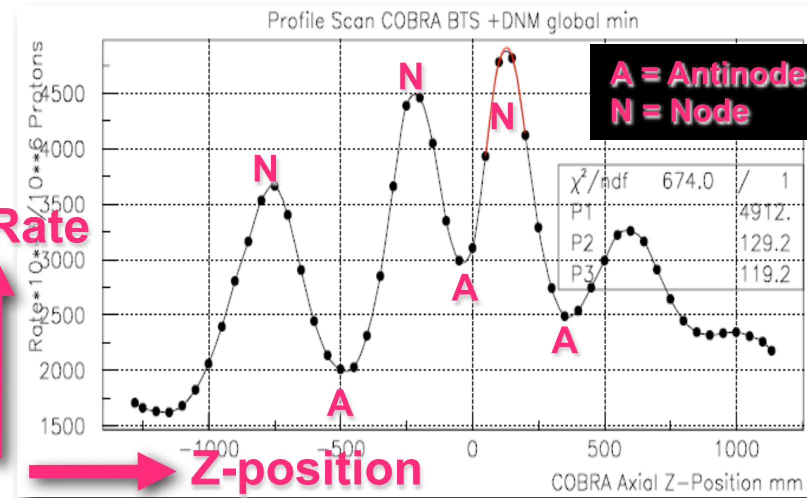


Improvised +He-Bag DS

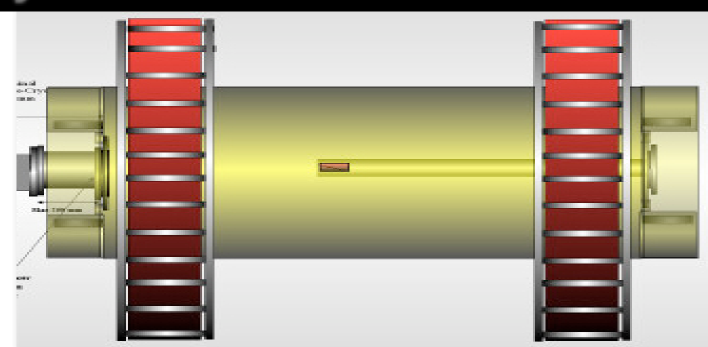
# Provisional Results Centre COBRA

**COBRA Axial z-scan (No Degrader)**




**Very similar to GEANT Predictions**



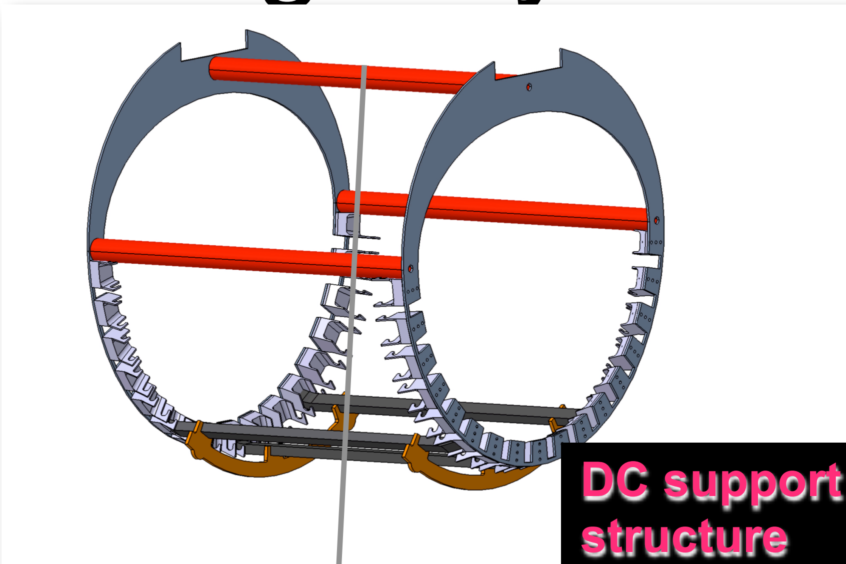
**BTS-Excitation Curve to focus beam in COBRA "unlike -+" Polarity**

**Measured Rate at Centre COBRA**
**(Dependent on mode)**

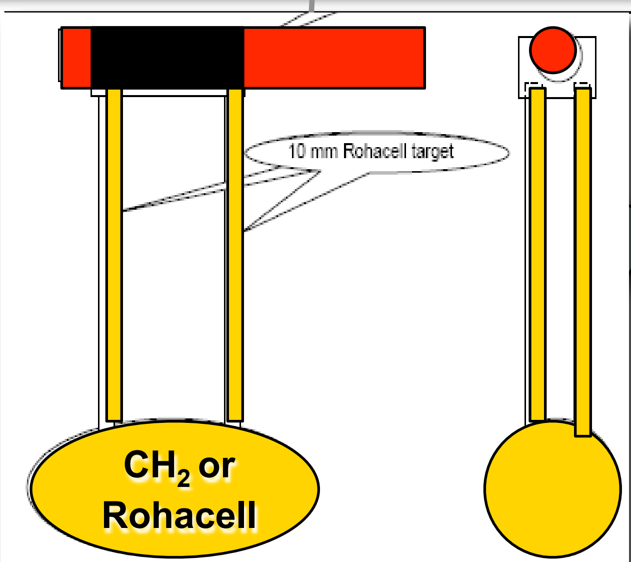
$R_\mu \sim (1.15 - 1.19) \cdot 10^8\ \mu^+\ s^{-1}$ at 1.8mA & 4 cm Tg.E

More than enough for MEG

# Target system



DC support structure




**Various solutions under study: UCI/PSI/KEK**

**Permanent Muon Target**
- Rohacell foam/$CH_2$ combination
- Complete Rohacell
- $CH_2$ or polystyrene Target + wire frame

**Support**
- from DC frame- rotatable or translational

Prototypes be investigated at UCI

**Position monitoring**

Idea of using several holes in target⇨ x,y,z

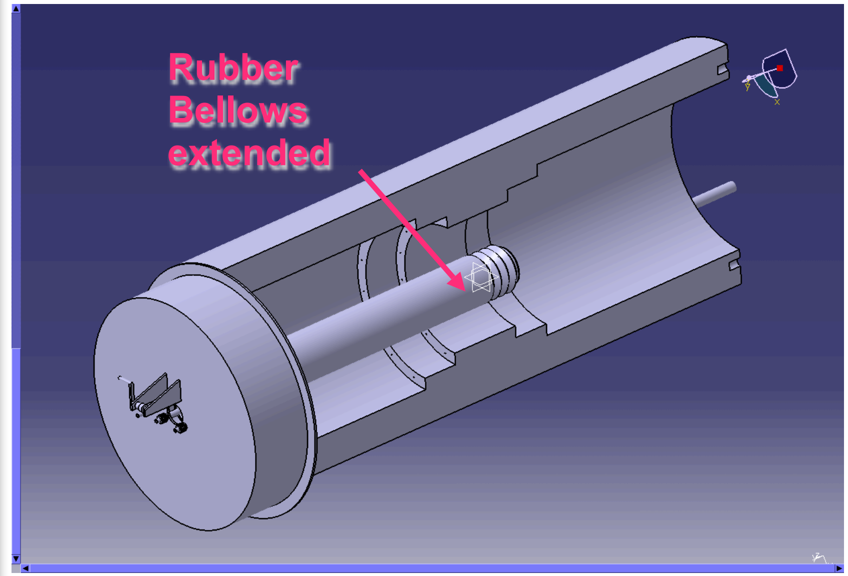
- Monte-Carlo simulations: - underway
- check of optimum target inclination wrt. Energy-loss, multiple scattering, high/low-energy photon generation, momentum resolution, DC/TC-efficiency
- effect of thicker solid Rohacell target as well as support structute on vertex & angular reconstruction resolution + timing resolution and back-ground generation

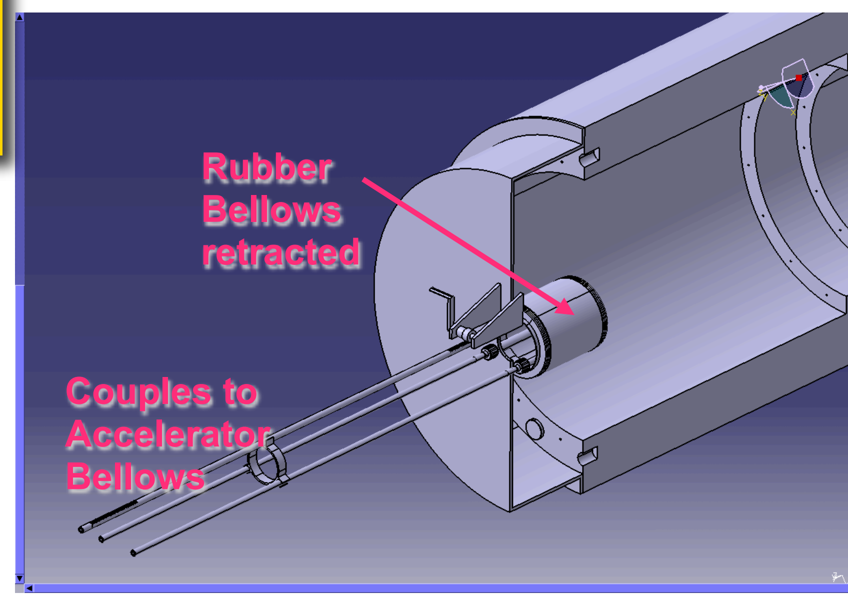
Others: Polarization data Rohacell

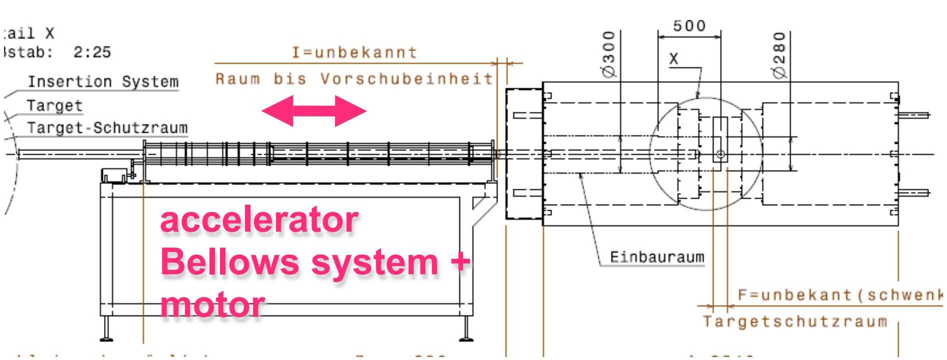
# Insertion System

**Insertion System:**

- telescopic triple-rod system with NBR rubber bellows 1mm thick outer dia. ~ 270 mm inner dia 170 mm
- attached to DS-end-cap & retractable into end-cap flange
- allows insertion up to z = -150 mm
- allows proton beam-pipe, $LH_2$-target, beam monitor as well as possible future devices to be inserted with minimal disturbance of COBRA He-environment
- motor driven via accelerator bellows motor
- hand driven possibility via friction drive



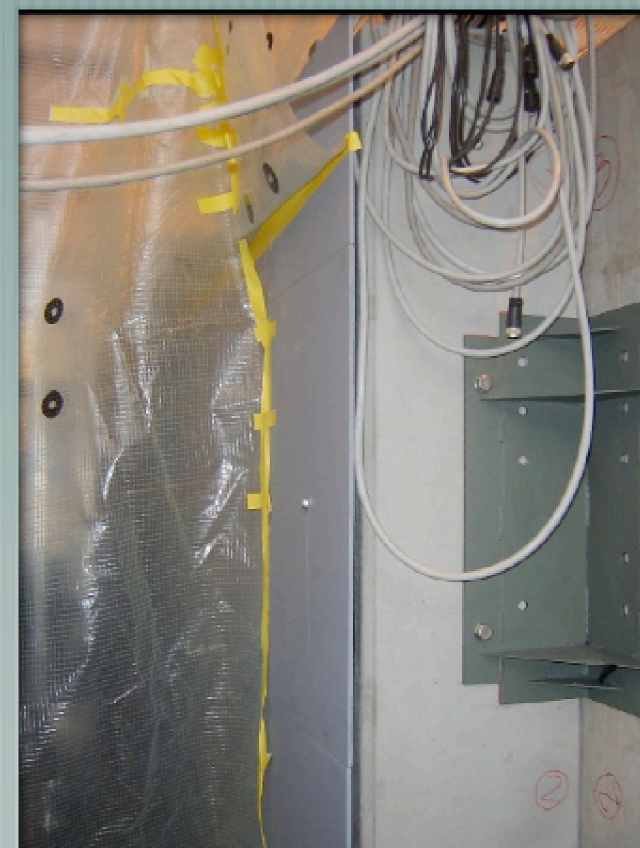

necessary for calibration targets

# COBRA magnet

Ready for ~2 years

# Fringe Field Shielding in πE3

- The side wall and the floor in the E3 are tiled with 10mm-thick soft iron plates.
- The shield plates are mobile.
- It worked as expected.
  - The residual field around the detector was measured to be 2Gauss with the shieldings. (cf. 4-5Gauss without the shieldings)
- Stray field problem is fixed, finally.



# Power Supply Trouble

- Power supply for the compensation coils was burned.
- Fire brigade and (even) police came to the area. Relatively big incident.
- Any interlock protection system in the power supply didn't work.

Problems solved; Necessary measures to take for a long, stable run

# Plan for Field Measurement

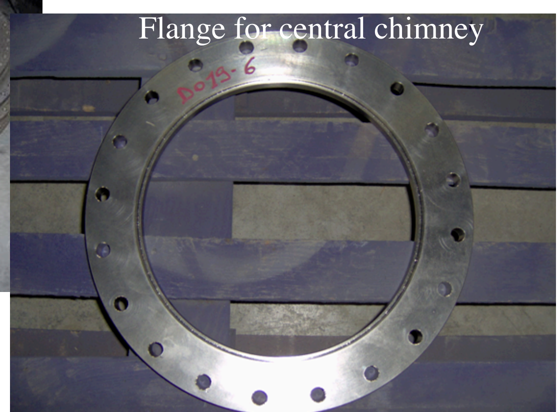
- The field measurement is delayed by two weeks because of the PS trouble.
- Plan for the measurement
  - Surveying+calibration: 1week
  - Measurement: 2-3 weeks
    - Measuring step: $\Delta Z$=2cm $\Delta R$=2cm $\Delta \Phi$=20deg
    - Possibly with finer mesh for the central region
    - Independent measurement of the BTS fringe field
  - Measure long term stability of the field using NMR

- We are starting the field measurement this week. Supposed to complete within February.

# Xenon Detector

# Cryostat Construction

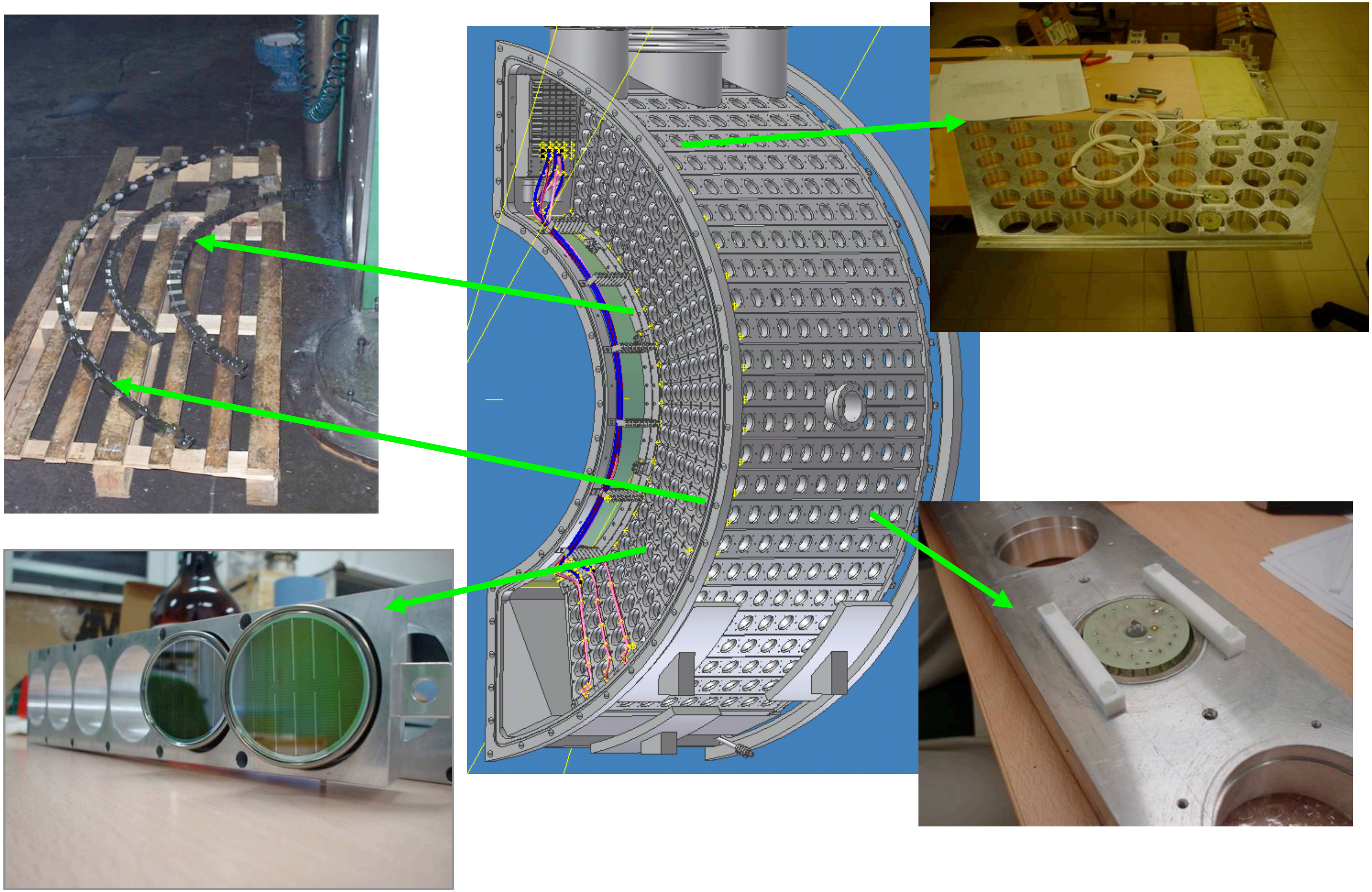
- Construction at SIMIC http://www.simic.it
- Stainless steel raw material, sheets, tubes, flanges etc. are ready at SIMIC
- Several design modifications
  - Feedthru mounting, cover handling, platform extension, SIMIC request etc.



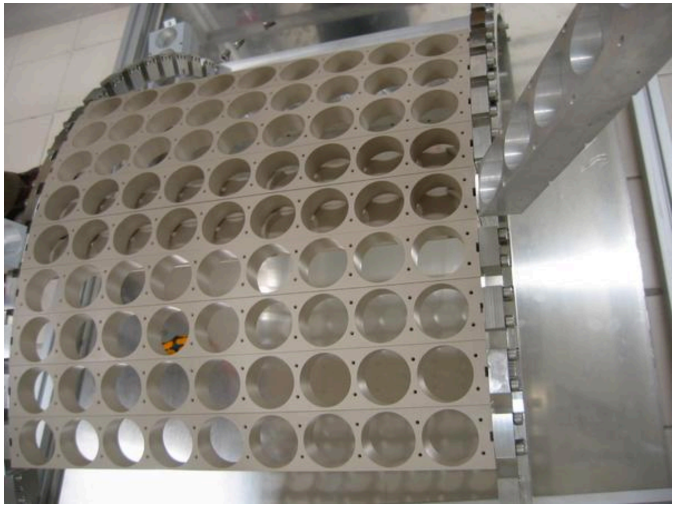
Flange for central chimney

Main flanges (not machined yet)

# PMT mounts

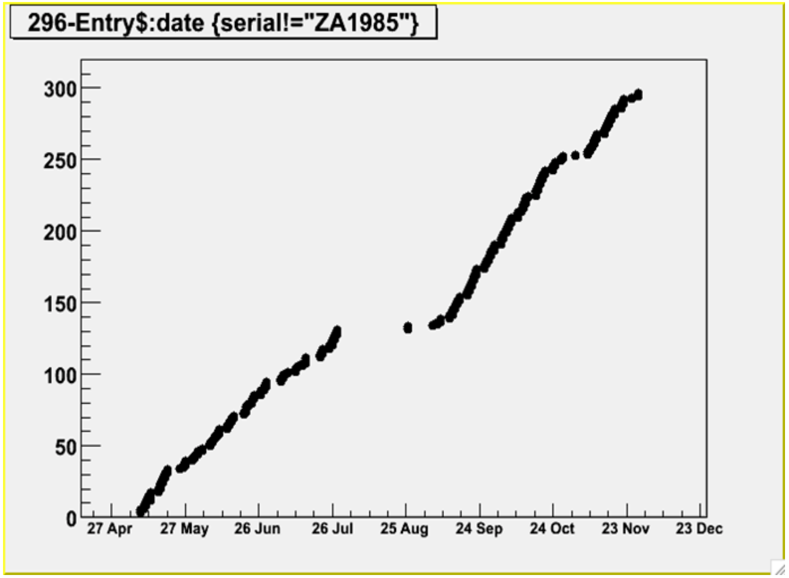


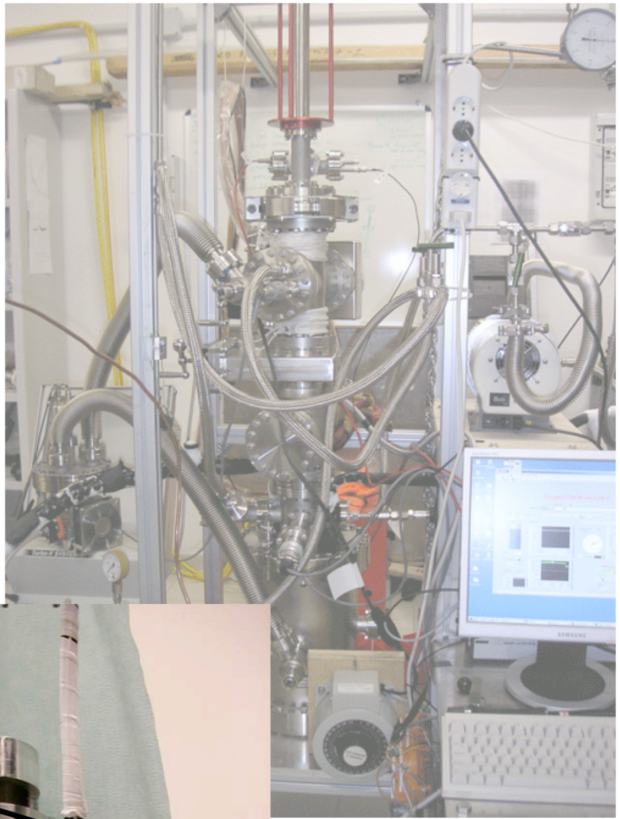
# PMT Mounts Assembly Test

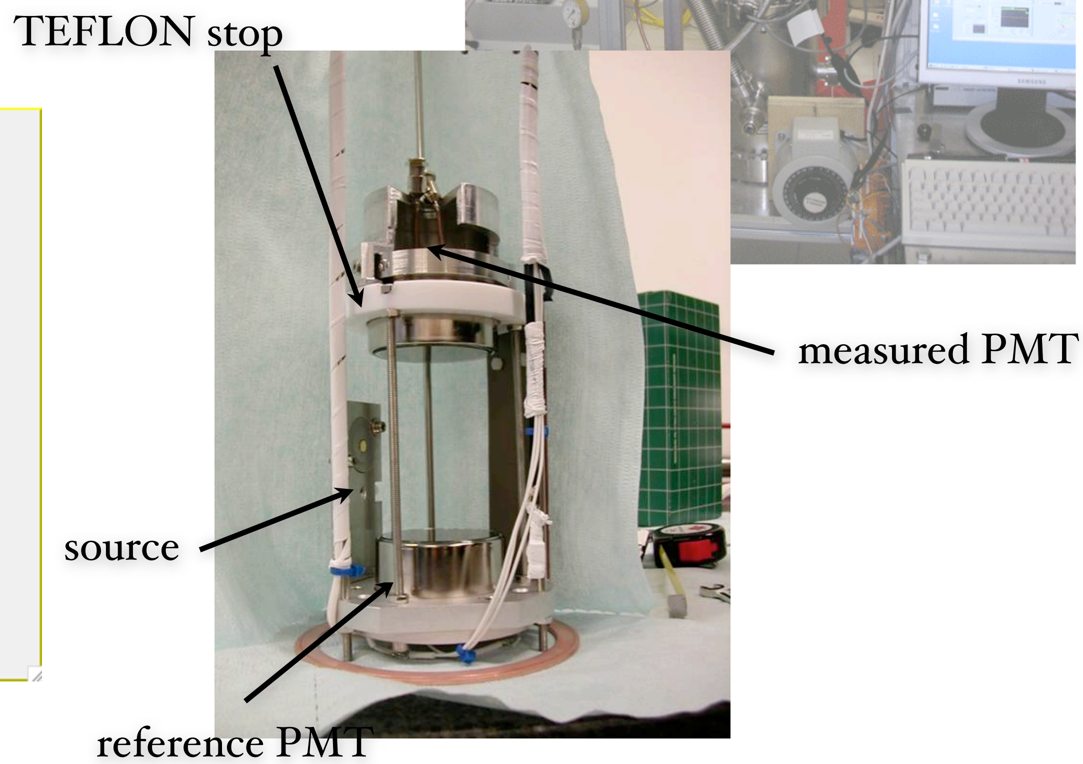


# Pisa PMT test

- 298 PMTs tested, total of 650 tests
- ~3PMTs/day, 2.5 hours for one test
- All data has been put into MySQL database

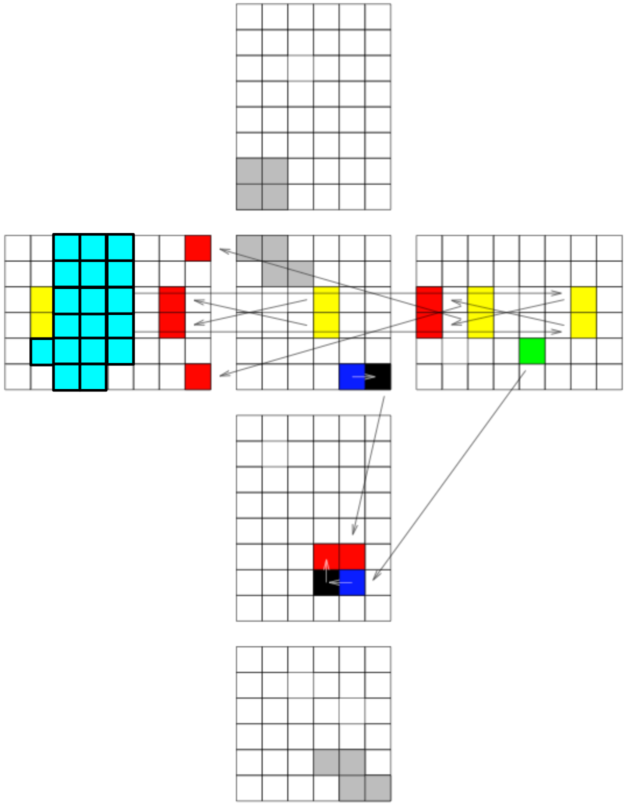




# PSI PMT test

- PMT test in liquid xenon by using LP cryostat.
- Up to 238 PMTs can be tested at once in two months
- We performed three tests
  - <u>Thanks to Students from Tokyo</u>
  - June – August, August – October, November – December
  - We tested not only newly delivered PMTs but also PMTs tested in Pisa, PMTs used in the previous test etc.
  - Gain, QE, Linearity of PMT output measured.

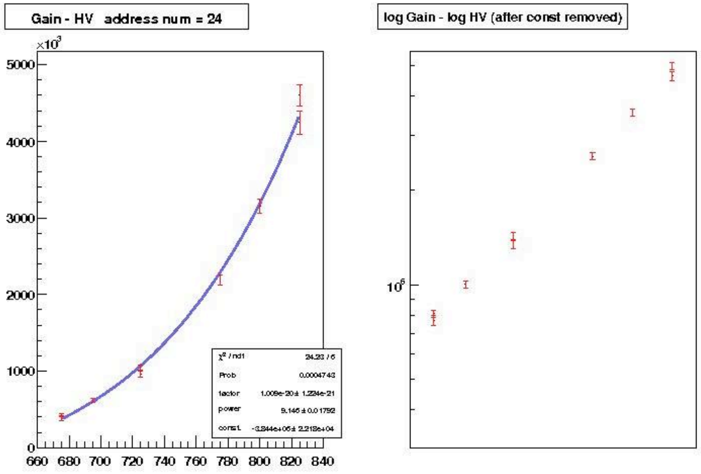


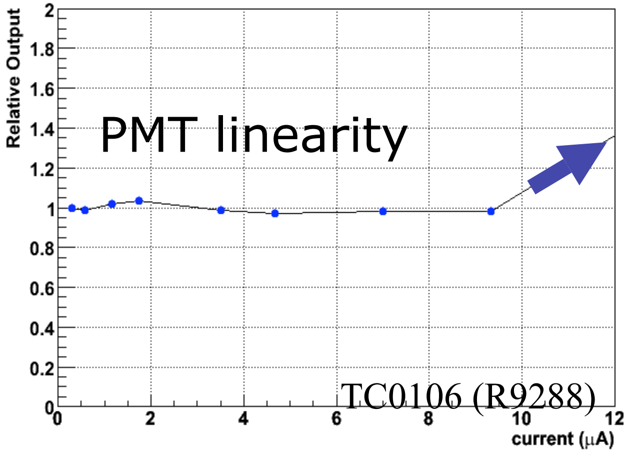
# PSI PMT test result

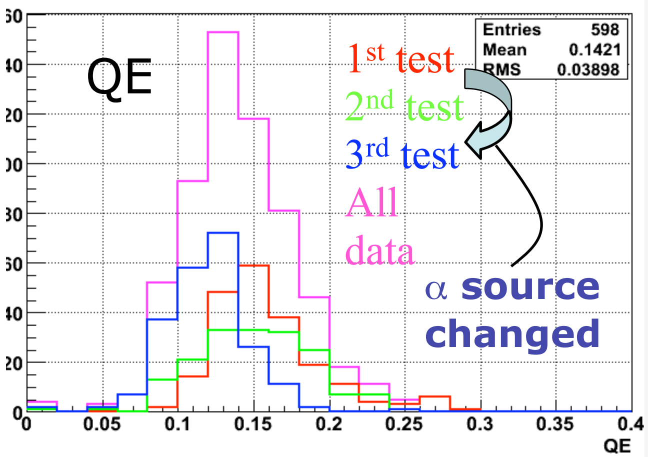
- Gain, linearity ← LED
- QE ← α sources on wires

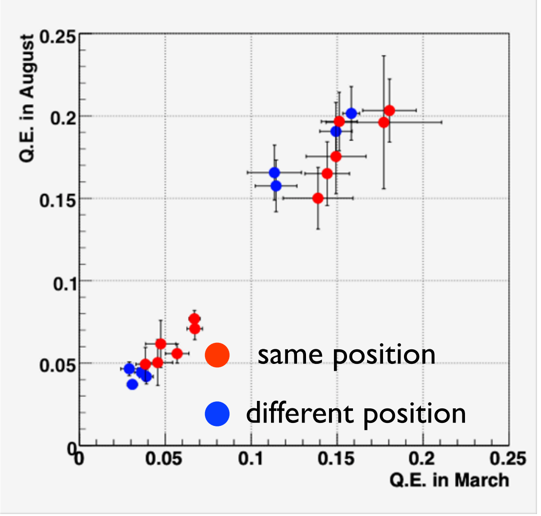
| | 1st | 2nd | 3rd | total |
|---|---|---|---|---|
| New PMTs | 188 | 184 | 144 | 516 |
| PISA & PSI | 30 | 19 | 30 | 79 |
| Re-test | 20 | 35 | 64 | 119 |

Gain Curve

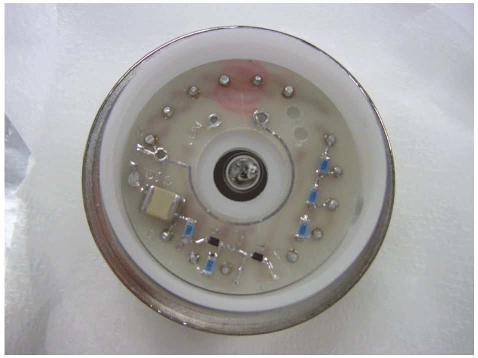


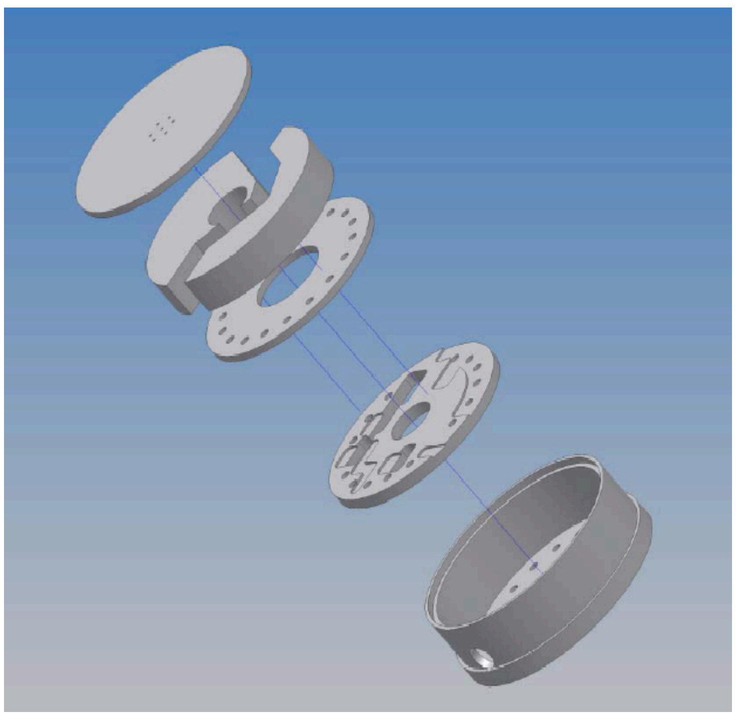



# Special work for inner PMTs





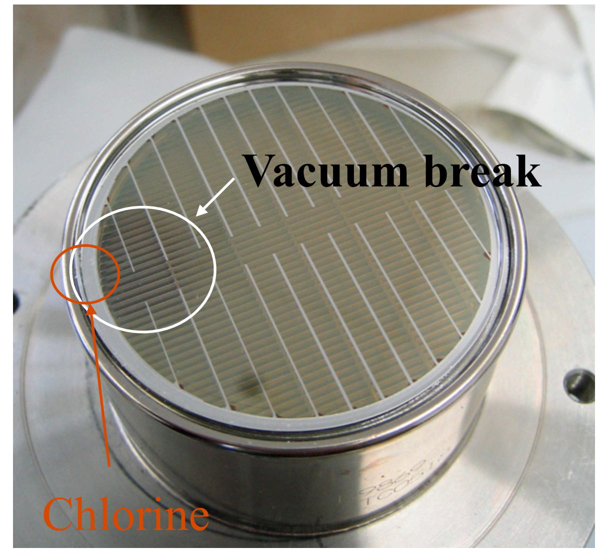
•"Spacer" will be installed to the inner face PMTs to reduce the liquid xenon contamination to the back of PMTs

•So far, 427 spacers are installed to PMTs. Next, we will install the spacers for the PMTs which are selected for inner face, and those for 98 PMTs should be installed.

•10 days for this work
( 5 PMTs/day/person ) x 2 people

# PMT Trouble

- About 8% PMTs delivered in April-July 2005 have undergone vacuum break at the window edge.
- HPK investigated this problem and found
  - Misalignment of the window during construction
  - Insufficient treatment to remove HCl after heat-sealing




Electron Probe Micro Analyzer

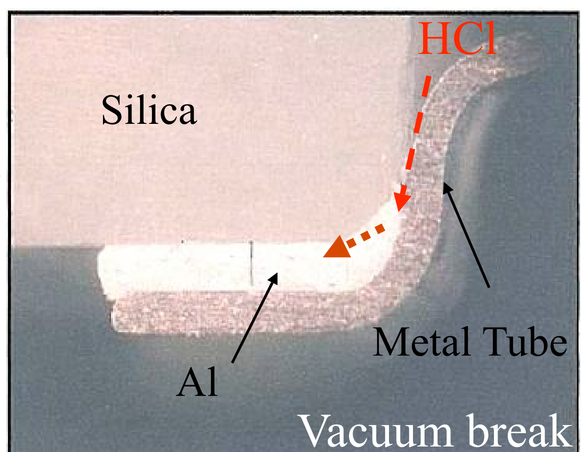
・ 分析方法と測定条件　　測定可能元素　　分析領域　　深さ　　横
EPMA(電子線微小部分析)　　C(6)～U(92)　　表面層　　(0～数μm)　　50μmφ
電子線加速電圧 15KV ビーム電流 0.1μA

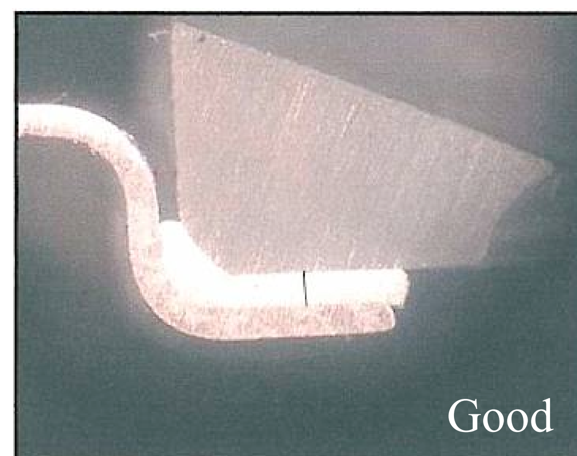
・ 分析データ

(WT%)

| No. | | O | Al | S | Cl | Fe | Mg |
|---|---|---|---|---|---|---|---|
| TC1126 | 接触面腐蝕部 | 17.80 | 80.80 | | 0.99 | 0.34 | 0.07 |
| | 接触面腐蝕部 | 31.93 | 56.80 | 9.19 | 2.09 | | |
| | 接触面腐蝕部 | 24.62 | 74.93 | | 0.12 | 0.28 | 0.05 |
| | 接触面腐蝕部 | 4.89 | 93.02 | 1.10 | 0.64 | 0.35 | |
| | 腐蝕部周辺 | 3.48 | 90.44 | 5.67 | | 0.41 | |
| | 接触面光沢部 | ハクリ不可(ガラスが僅かに残る) | | | | | |

・ 分析データの評価
・接触面腐蝕部を4点測定したが、何れからもClが検出された。
→コバール研磨前の塩酸処理による腐蝕か？



# PMT trouble summary

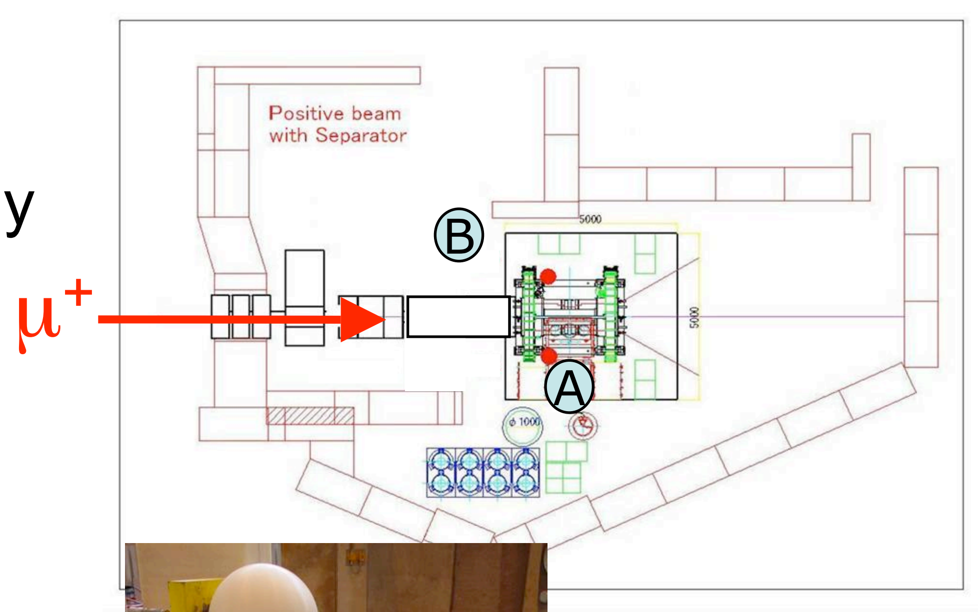
- About 8% of delivered PMTs suffered from vacuum break.
- Hamamatsu investigated the problem and found that this was caused by remaining HCl that could not be removed due to window tilt.
- They introduced in their production
  - Guiding tool
  - Ultra-sonic cleaning after HCl wash
- They will deliver > 150PMTs soon for replacement and spares. Those will be tested in PSI ($4^{th}$ LP test) and Pisa.

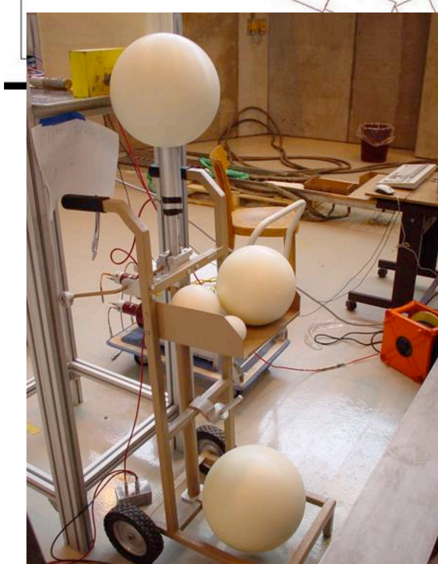
- We should not use PMTs with very large tilt (d > 0.35~0.4mm).
- This new PMT selection criteria is expected to suppress the problem during detector operation.

Some delays, but will be in time

# Neutron Background Measurement

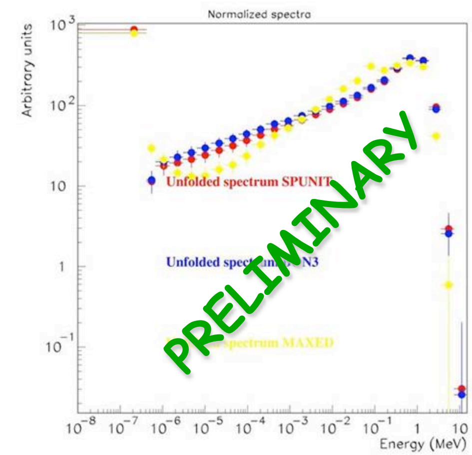
- Measurements of neutron flux and energy spectrum in the πE5 area
- Evaluation of the effects on the detector
- Setup
  - NaI detector (4 inch x 4inch)
  - Bonner sphere system with a $^{3}$He detector
- Two measurements
  - Aug/2004 (w/o BTS)
  - Dec/2005 (w/ BTS)

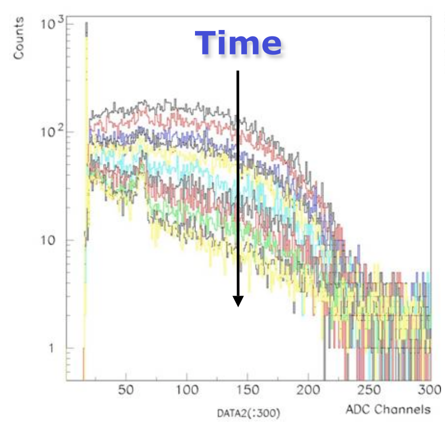


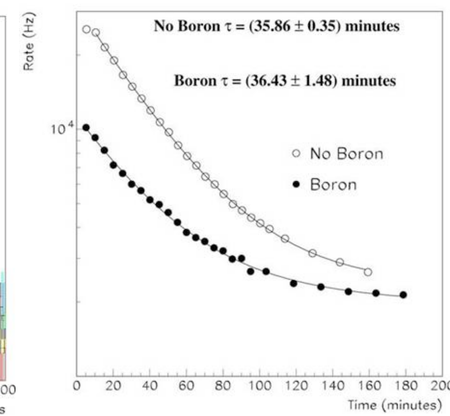



# Neutron Background (preliminary)

- 1.8mA proton current, $1.2\times10^{8}\ \mu^{+}/s$
- Location A (by Bonner Sphere in Dec/2005)
  - Thermal neutron flux: 1-1.2 $n/s/cm^2$
  - Total neutron flux: 4-4.5$n/s/cm^2$
  - Consistent with Aug/2004 measurement
- Location B (by Bonner Sphere in Dec/2005)
  - Thermal neutron flux: 3.7-5.4 $n/s/cm^2$
  - Total neutron flux: 10-10.5 $n/s/cm^2$
- NaI activation ($^{128}I$ activation) method (Location B)
  - Thermal neutron flux: 1.8+/-0.3 $n/s/cm^2$
    - A bit lower but compatible with a factor of 1.5
  - Nonthermal neutron flux: ~10 $n/s/cm^2$
    - Large uncertainty. Good agreement with He3 measurements
- PMT background current due to neutron
  - IPMT < 1$\mu$A
  - PMT response is linear far above this level
  - No need of neutron shielding




**No shielding necessary for operation**

# *Gamma line measurements*

Main method to check the energy scale and stability of the calorimeter on almost-daily basis

We tested the calibration method by means of $p(N,\gamma)N'$ reactions with the Legnaro VdG accelerator coupled to a custom target tube with different home made targets:

| *Reaction* | *Resonance energy* | $\sigma$ peak | $\gamma$-lines |
|---|---|---|---|
| *Li(p,γ)Be* | *440 keV* | 5 mb | 17.6 MeV, 14.6 MeV |
| *B(p,γ)C* | *163 keV* | $2\ 10^{-1}$ mb | 4.4 MeV, 11.7 MeV, 16.1 MeV |

We studied the reliability of the method paying attention to:

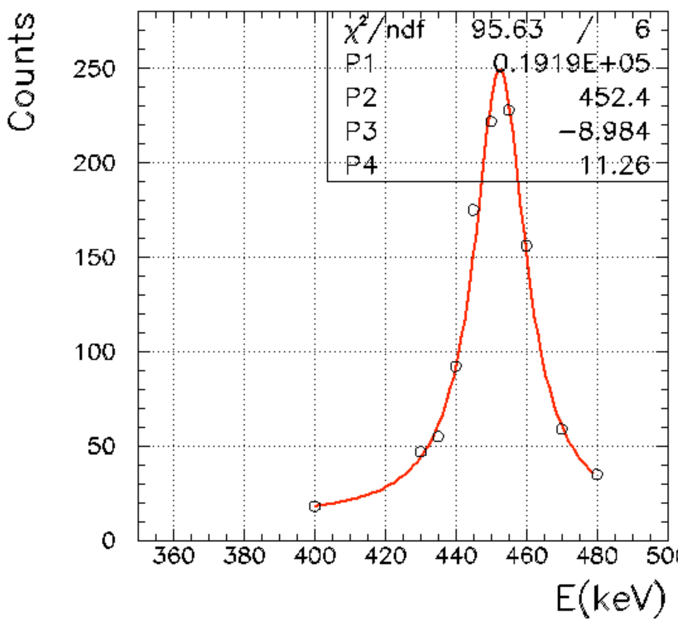
- Reactions rates at different energies
- Different target thickness
- Quality of the $\gamma$-lines

**LXe calibration method verifed at Legnaro VdG**

# LiF target excitation curve

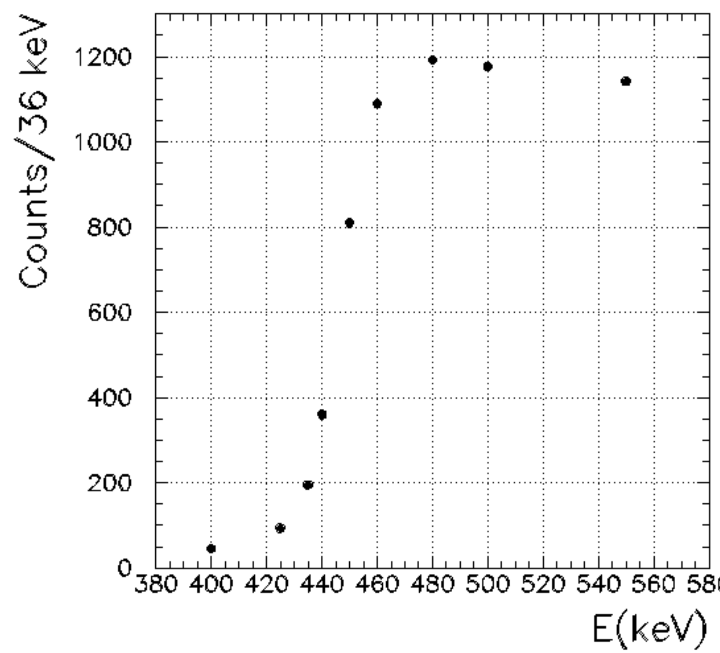
- Number of collected photons in *Li* peak as a function of the proton energy
- We checked the energy scale and resolution of Legnaro VdG!

*Thin target: only resonant protons do react*
*Thickness = 0.11 μm*




*Γ(keV) = 17.97 ± 0.03*
*μ (keV) = 452.4 ± 0.5*

*Thick target: during slowing down in target all protons eventually reach the resonance*
*Thickness = 1.34 μm*

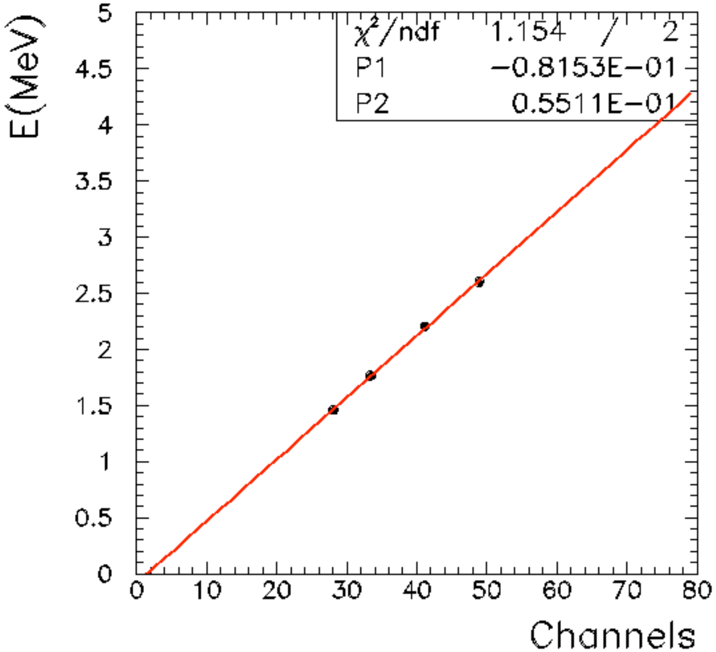


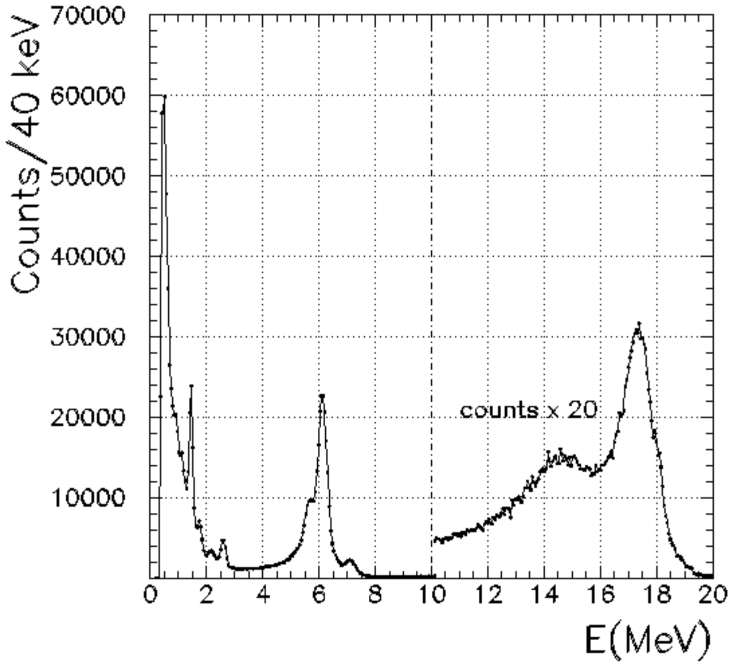

*Γ(keV) = 10 ± 1*
*μ (keV) = 446 ± 1*

# The 17.6 MeV γ-line

- Gamma lines from natural radioactivity are used to calibrate the energy scale

$^{40}$K (1.460 MeV) $^{214}$Bi (1.764 MeV) $^{214}$Bi (2.204 MeV) $^{208}$Tl (2.601 MeV)




Large NaI Energy Resolution
$\sigma(E)/E = 3.09 \pm 0.03$ %
*(at 17.6 MeV)*

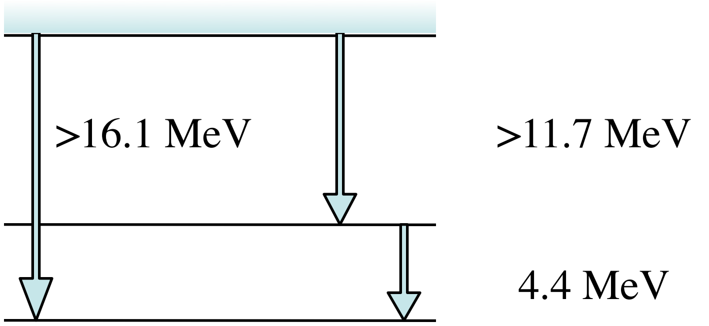
*I ~ 90 nA*

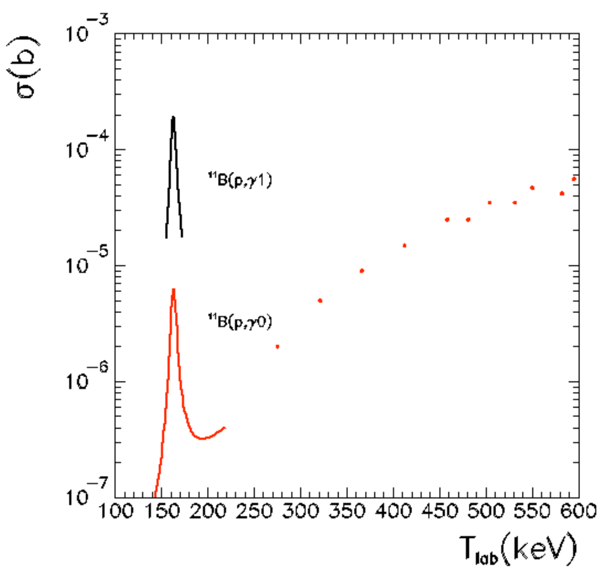
$T_p$ *= 500 keV*

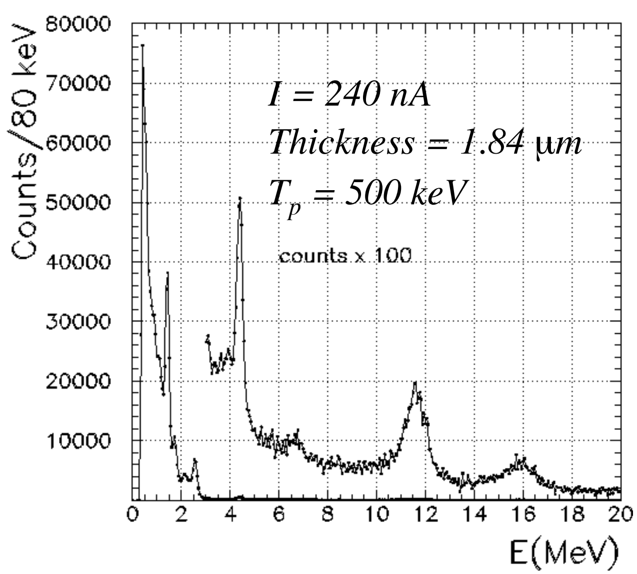
Rate(17.6 MeV) on LXe = 1.8 kHz / μA

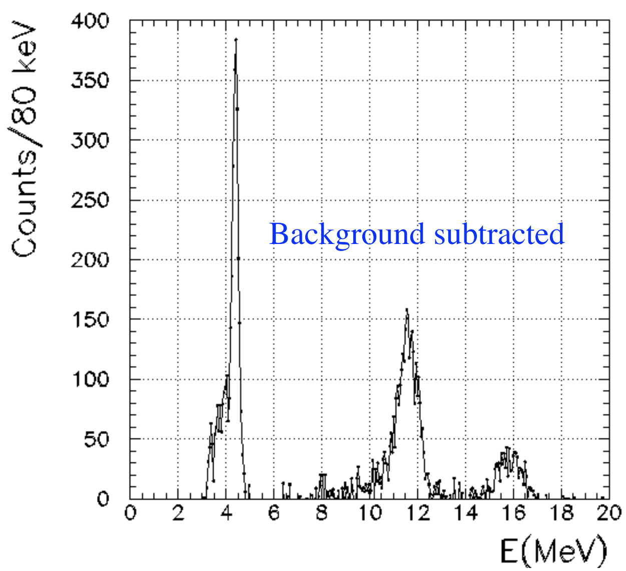
# B(p,γ)C reaction

- From the de-excitation of Carbon ~ 94% of the times the 16.1 level decays in two photons
- Three energetic gamma lines
- Powerful tool to explore the capability of the MEG calorimeter to reject pile-up events.



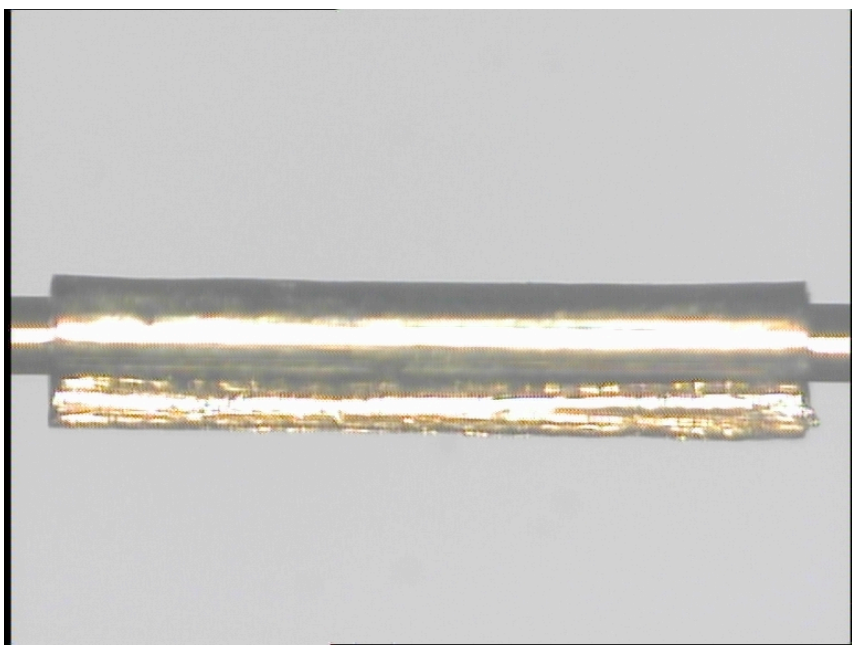



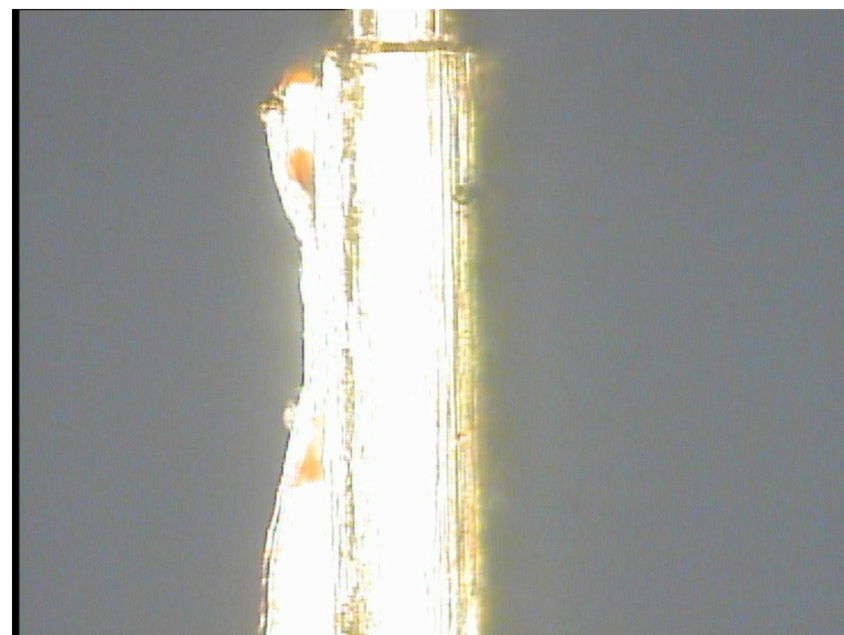



# SORAD $\alpha$-source Photos

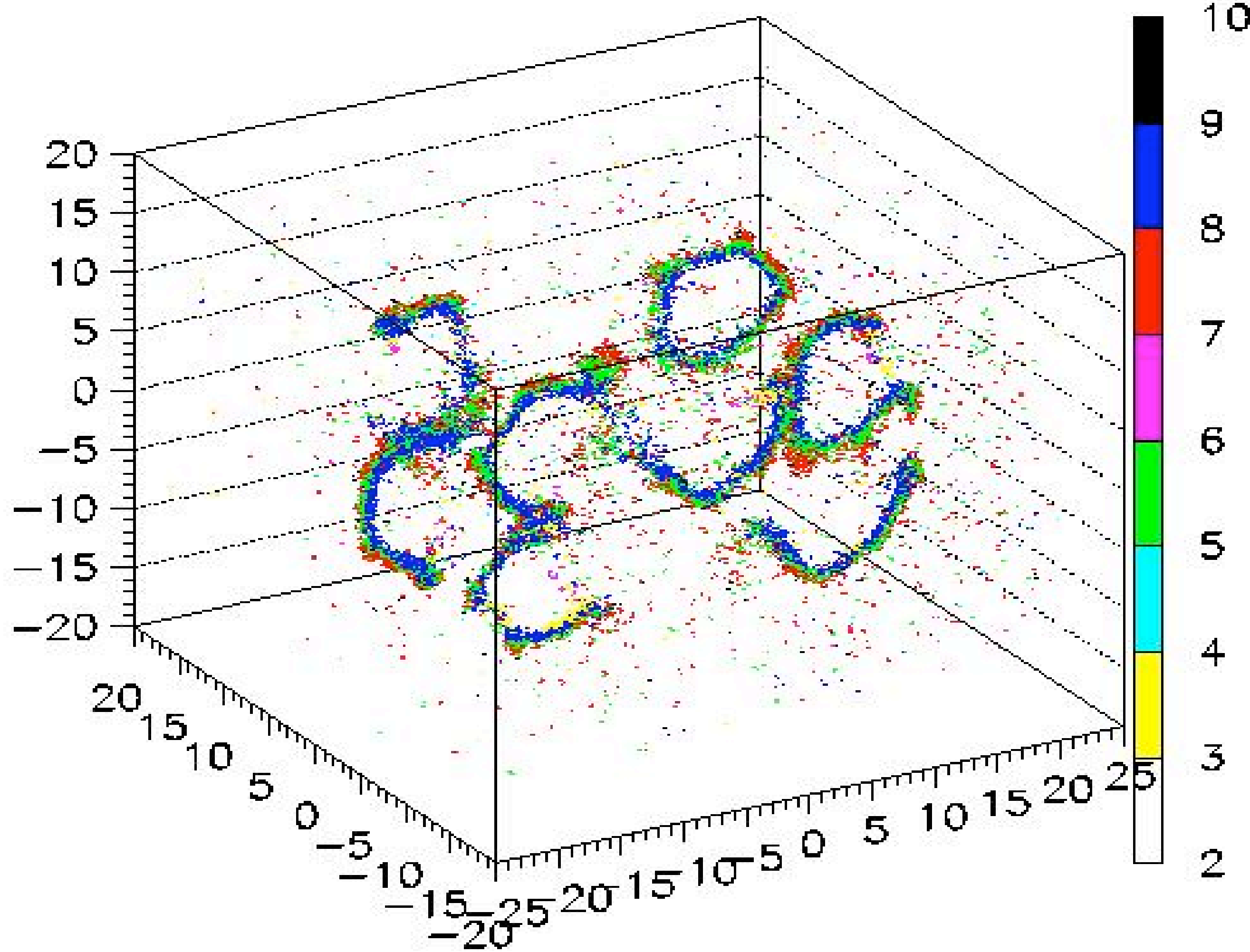
- Am sources much larger half-life (kyears instead of 130 days)
- Difficult to prepare
  - $^{210}$Po electrodeposited
  - Not possible for $^{241}$Am
- Clipping of Au foils on thin wire





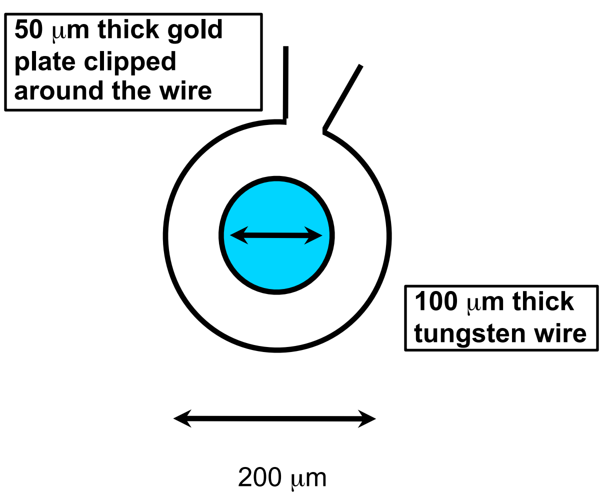
# Reconstructed alpha sources in LXe

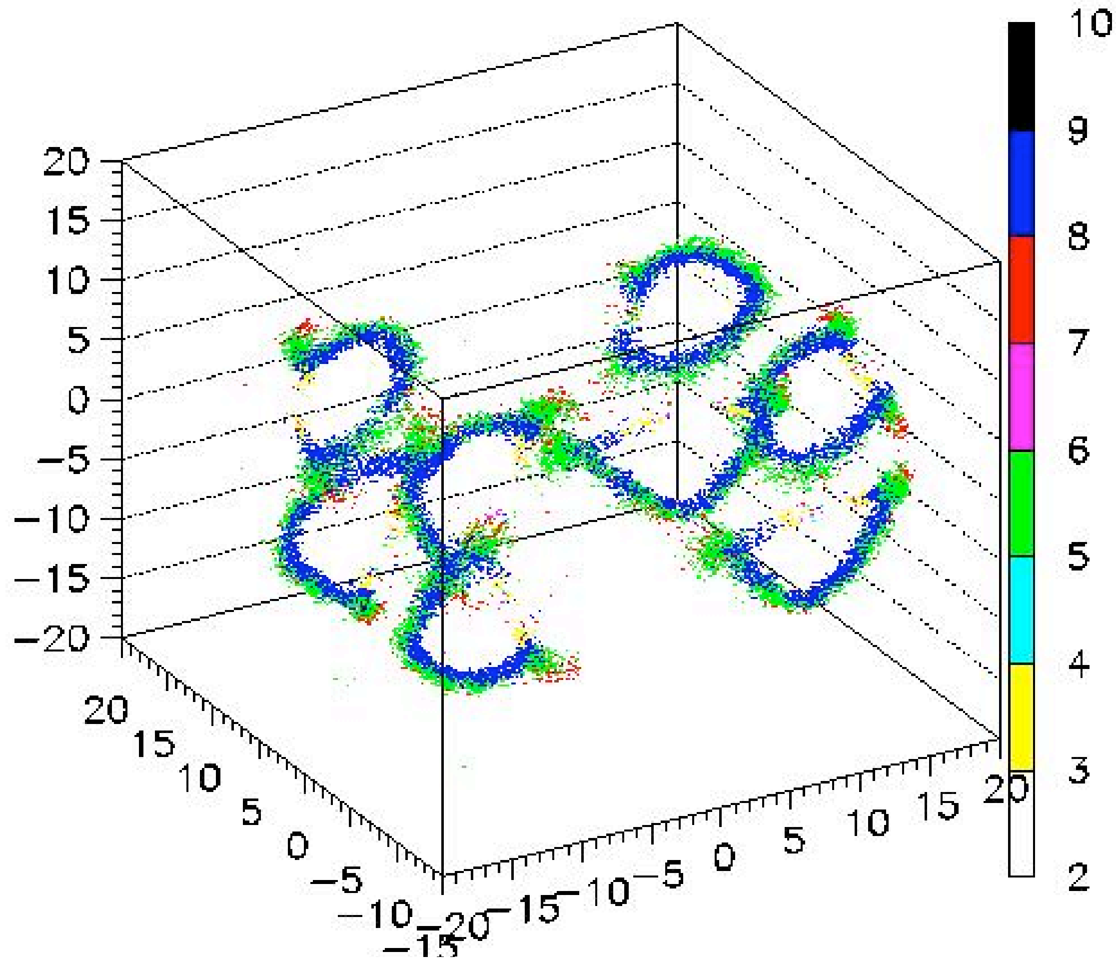
- No more rings as in the $^{210}Po$ case



# Properly simulated by our MC

- Our MC simulation is good!
- An investigation with the factory is in progress to improve the symmetry.

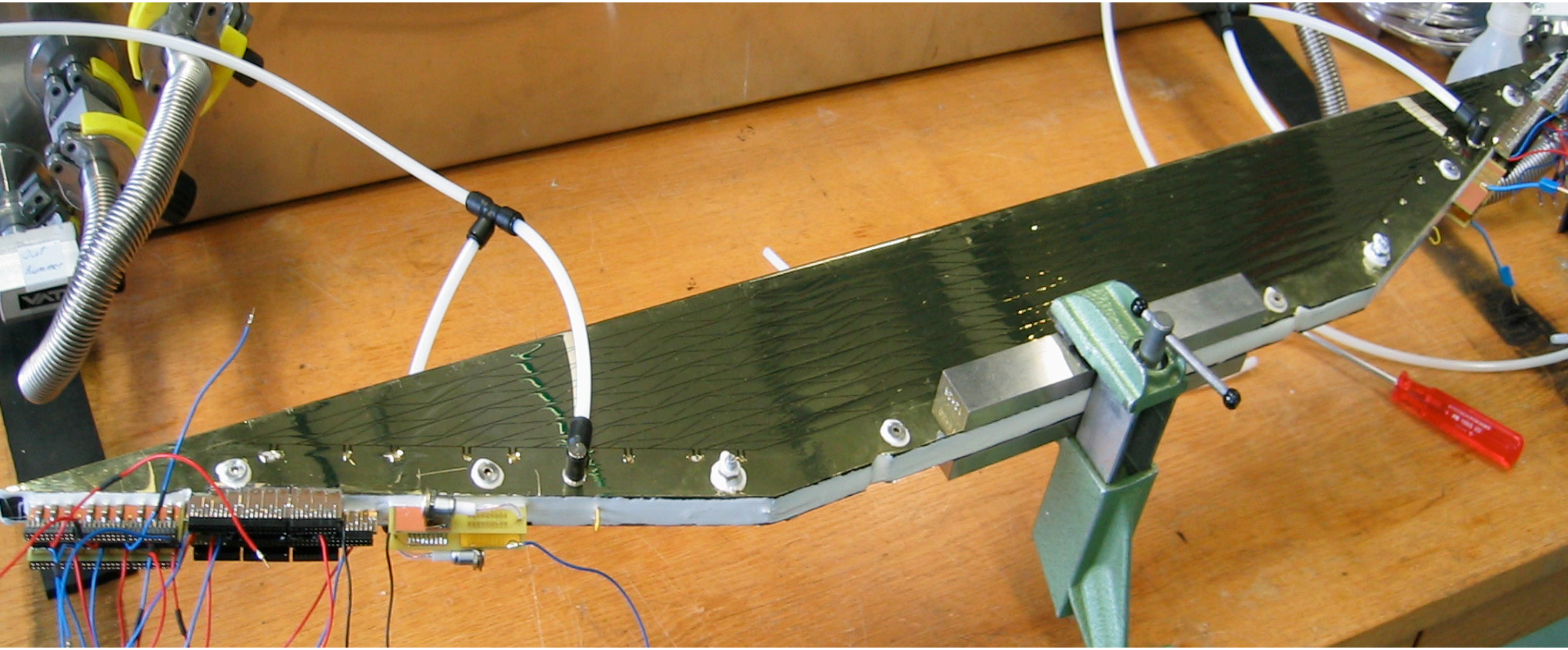


# Drift Chambers

# The first Drift Chamber has been assembled

0.1 mm  precision to frame reference points reached for anode, cathode and hood



# Various tests scheduled toward final installation

a) HV test with assembled DC :
[anode prints, parameters for pressure behavior]

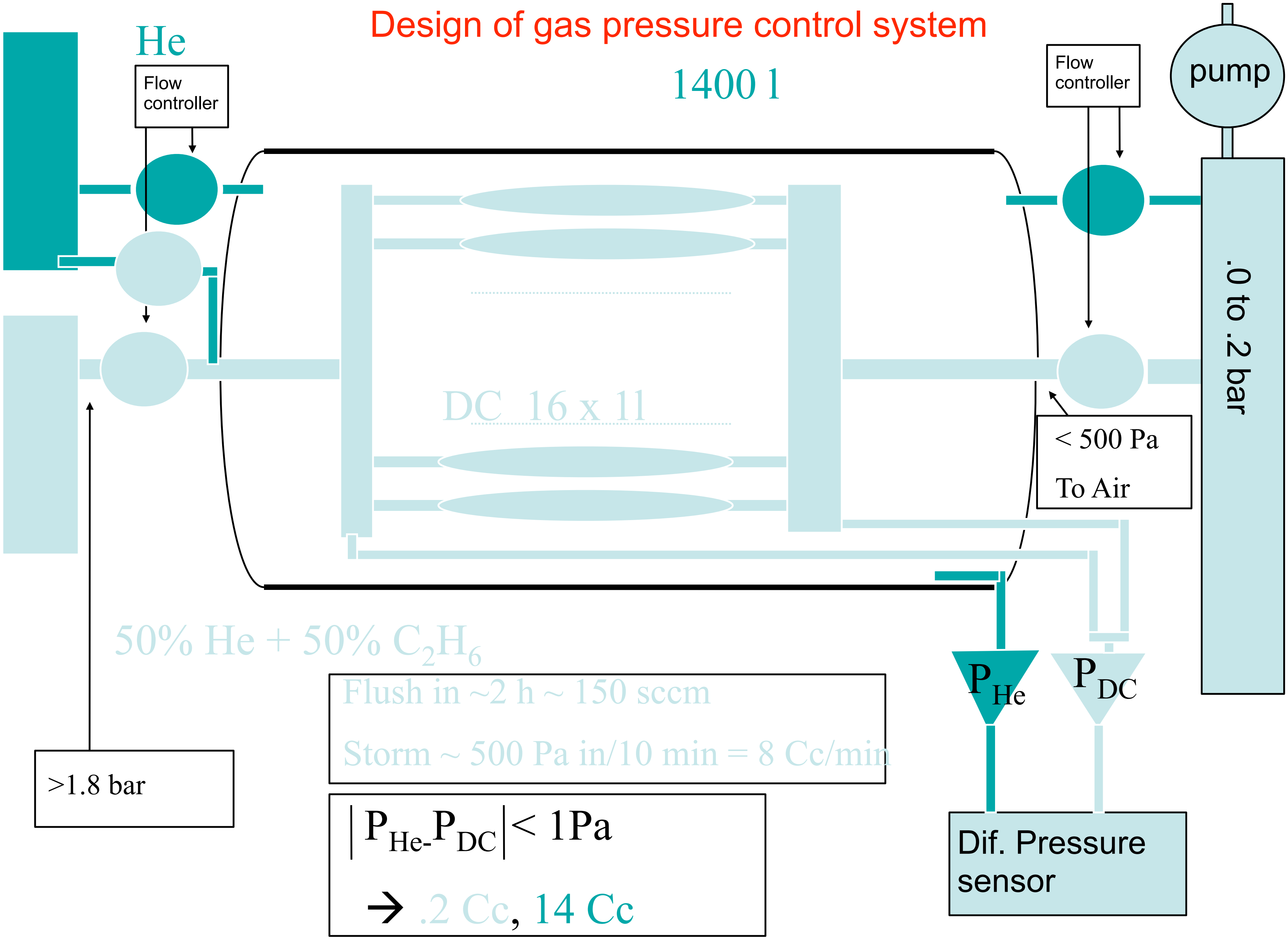
b) HV test with preamps and DRS with $Sr^{90}$ and cosmics:
[ preamps, DRS,..]

c) 6-11 April : test in $\pi E(M)1$ with minimal ionizing $\pi$ (>150 MeV/c) or e 50 MeV/c)
1 DC + Al-DC
[preamp, DRS, DC calibration, resolution,…]

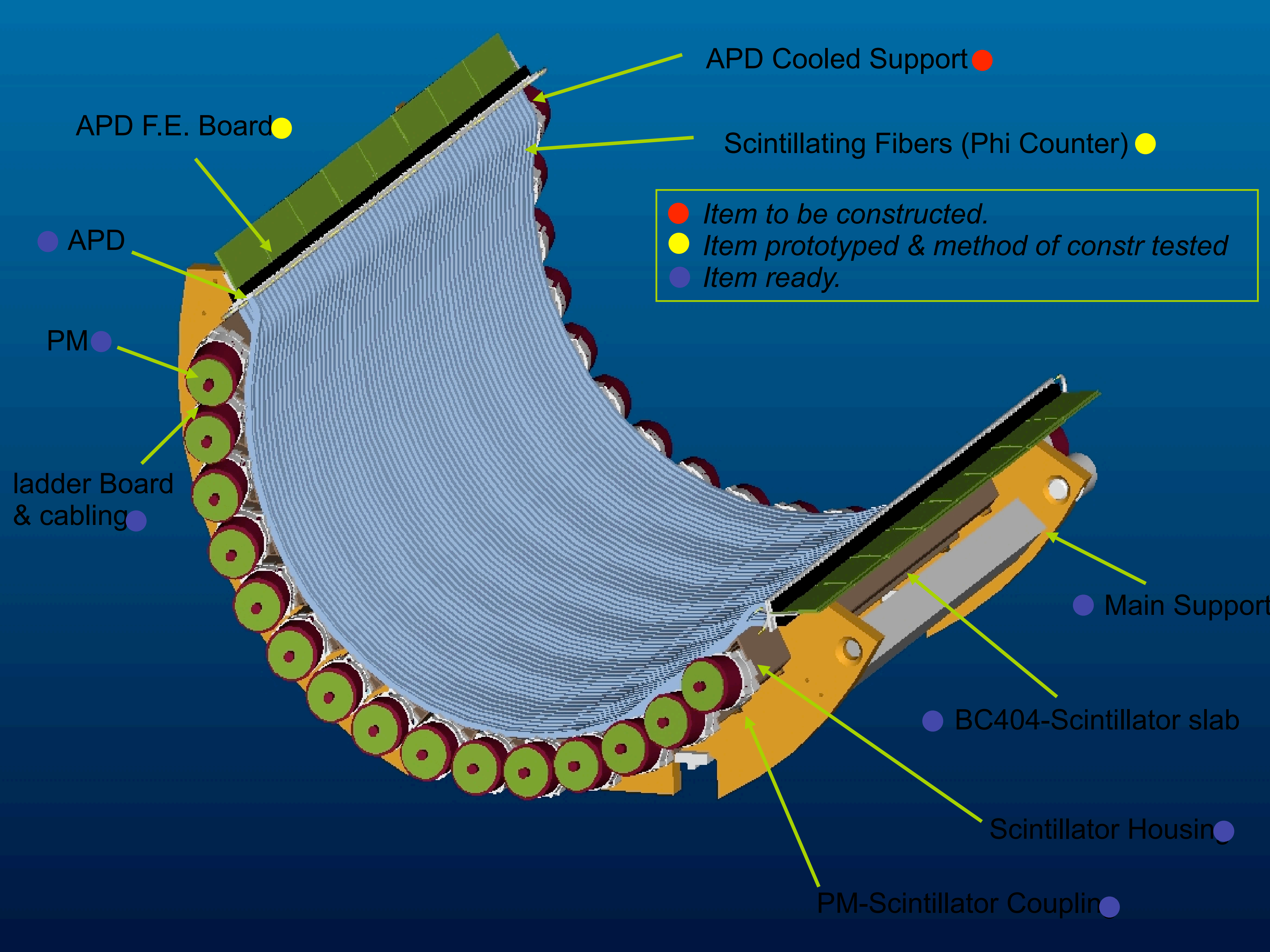
d) 11-16(24) May : test in Cobra, Field on + $e^+$beam with < 3 DC's
[DC behavior in Cobra background , 511 keV]

e) Eventually second test in pE1 with more DC
[ better DC calibration]

# Design of gas pressure control system

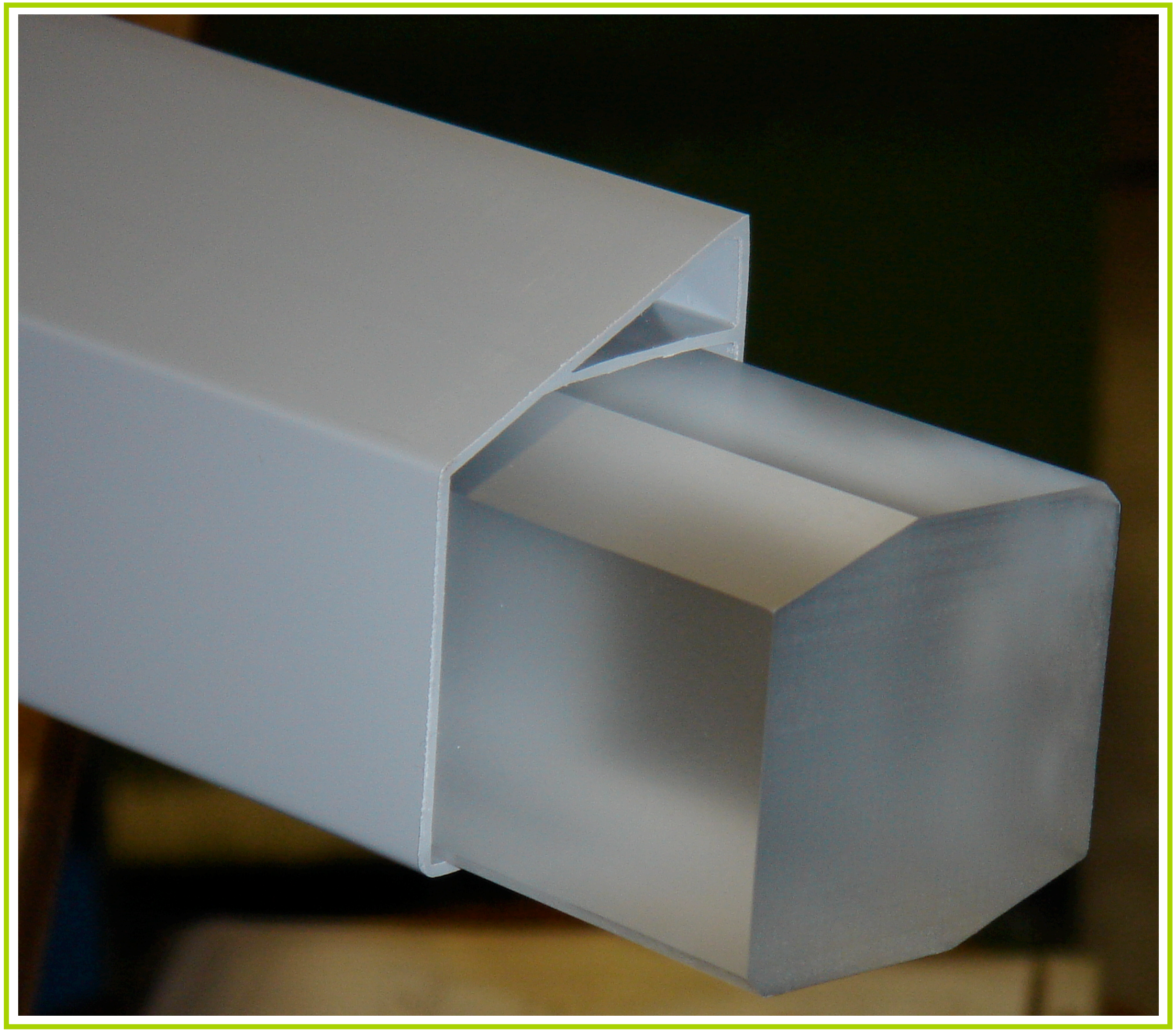


# Timing Counter



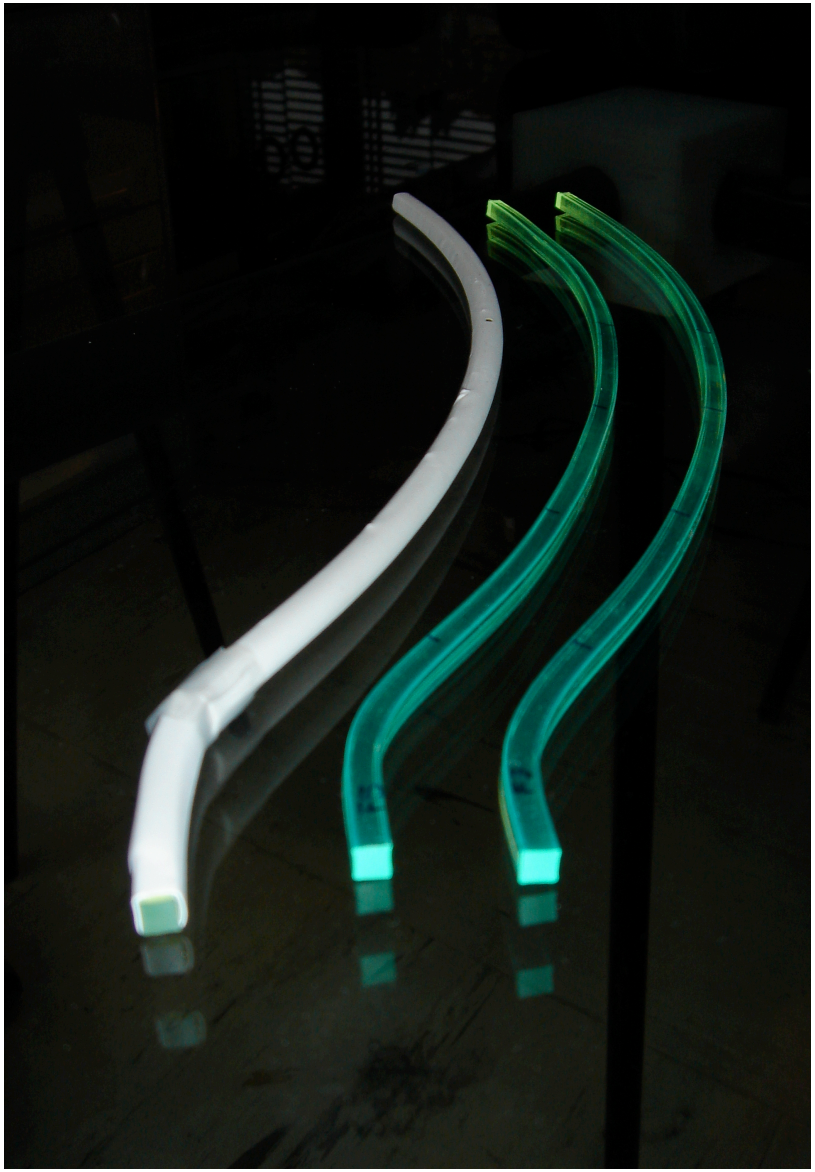
APD Cooled Support
APD F.E. Board
Scintillating Fibers (Phi Counter)
Item to be constructed.
Item prototyped & method of constr tested
Item ready.
APD
PM
ladder Board
& cabling
Main Support
BC404-Scintillator slab
Scintillator Housing
PM-Scintillator Couplin

A sample of BC404 bar and the plastics housing

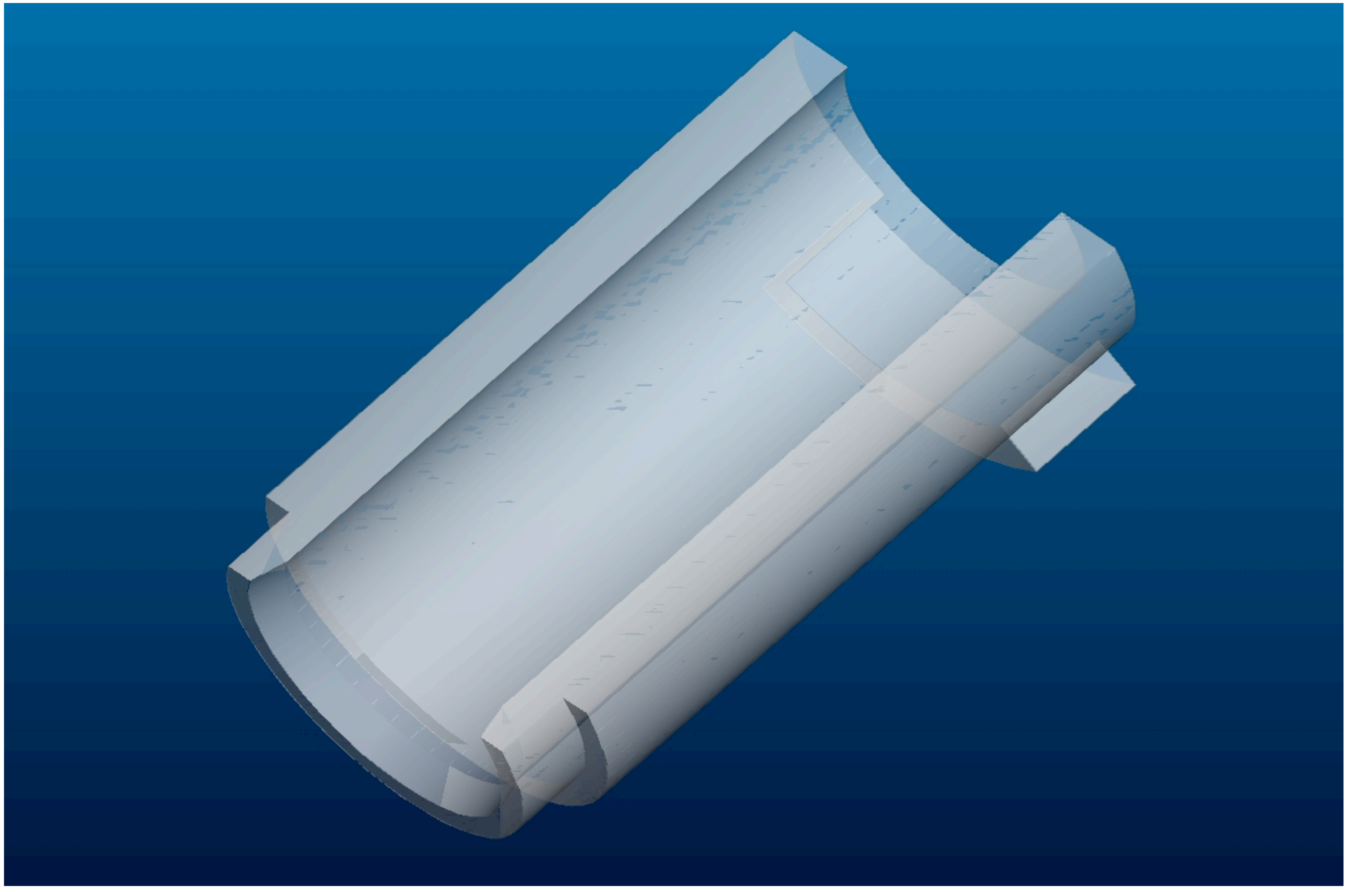


Production scheme of
Scintilating Fibers tested:

- Hot forming with and without jacket. √
- Test for light losses, i.e., trapping efficiency. √
- Test of several diffusing or reflecting jacket. √
- Coupling to the APD via EPOTEK H301-2. √



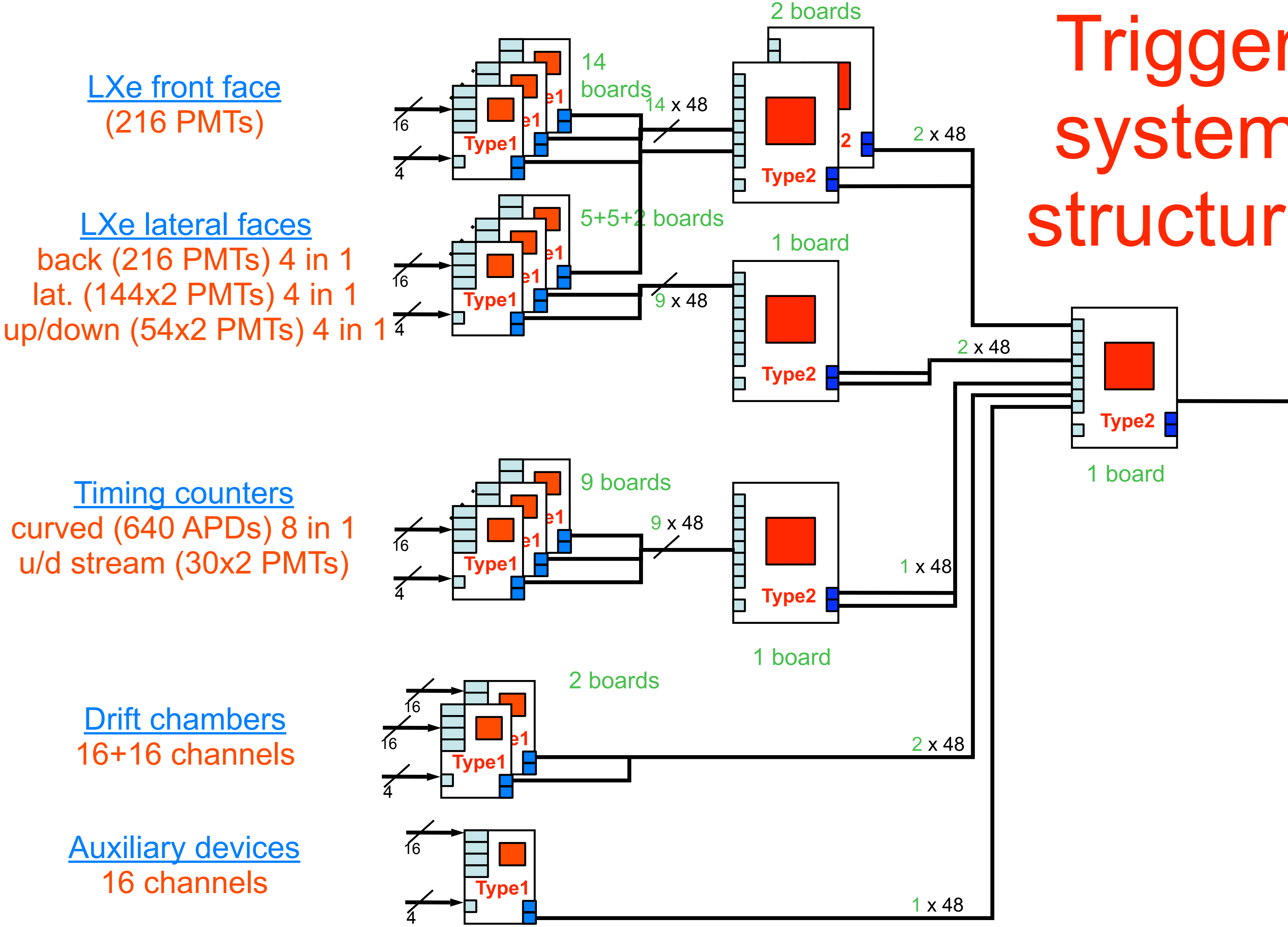
# N2 bag

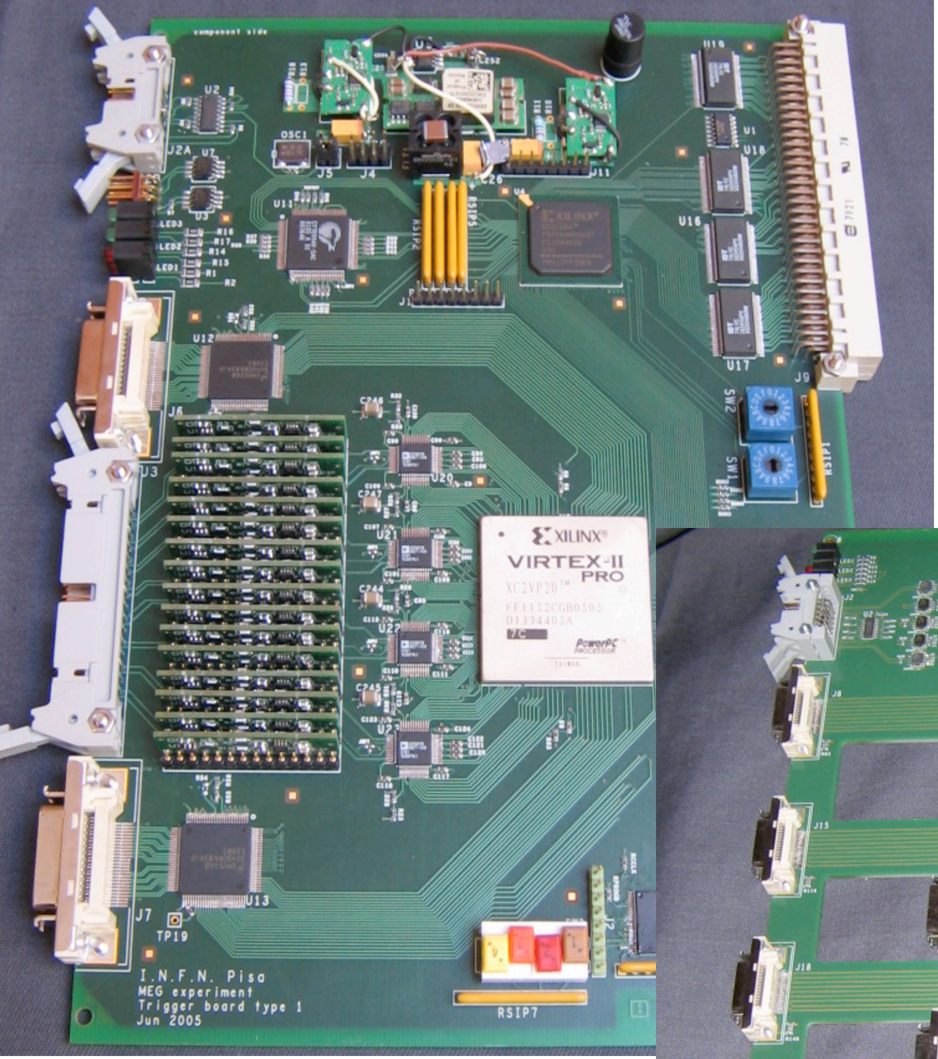


- 0.25 mm tick EVAL T foil in a sandwich of two PE foils
- The foils will be formed on the mockup and assembled by thermo-welding or epoxy: these joints are successfully tested
- Construction will start after the completion of the first TC (middle of march)

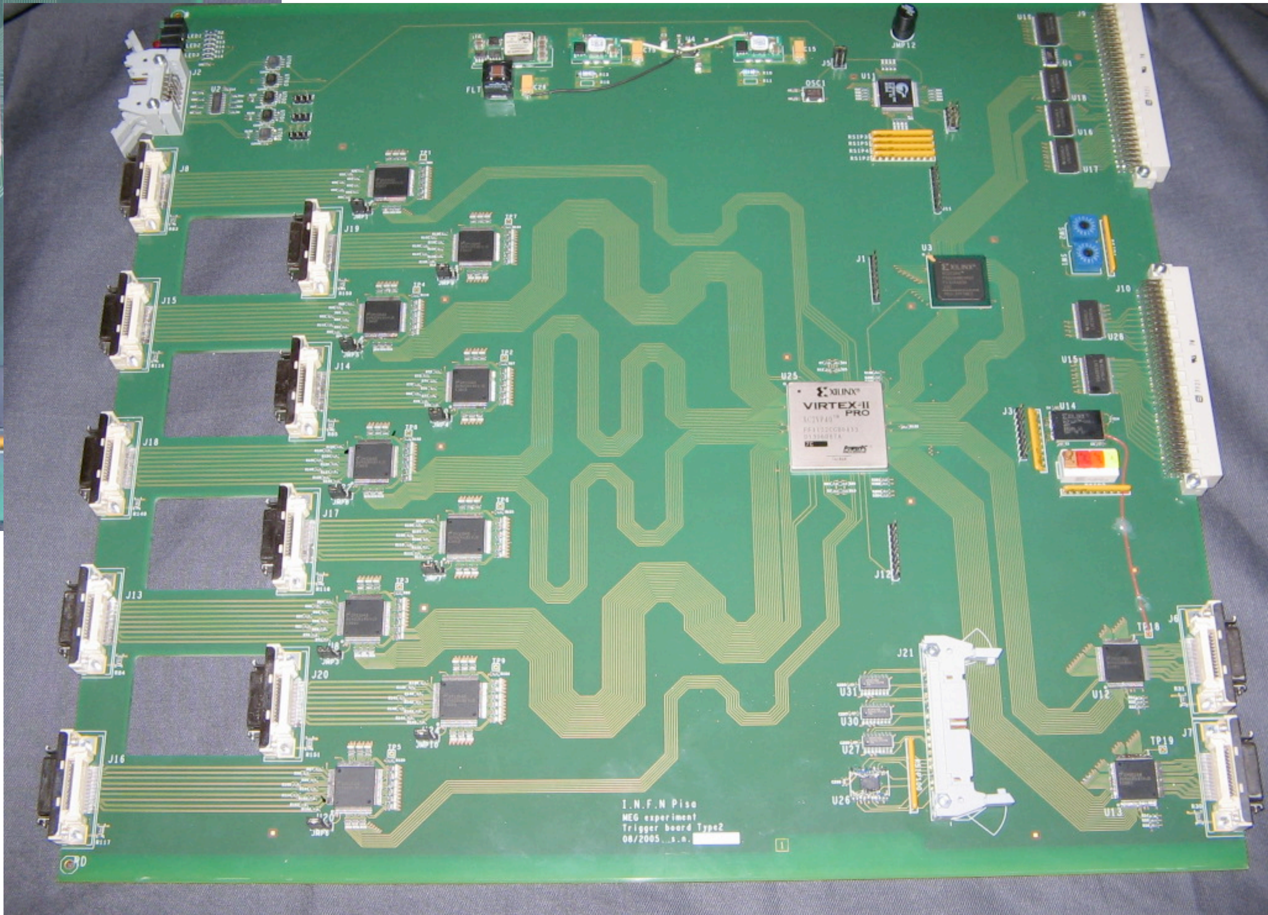
# Trigger, DAQ and Electronics

# Trigger system structure



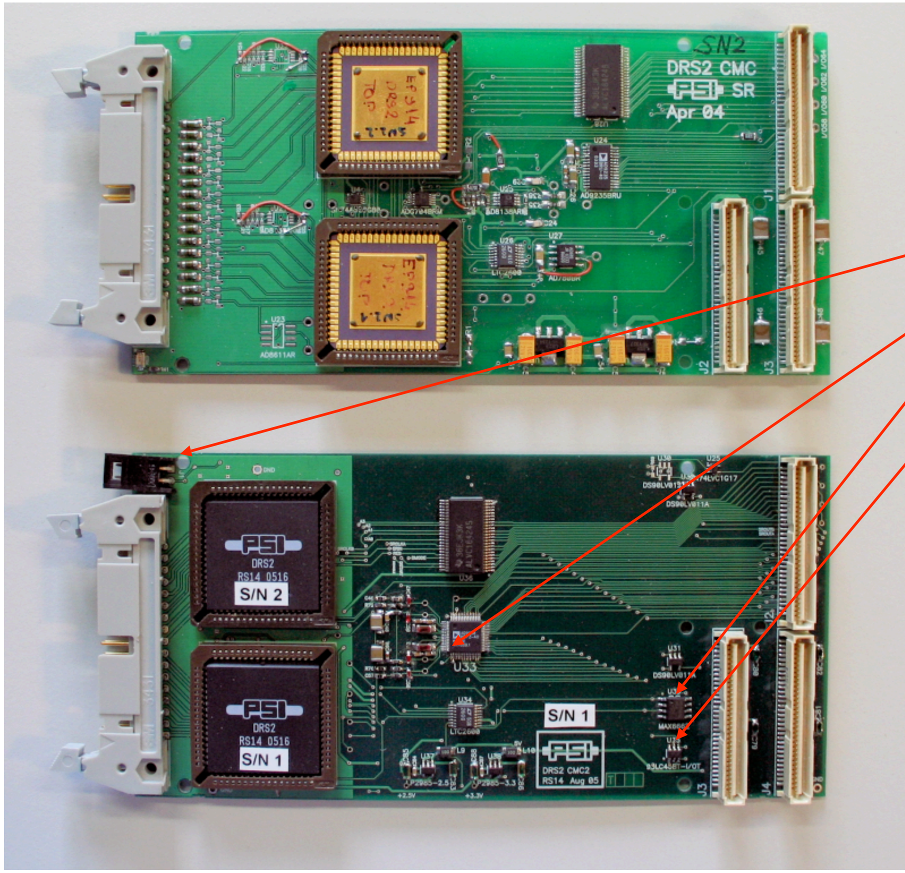

XILINX
VIRTEX-II
PRO
I.N.F.N. Pisa
MEG experiment
Trigger board type 1
Jun 2005

Type1


XILINX
VIRTEX-II
PRO
I.N.F.N Pisa
MEG experiment
Trigger board Type2

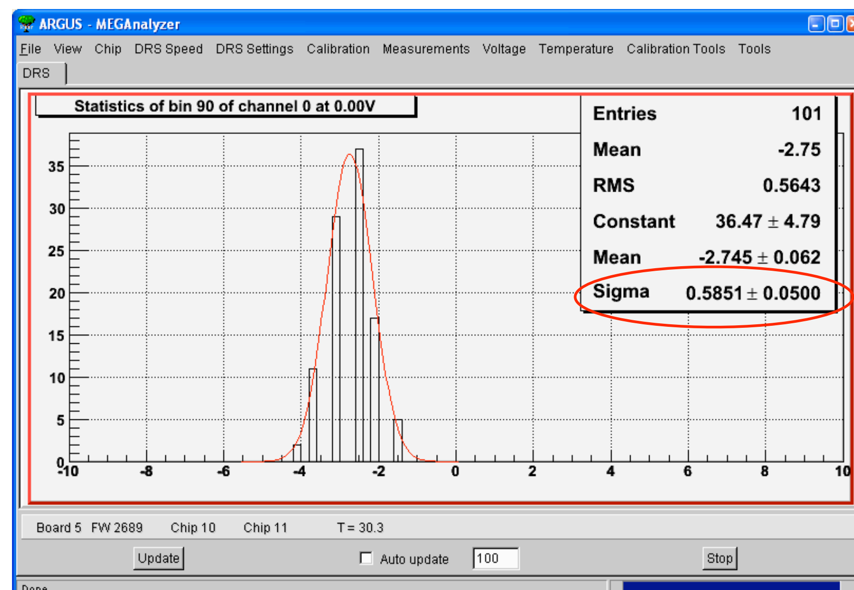
Type2

# DRS2 - new CMC card

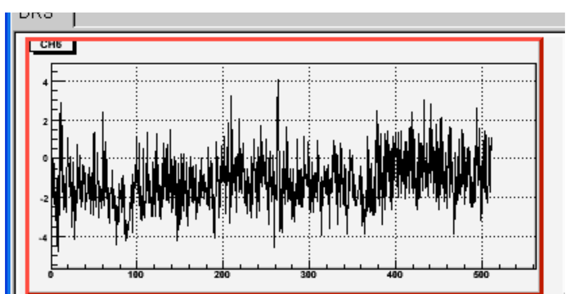



- Better analog design (lower crosstalk and noise
- Moved chips more to front
- Dedicated clock input
- Dual FADC
- Temperature sensor
- 1k EEPROM

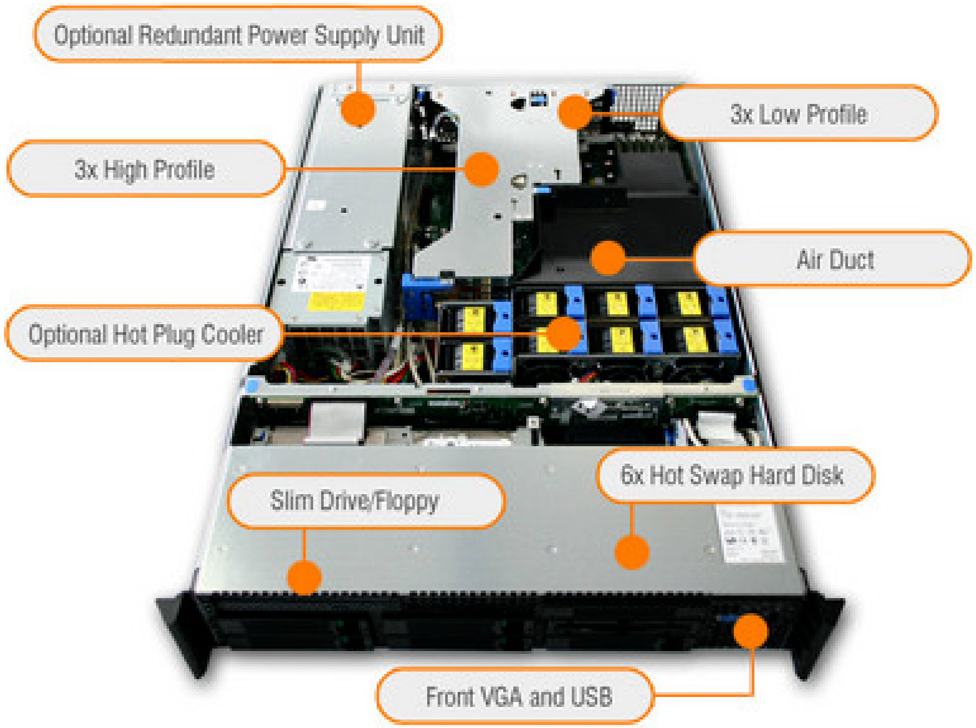
128 DRS2 channels ready




Noise level with the new CMC



| Issue | Solution | DRS2 | DRS3 |
|---|---|---|---|
| Voltage nonlinearity | Calibration with cubic splines in Front-end | ✓ | |
| Clock nonlinearity | Time calibration & frequency regulation | ✓ | |
| Cross talk<br>1% @ 7ns risetime | Redesign of CMC card with ERNI 68-pin connector and interleaved ground lines | ✓ | |
| Temperature dependence | - Calibration maybe possible to some extend<br>- Keep electronics temperature constant<br>- On-chip temperature compensation | ?<br>(✓) | ✓ |
| Self-heating of cells | - Only use small signals (<0.5 V)<br>- On-chip temperature compensation | (✓) | ✓ |
| Ghost pulses | - Veto trigger ~5us after cosmic or LED event<br>- Veto trigger after other calorimeter hits?<br>- Record 2us calorimeter history in each event?<br>- Redesign sampling cell | ✓<br>?<br>? | ✓ |
| | | this year | next year |



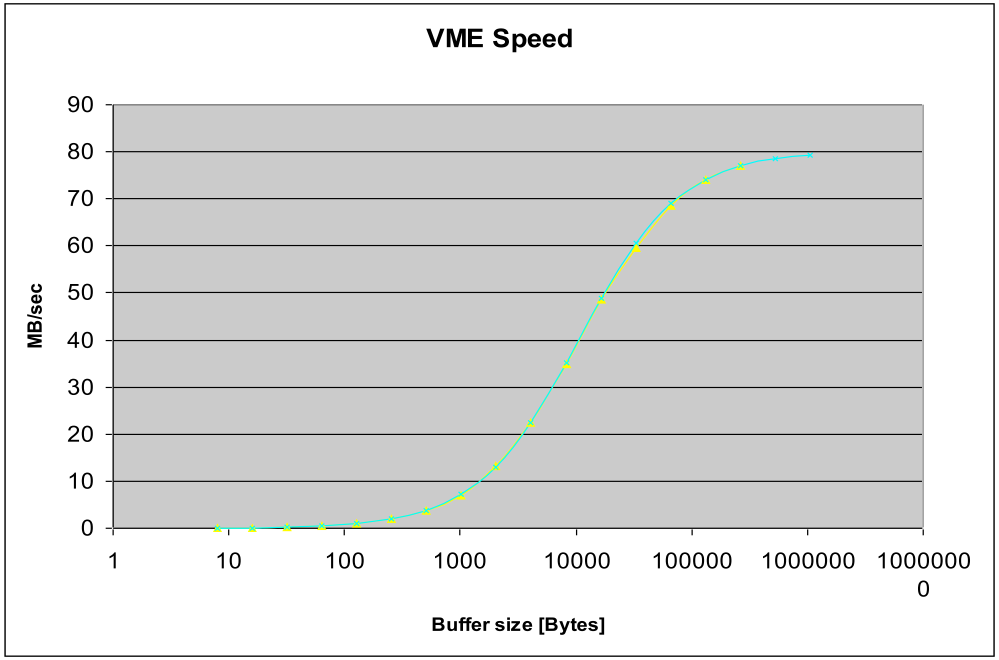

# DAQ

## Readout speed

- Struck SIS3100
- VPC board with CMC
- 2eVME transfer protocol
- Desktop PC (2.6 GHz P4)

T = 125us + size/84 MB/sec

25 ms/event at full readout



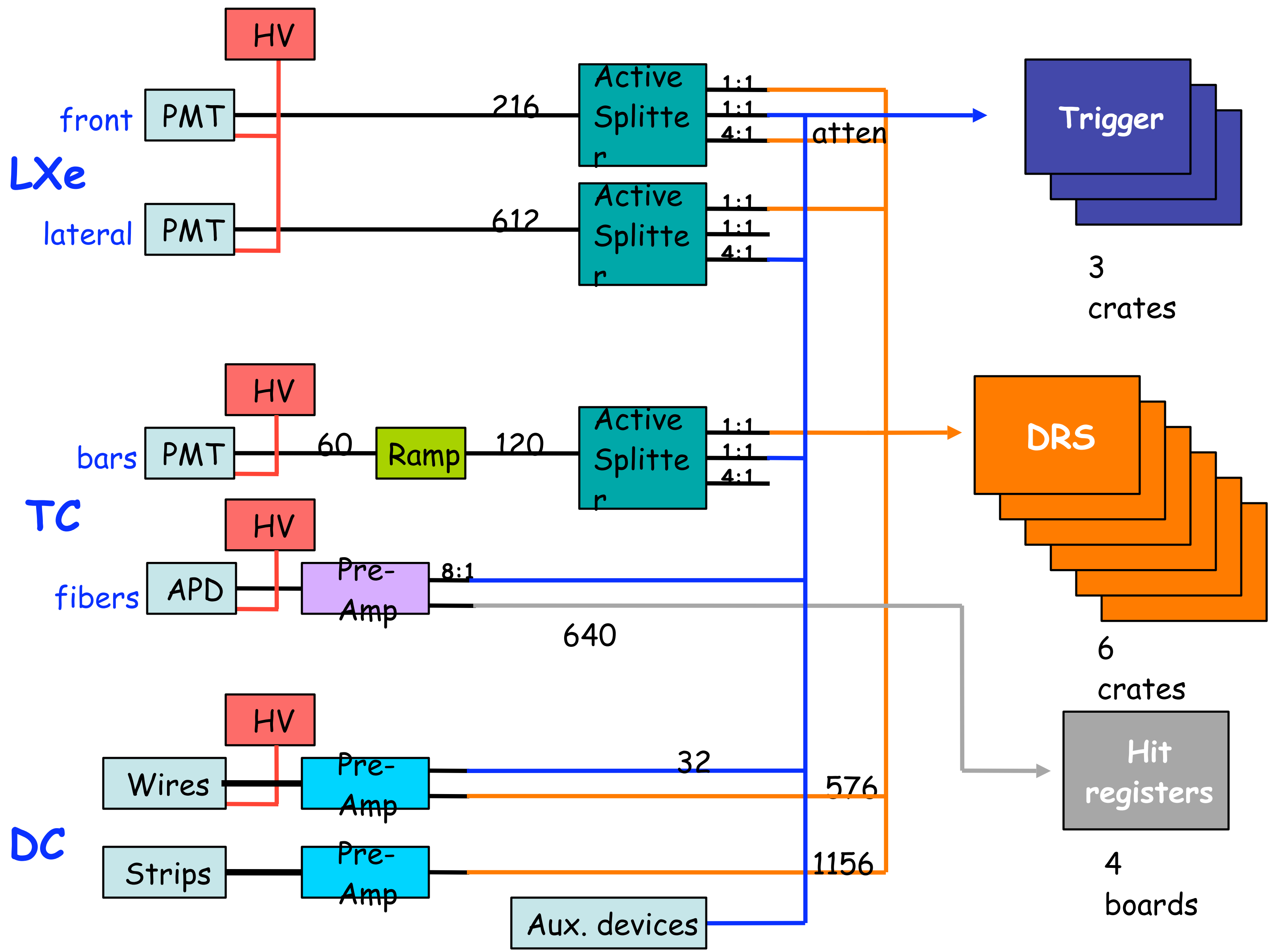

## DAQ computers

Producer: www.thomas-krenn.com

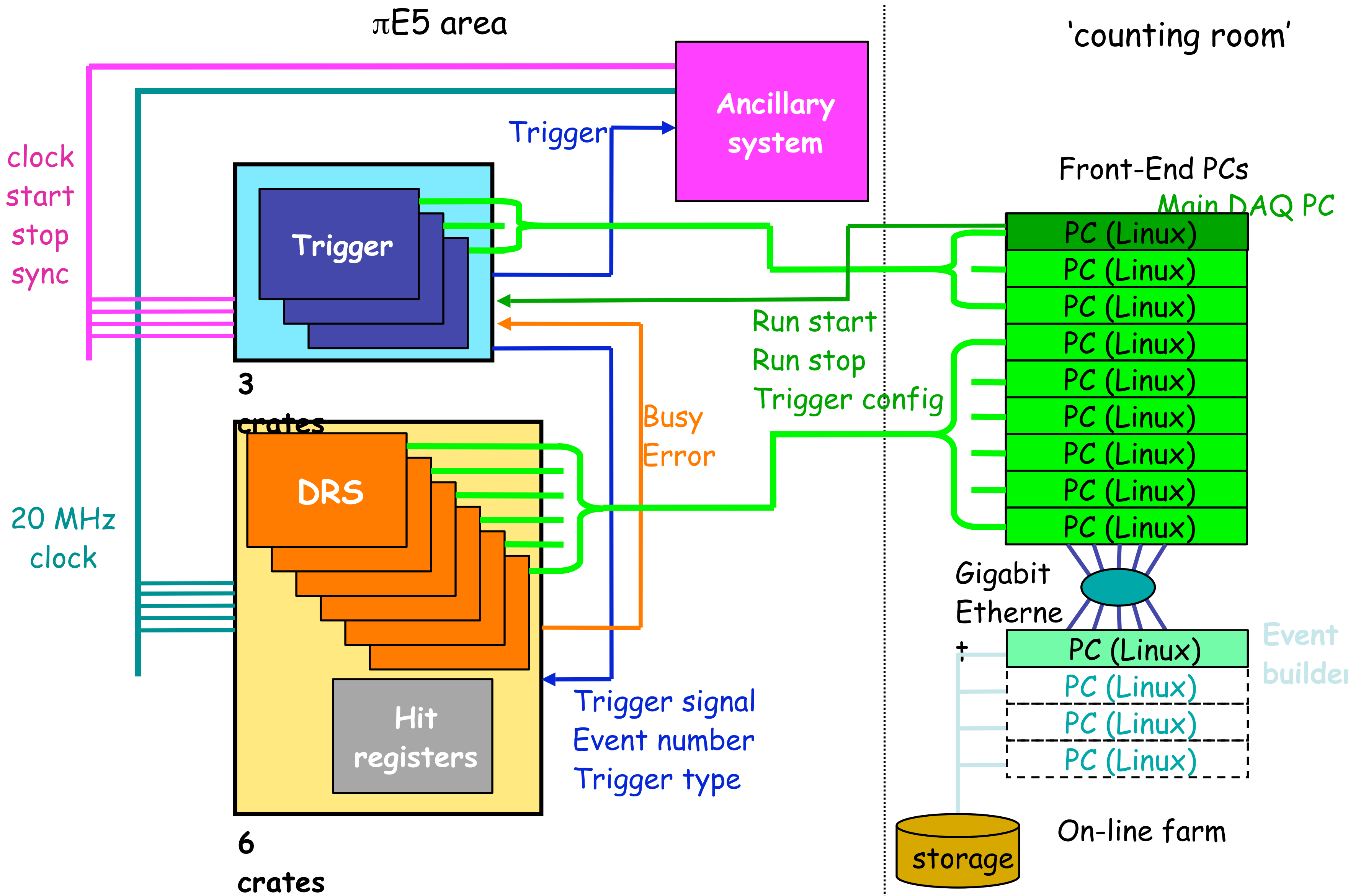
Cost: 1800 €

- Hot-plug cooler
- Redundant power supply
- Hot swap hard disks
- Remote management card

# Electronic chain



# DAQ and control



# Offline

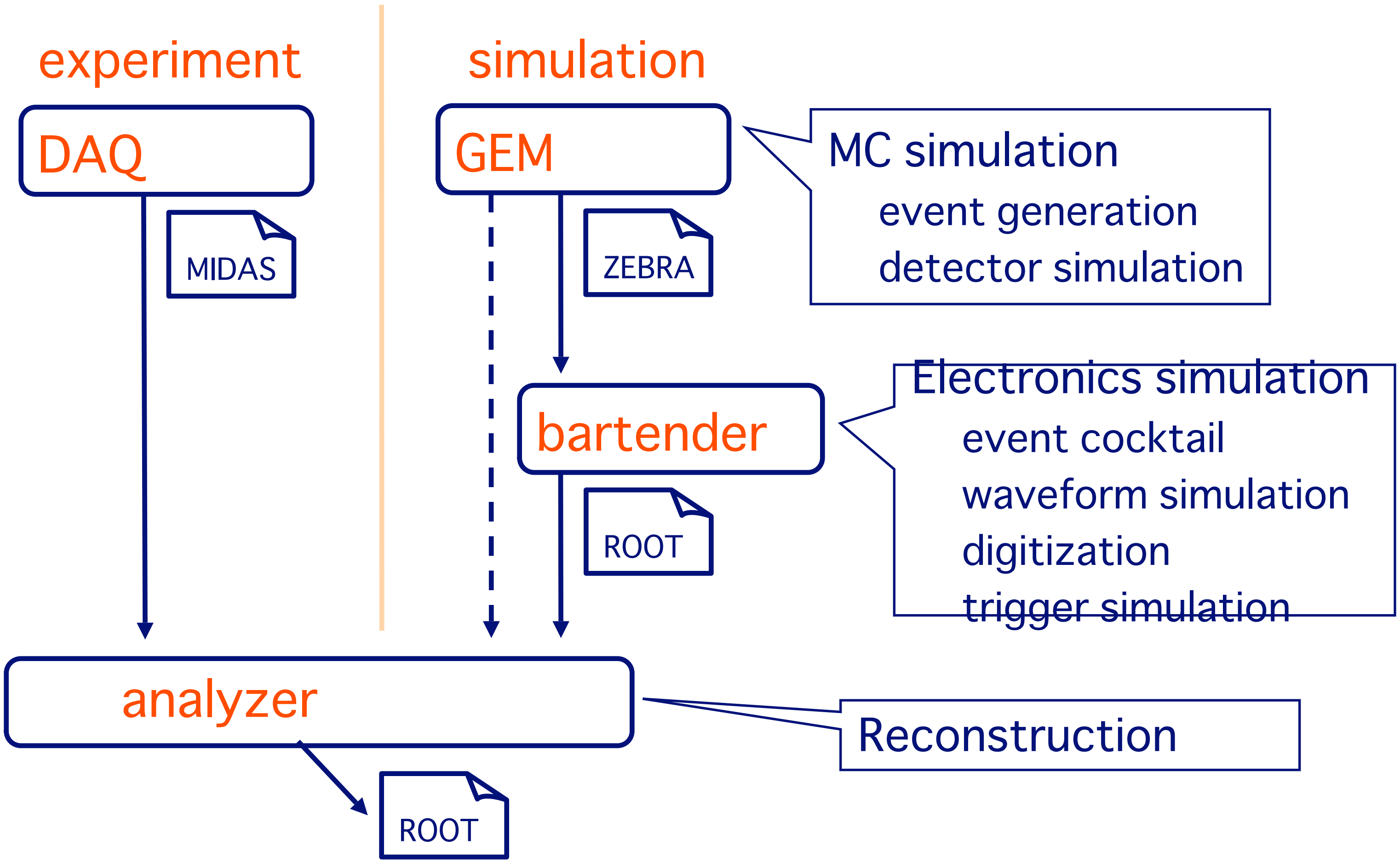
# New Software Organization

| | | |
|---|---|---|
| Simulation | DC | H. Nishiguchi |
| | TC | P. Cattaneo |
| | XE | F. Cei + S. Yamada |
| | Beam/Target | W. Ootani + K. Ozone + V. Tumakov |
| | Calibration | F. Cei |
| | DC digitization | P. Huwe |
| | TC digitization | F. Xiao + TBA |
| | XE digitization | Y. Uchiyama |
| | Trigger simulation | D. Nicolo' + Y. Hisamatsu |
| Analysis | Framework | M. Schneebeli |
| | Database | R. Sawada |
| | DC | H. Nishiguchi + M. Schneebeli |
| | TC | D. Zanello |
| | XE | G. Signorelli + R. Sawada |

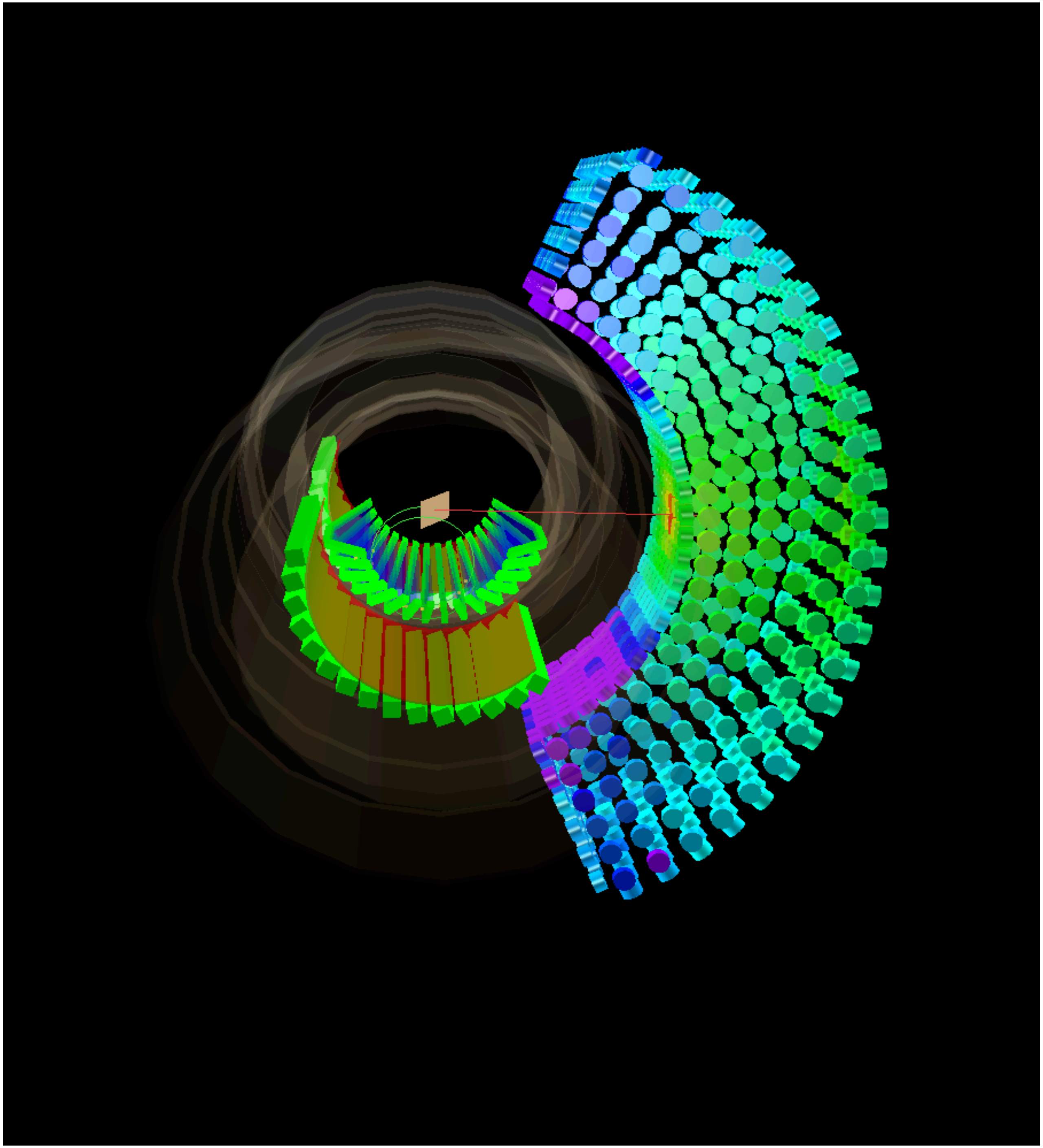
# ROME based analysis tool

- MegRoot was rejected
- Analysis tools based on ROME was approved
  - megbartender : event cocktail & digitization
  - meganalyzer : reconstruction (was called gemframework)
- New software coordination
  - Repository : Fabrizio Cei, Shuei Yamada
  - MC : Fabrizio Cei, Shuei Yamada
  - Offline : Matthias Scheebeli, Ryu Sawada
  - Online : Stefan Ritt

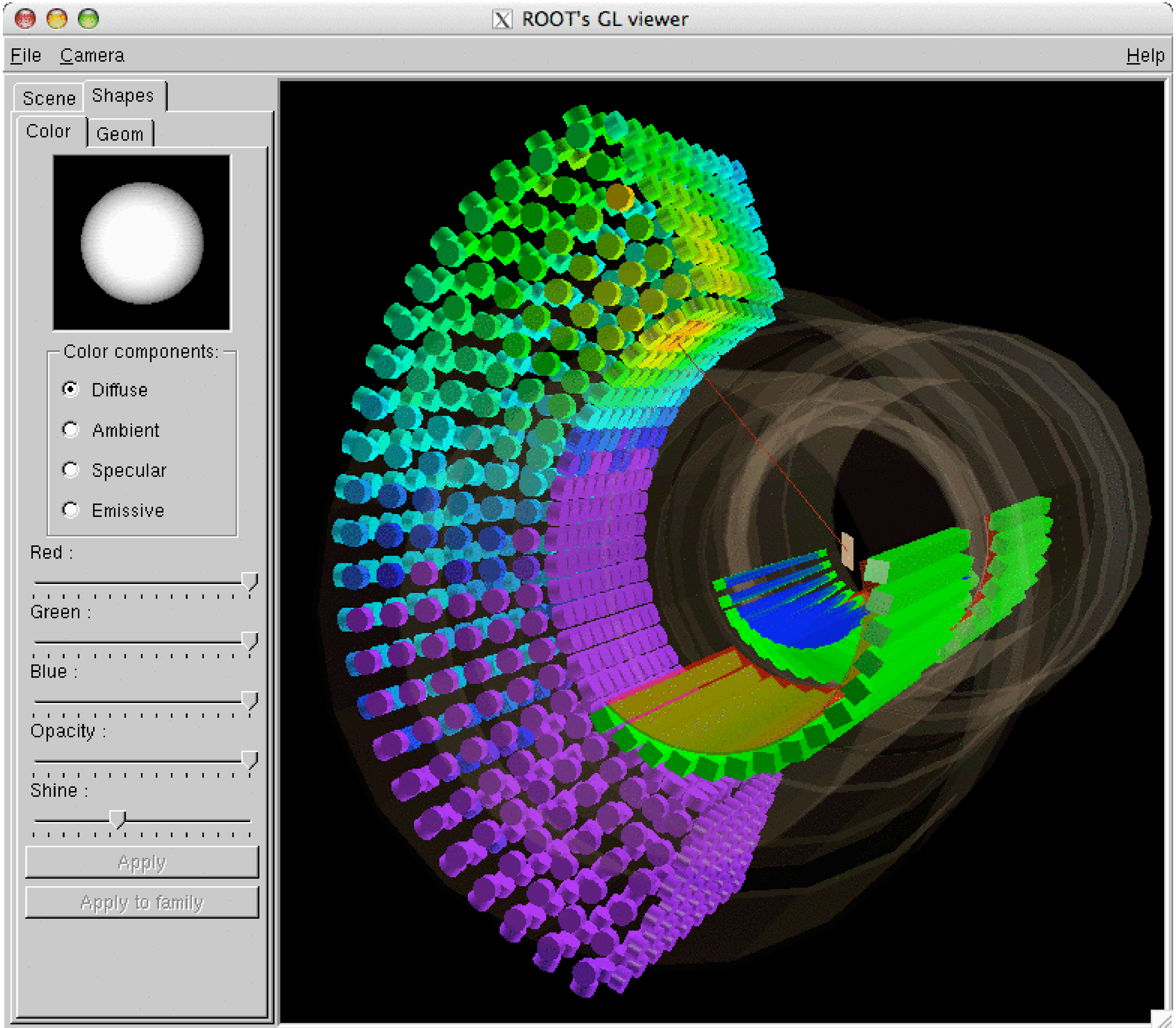
# Procedure of Analysis



# Event Display



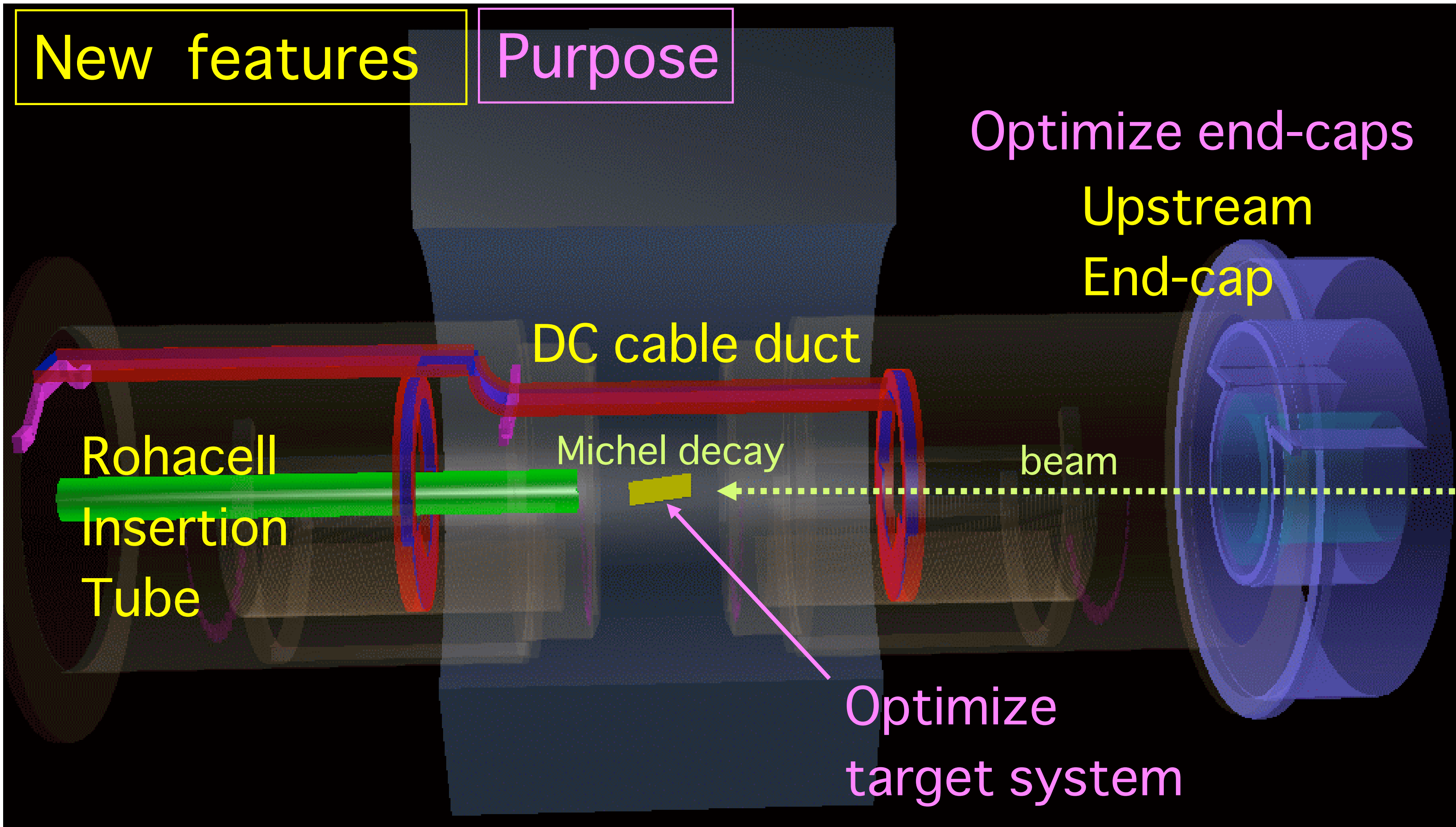
- Both for online & offline


ROOT's GL viewer
File
Camera
Help
Scene
Shapes
Color
Geom
Color components:
Diffuse
Ambient
Specular
Emissive
Red :
Green :
Blue :
Opacity :
Shine :
Apply
Apply to family

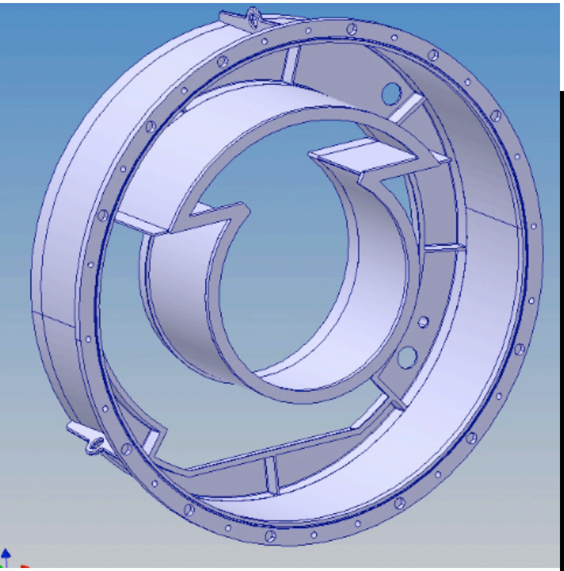
# Ongoing Studies Using MC

- Background Source Study
  - Optimize end cap, target system and Rohacell tube design
- "Annihilation in Flight" (AIF) background in LXe
  - Source of AIF gammas
  - AIF gammas' spectrum & yield
  - AIF Rejection
- LXe Waveform
  - Waveform simulation
  - Pile-up rejection

# BG Source Study



# BG from End Cap

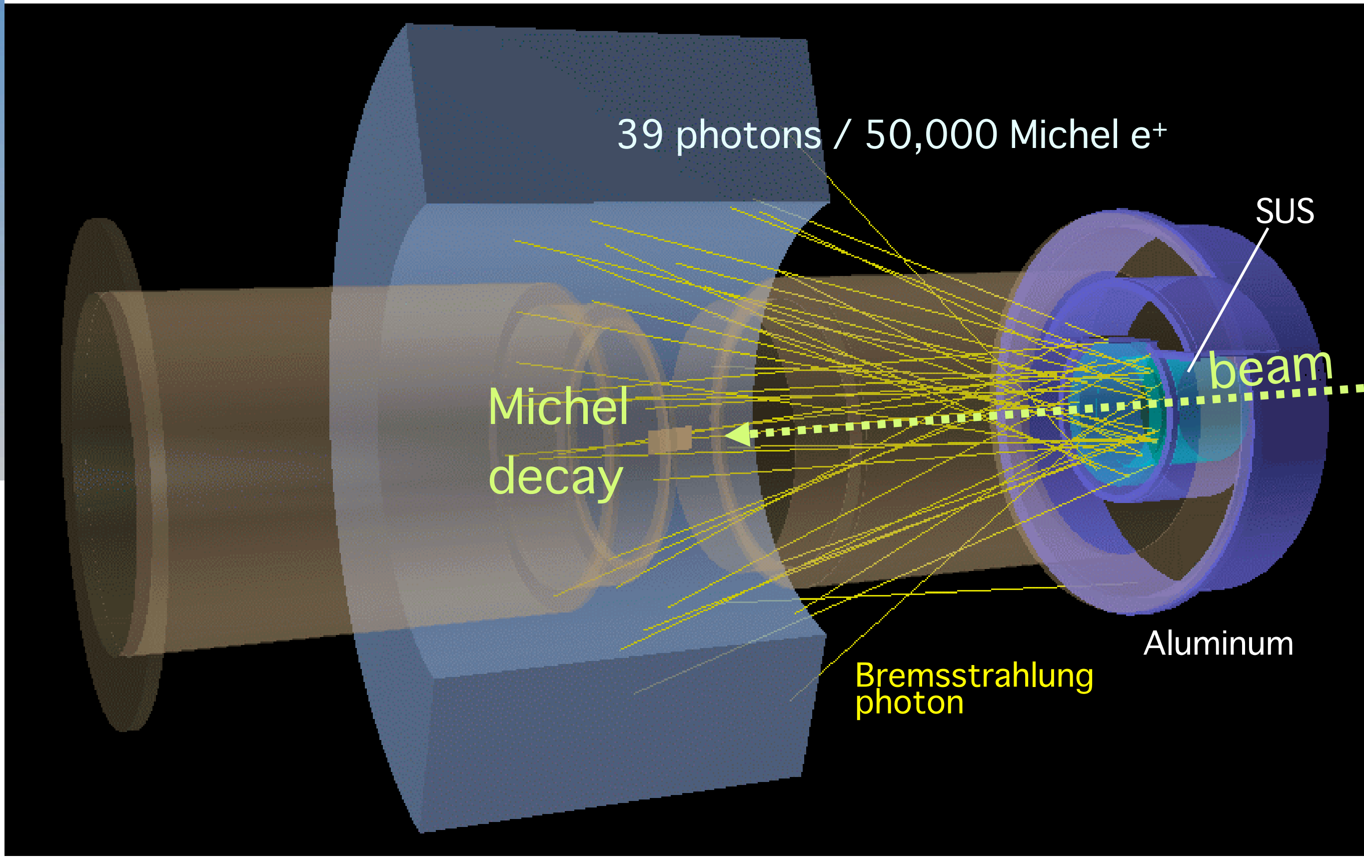


Designed end-cap

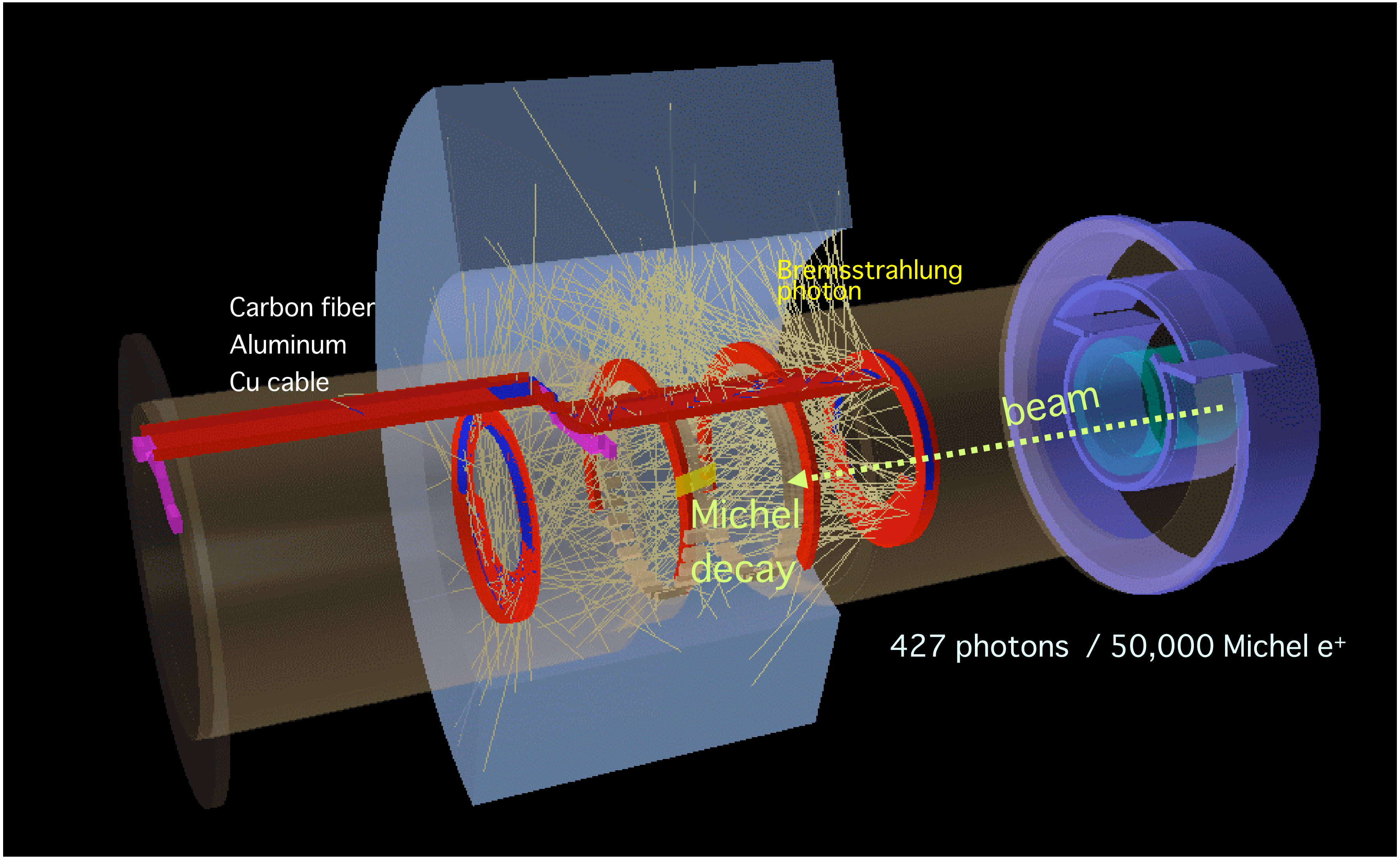
(Aluminum part)

+

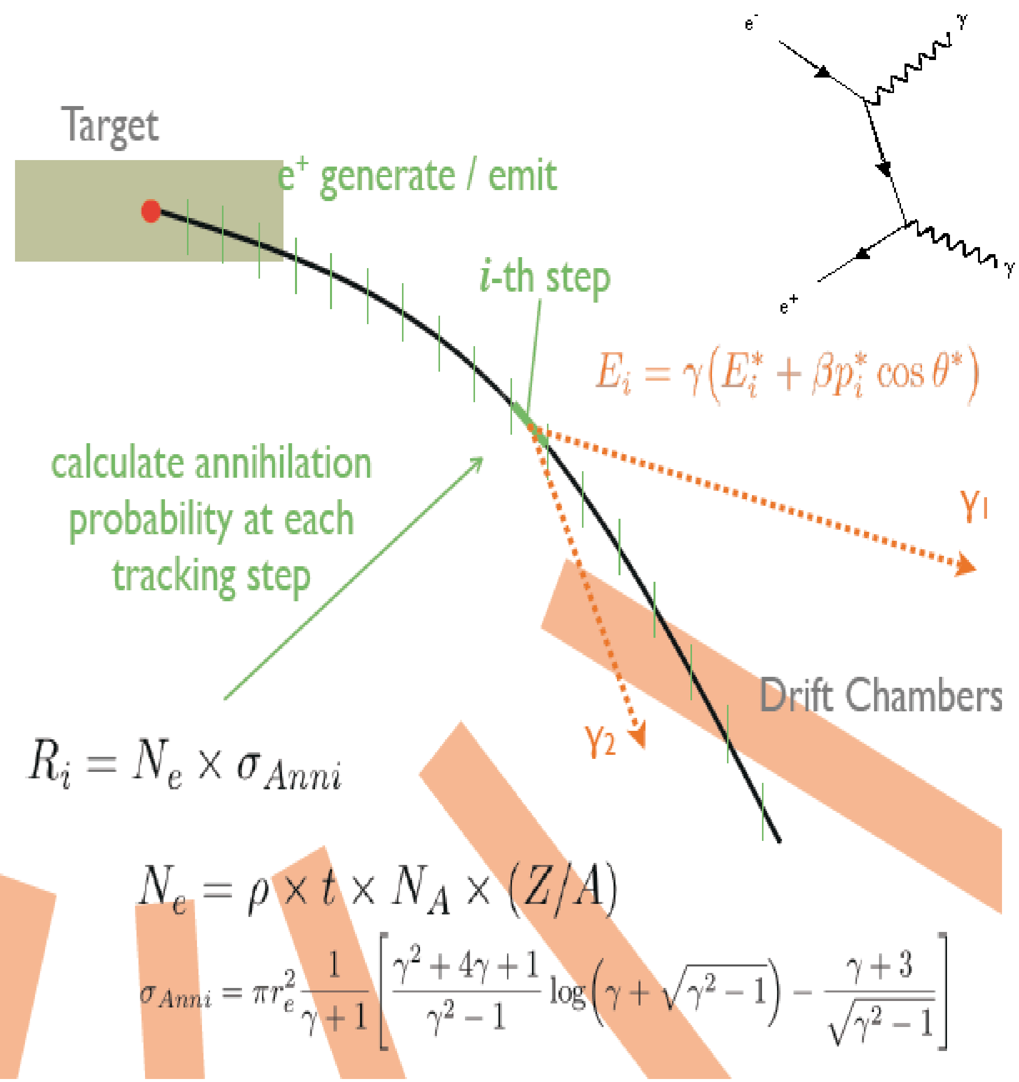
SUS Beam Pipe



# BG from DC cable duct



# AIF study using MC




$$E_i = \gamma\left(E_i^* + \beta p_i^* \cos\theta^*\right)$$

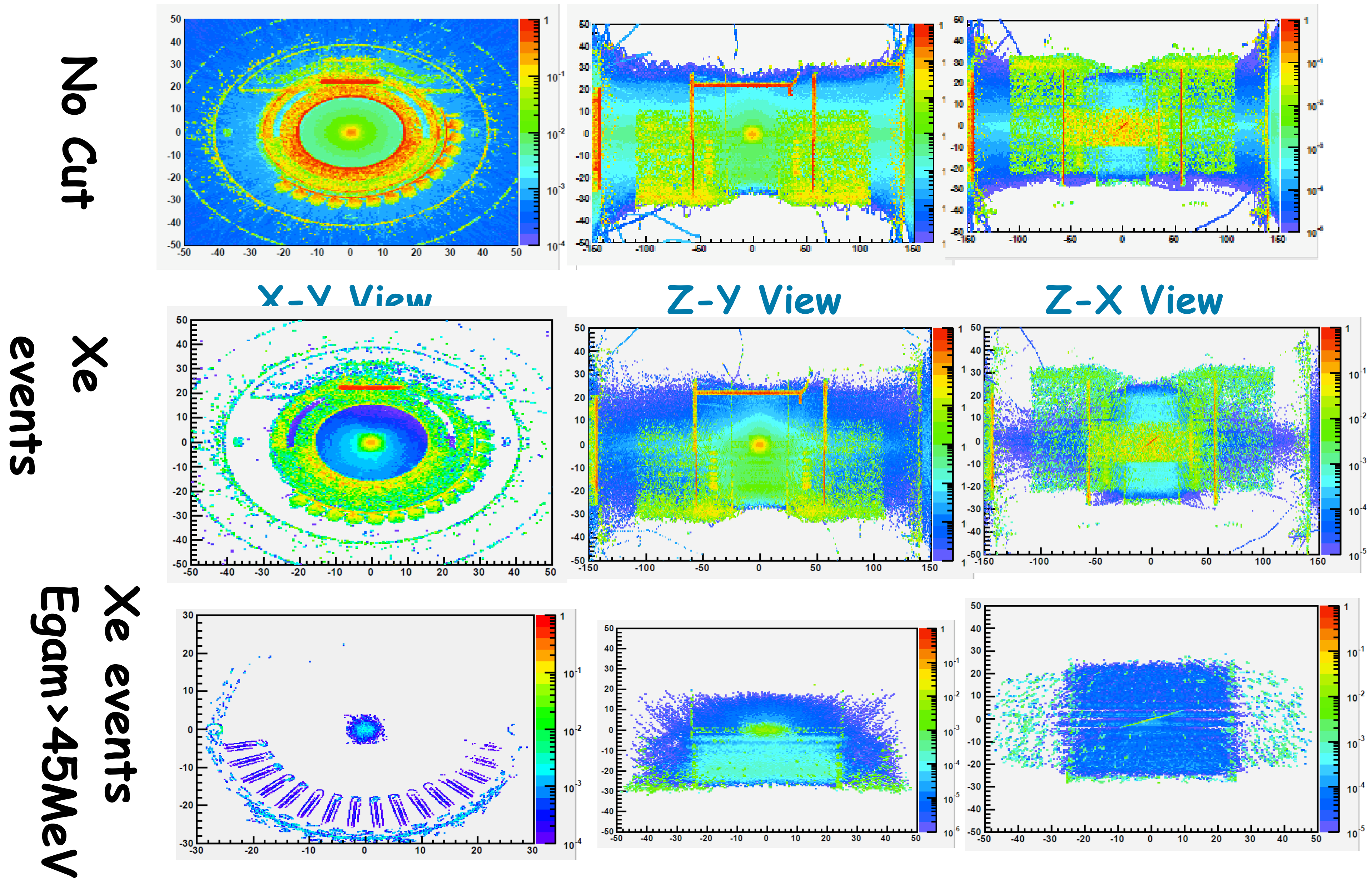
$$R_i = N_e \times \sigma_{Anni}$$

$$N_e = \rho \times t \times N_A \times (Z/A)$$

$$\sigma_{Anni} = \pi r_e^2 \frac{1}{\gamma+1}\left[\frac{\gamma^2+4\gamma+1}{\gamma^2-1}\log\left(\gamma+\sqrt{\gamma^2-1}\right) - \frac{\gamma+3}{\sqrt{\gamma^2-1}}\right]$$

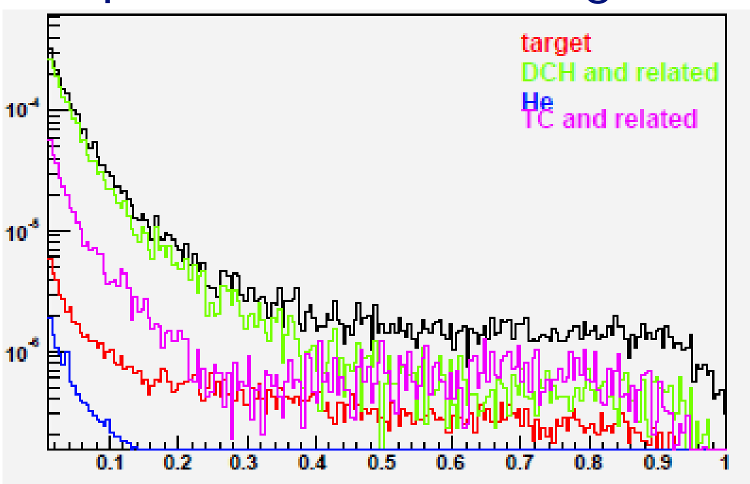
1. Generate Michel e+ in target, emit them for $4\pi$
2. At the each GEANT tracking step, calculate annihilation probability by material information and Michel e+ momentum information
3. Generate 2 $\gamma$ at each step weighted by this probability
4. Trace 2$\gamma$, if it enters Xe cryostat

# AIF probability map



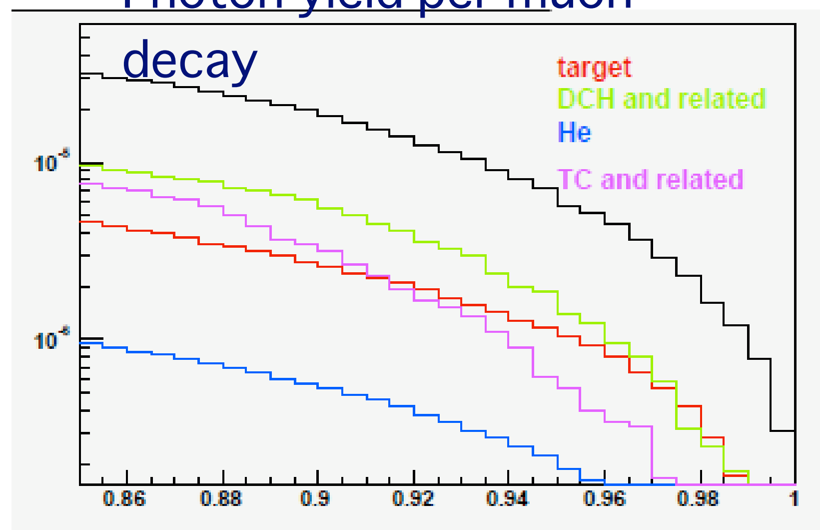
# AIF Spectrum & Photon Yield

AIF spectrum and their origin



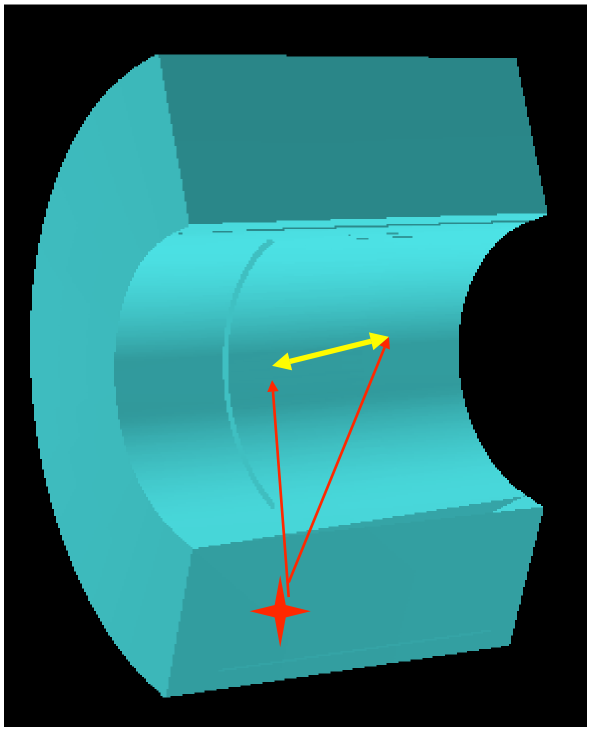

Egam MeV/52.8MeV

Photon yield per muon decay

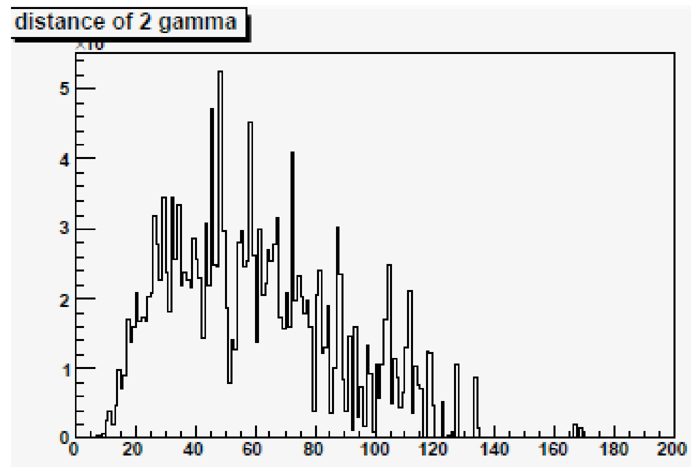



Egam MeV/52.8MeV

# AIF Event Identification in LXe



distance between 2 incident gama rays




$\delta X_{2gamma}$ [cm]

mostly easily identified

# Data Storage Resource & Needs

| | PSI Tapes | PSI Disks | MEG Needs |
|---|---|---|---|
| | 30-40 TBytes (free)<br>+<br>40 TBytes occupied by back up (to be freed) | 4TBytes (backuped)<br>+<br>6TBytes(not backuped) | ～10TBytes/yr (read data)<br>～40-50TBytes/yr (MC Production)<br>～10TB/yr (overheads, DSTs) |
| total | 70-80 TBytes | 10TBytes | 60-70TBytes/yr |

- MEG Needs ～ 5 TBytes/year of Disk Space for DATA
  - Assuming 1/2 of the data collected in one year reside on disk for monitoring, calibrations, faster analysis, etc…

likely need investment for more storage space in the future

# CPU Resource & Needs

| | PSI Nodes | MEG Needs (CPUs/yr) |
| --- | --- | --- |
| | ~~≤ 64~~ ⬇ 128 CPUs | ∼3 CPUs (real data, w/o Waveform fitting) |
| | | < 1 CPU (selected data w/ Waveform fitting) |
| | | ∼20 CPUs (MC production & bartender) |
| | | ∼10 CPUs (MC reconstruction = 3x data, w/o WF fitting) |
| | 128 CPUs ⬆ | < 1 CPU (MC selected sample w/ WF fitting) |
| Total | ~~64 CPUs~~ | ∼33 (+20 per 10 repr.) CPU/yr |

resources available at PSI ~ probably sufficient

# Data Access Resource & Needs

| | PSI Link Speed | MEG Needs |
|---|---|---|
| | 25MBytes/s<br>to tapes via FTP<br>1Gbits/s<br>to disks from CPUs | ～ 1MBytes/s<br>(w/ Waveform compression)<br>～10MBytes/s<br>(w/o Waveform compression) |

resources available at PSI ~ sufficient

PAUL SCHERRER INSTITUT

# Analysis Compute Cluster

Standard Cluster HW for different experimental groups. Store data on disk with fast access from CPU cluster over Gbit network. Evaluation is ongoing.

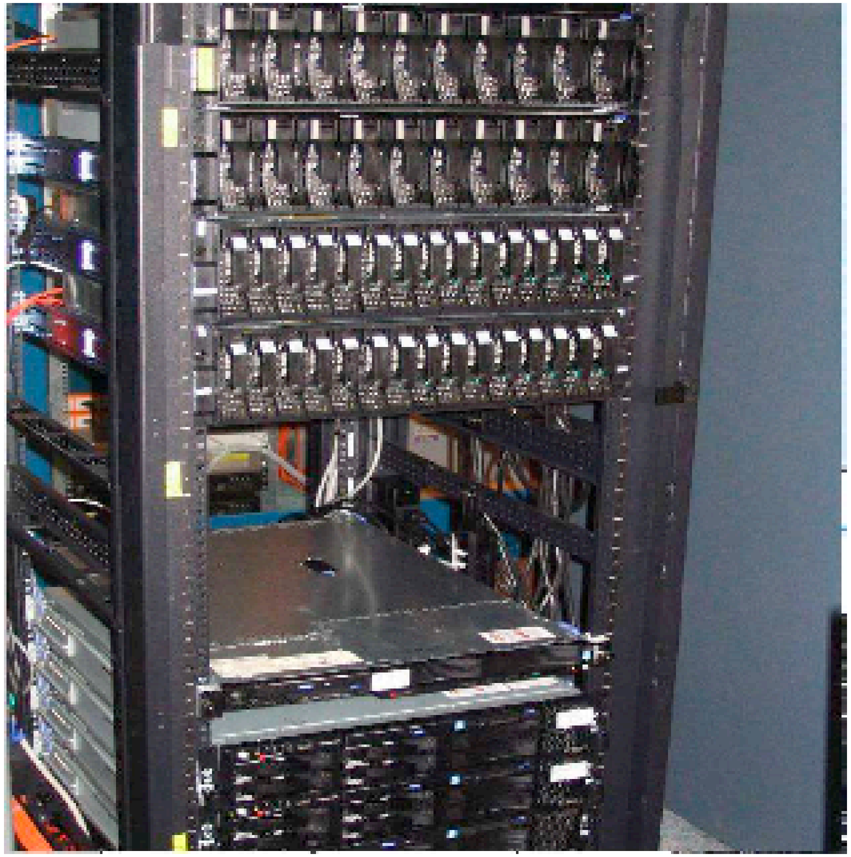
Rackmounted, Remote controllable

Probably Opteron Processors

CPU + Disk Storage, Global FS

Pricing Proposal:  50% of dedicated clusters are paid by the experiment

What is the expected size of the cluster in terms of CPU and storage requirements ?



# Tape Archive System

Access via FTP (for user looks like a big FTP server)

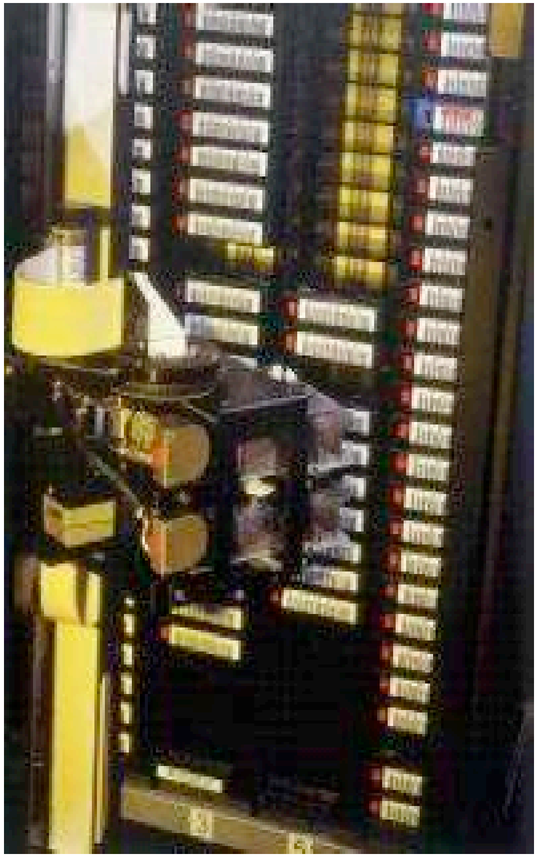
Located in PSI East and West, in total 6 LTO2 drives 30 MB/s write speed. Mirroring optional. 200GB uncompressed per LTO2 tape

FTP server today can accept about 25 MB/s input data rate sustained, new server HW planned

Current size 75 TB, free slot space for about 30-40TB (depends on compression), can be extended by freeing space now occupied for backup which may yield another 40 TB. Further tape cabinets possible.

Experiment should pay the media costs of 50 CHF/Tape

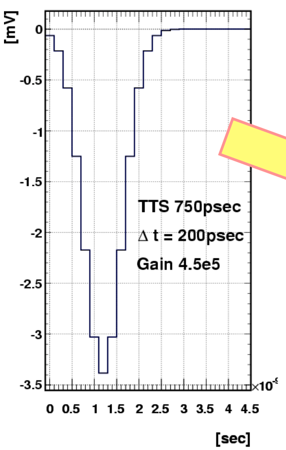
For more details see https://archiv.web.psi.ch/docu.php

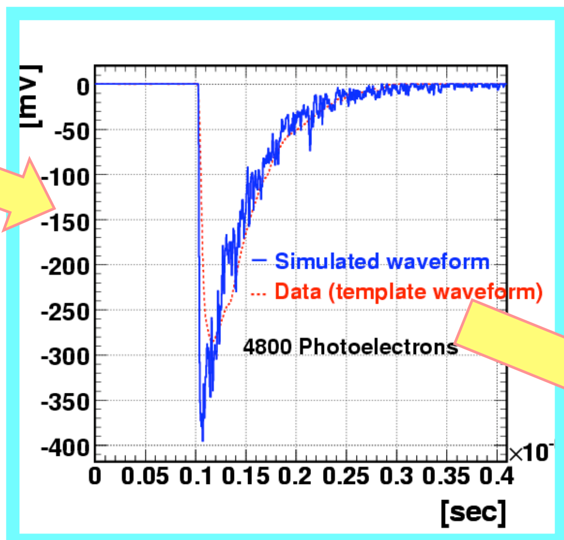


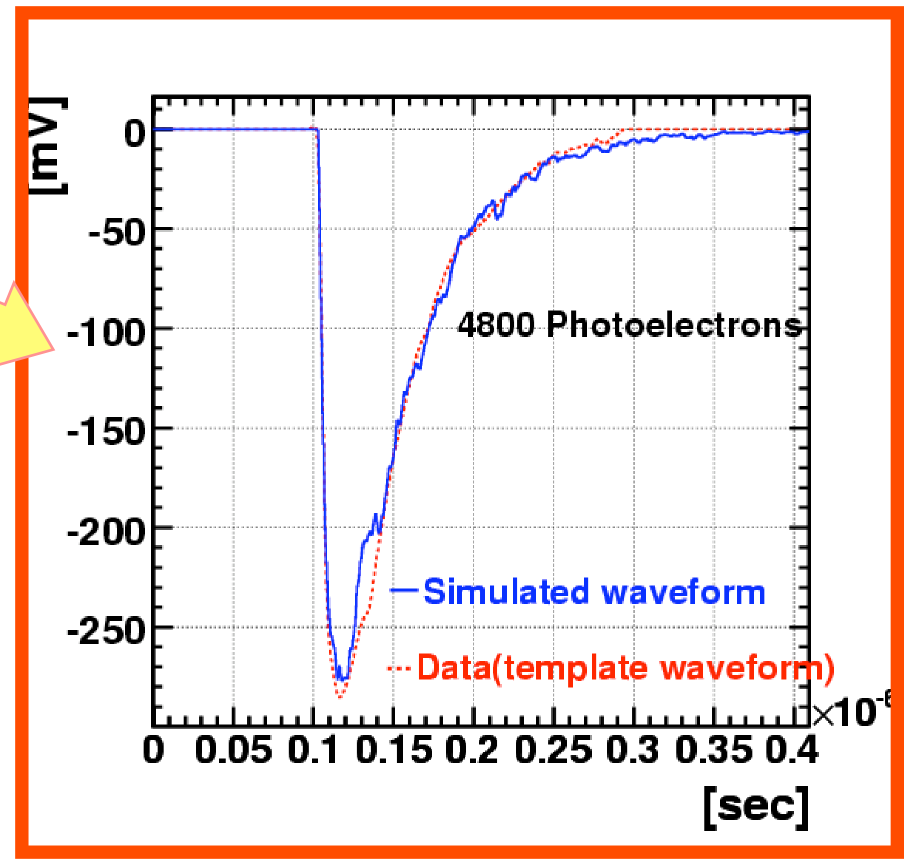
# Simulation of LXe waveforms

## 1. Sum up single electron pulses for all photoelectrons.

- Summed according to each arrival time
- Gaussian whose spread is equal to TTS for single electron response.



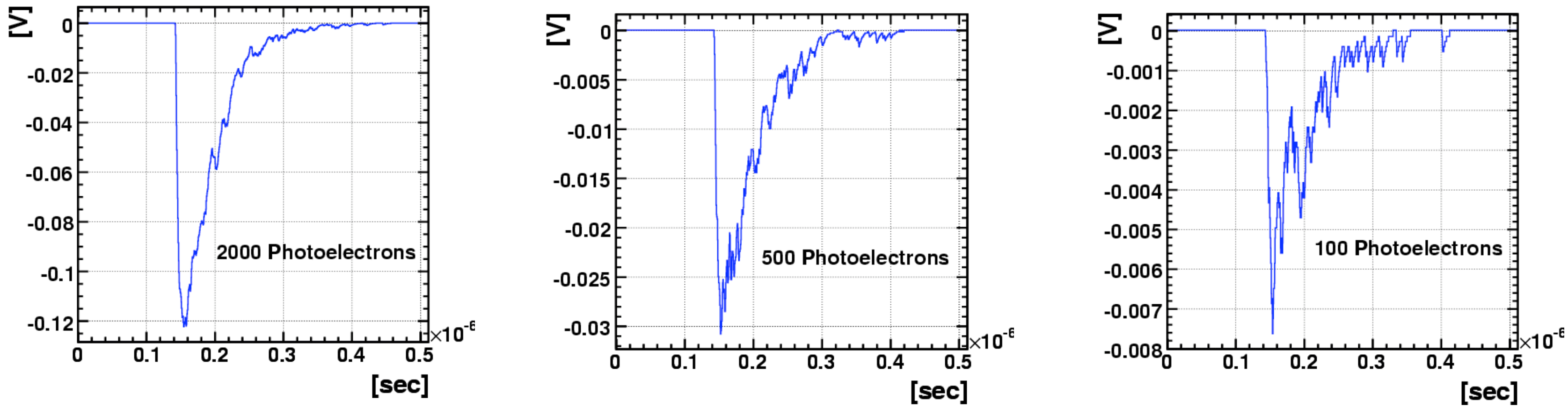




## 2. Shaping from Low Pass Filter

- RC shaping ( Integration circuit )
- Time constant RC = 5nsec

# fluctuations also properly simulated



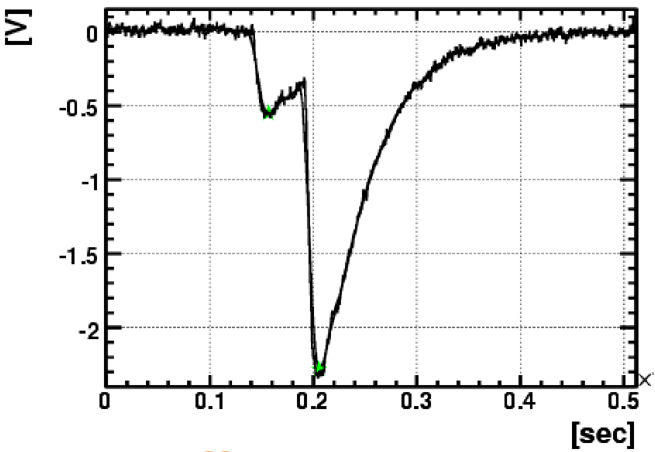

Pulse shapes are not constant especially for small pulses because of statistics.

essentially important for pile-up study.

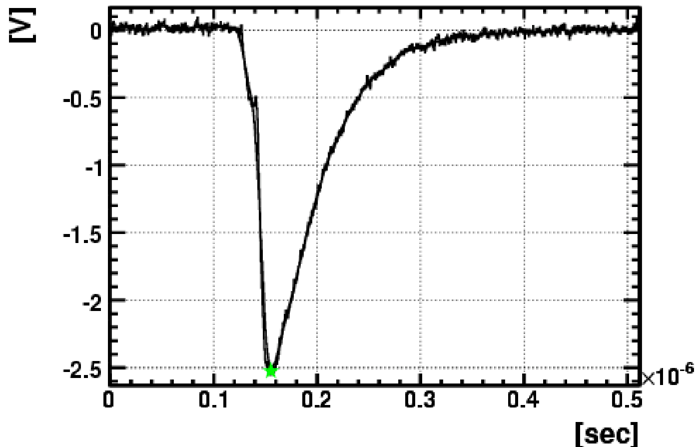
# Quick identification of Pile-up

Peak search method simplest way but powerful in case of large $\Delta T$

**$\Delta T$=50ns.**

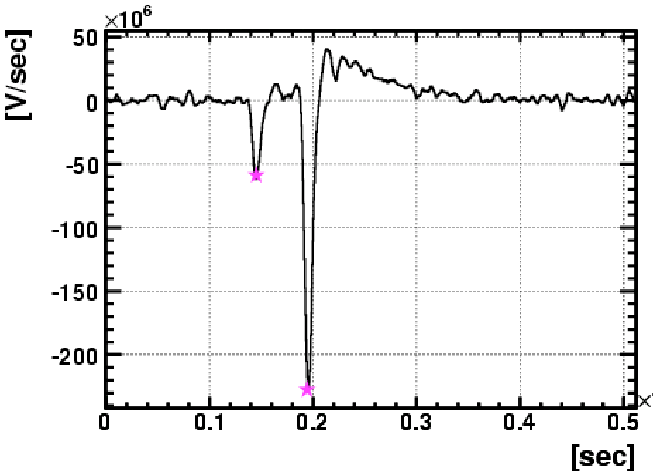


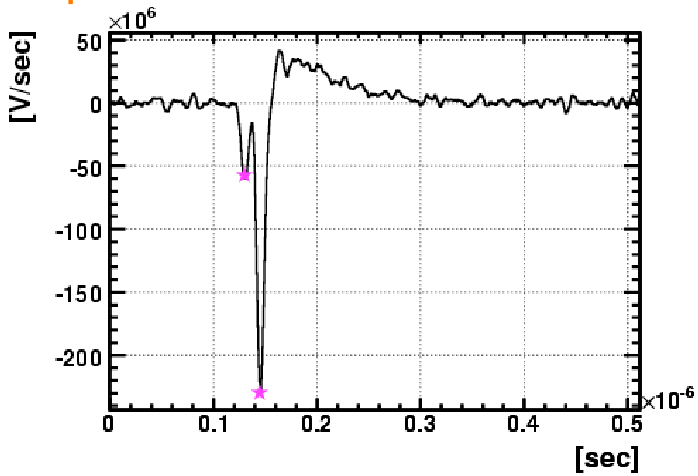

**$\Delta T$=15ns**




Take moving average and count peaks

Differential method powerful in case of $\Delta T$ around rise time



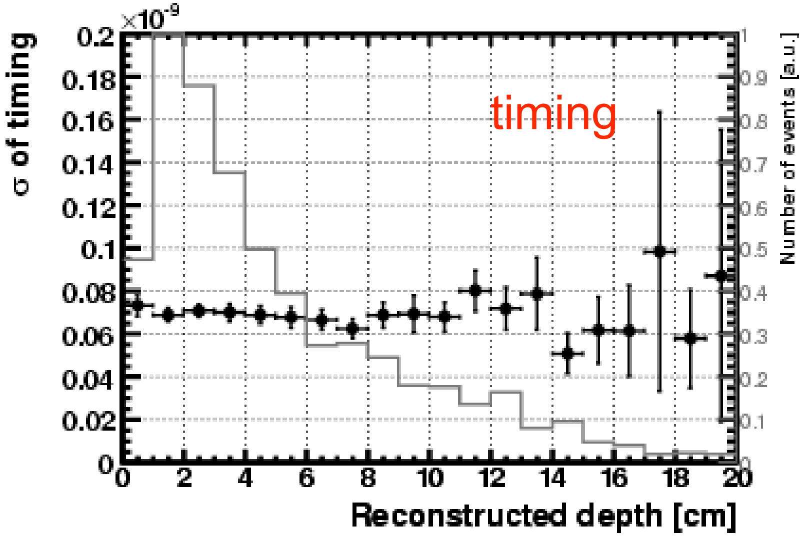




Take differentiation and count its peaks

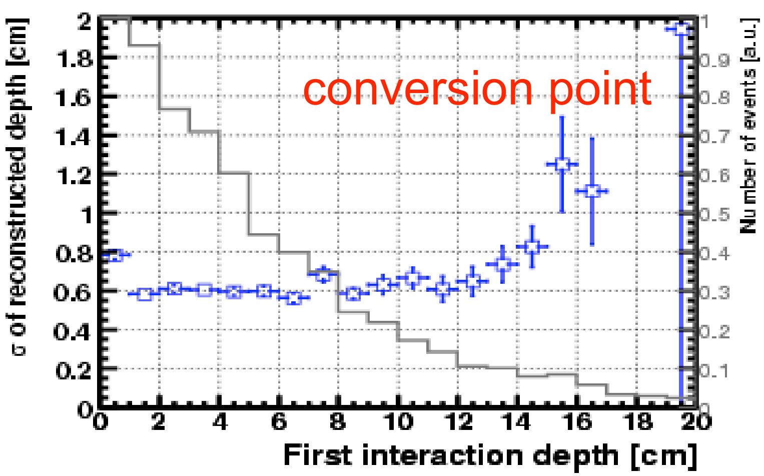
11MeV + 42MeV

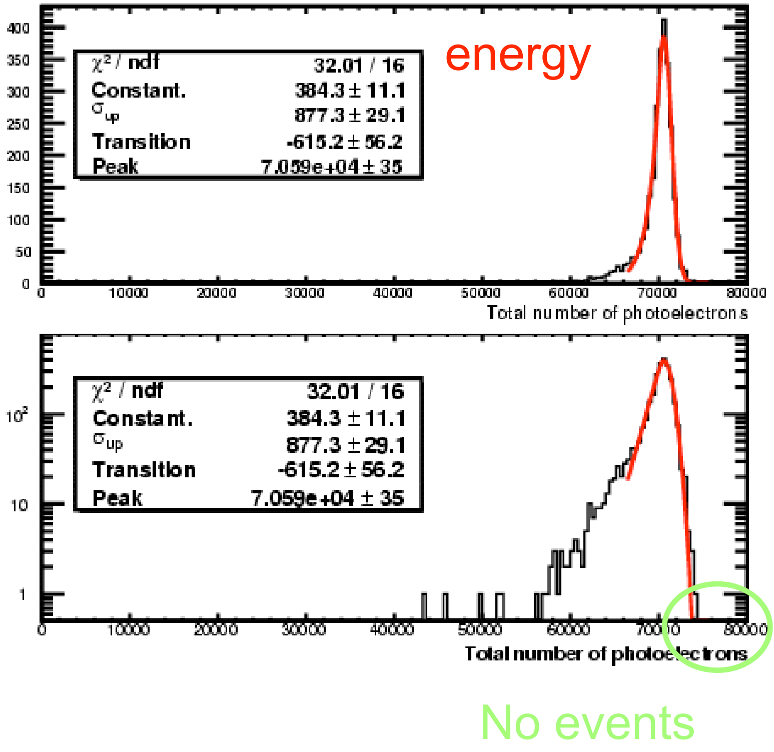
Final analysis would require more sophisticated method - waveform fit

# Resolutions from Waveforms




The MC study shows waveforms will provide resolutions similar to those obtained by the prototype using standard ADCs and TDCs



# Schedule 2006

final beam tuning + detector installation + commissioning the MEG experiment

**Beam Line Commissioning & Associated Detector Schedules Version2,** *22/01/2006*

*Definitions:*
*Date format: ddmmyyyy*
*d =1 working day*
*w = 7 days*

**Updated Schedules associated with the Beam Line:**

- Shutdown -→ until end March 2006
- BEAM START 6/4/2006 (6th April)
- Beam Commissioning + BTS Control System Testing Σ5weeks (4w + 1w contingency due to beam quality post shutdown ) 5/4/2006 → 10/5/2006
- DC-Test **2w** 11/5/2006 → 24/5/2006

final beam tuning
DC test

- BTS Warm-up + Beam Line removal prior to TC-Insertion upstream (US) 5 days (5d) 25/5/2006 → 29/5/2006
- Upstream TC-Installation & testing **11d** 30/5/2006 → 14/6/2006
- Upstream COBRA End-Cap delivery + setup ( not confirmed yet but industry says not unreasonable) ~ 12/6/2006, +5d setup & assembly in PSI Workshops 12/6/2006 → 16/6/2006

upstream TC installation

- Installation COBRA US End-Cap 5d 19/6/2006 → 23/6/2006
- Beam Time for either π-H Collaboration 6w (Gotta et al.) or μ-H Collaboration 8w (Kottmann et al.) (most likely is Kottmann et al.) → 8w 28/6/2006 → 23/8/2006

target + DC + TC installation

- Downstream COBRA End-Cap delivery + setup ( not confirmed yet but industry says not unreasonable) ~ 24/7/2006, +5d setup & assembly in PSI Workshops 24/7/2006 → 28/7/2006
- Installation COBRA DS End-Cap + Insertion System 10d 31/7/2006 → 11/8/2006

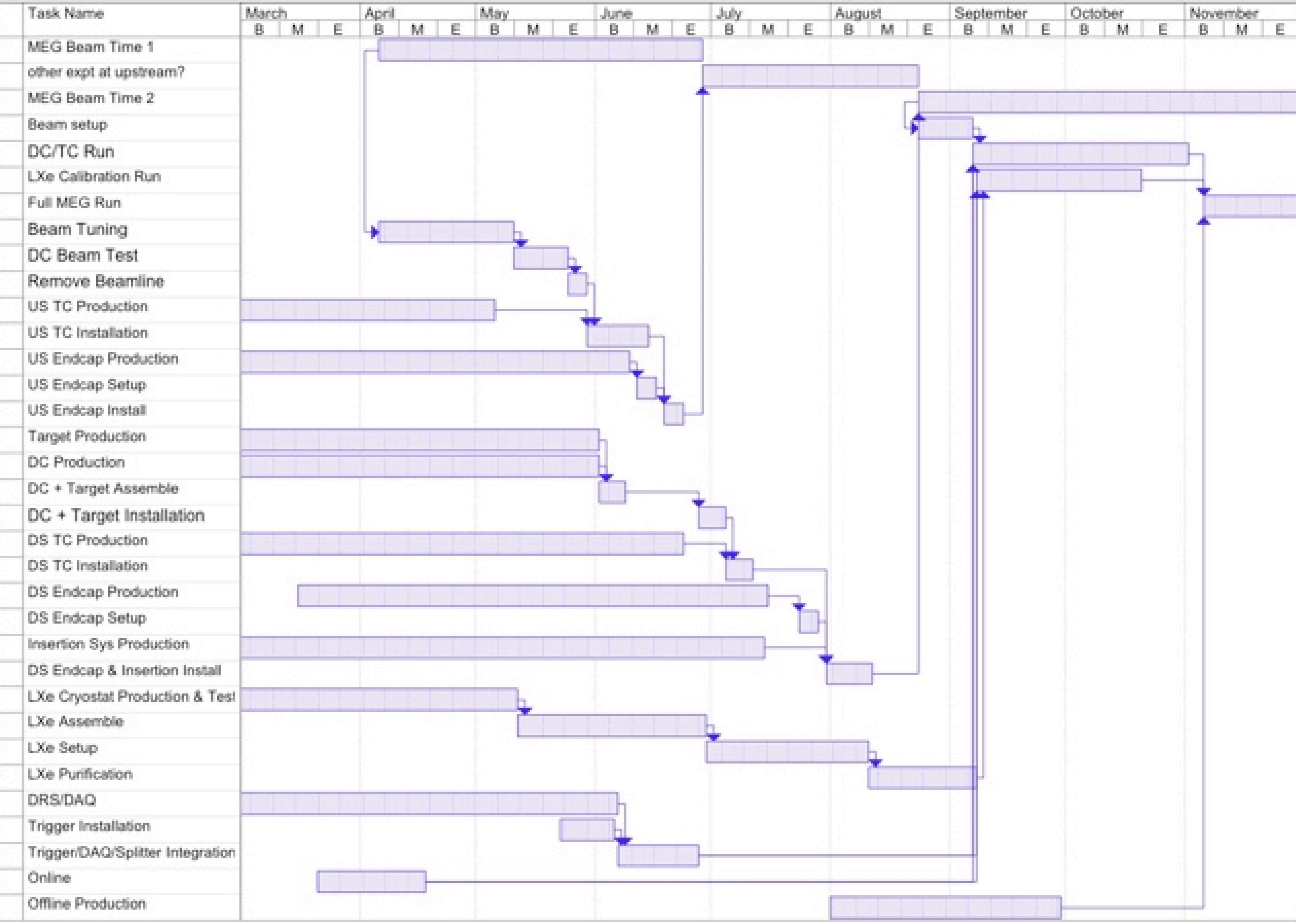
- Re-Installation of MEG Beam Line - Install Separator + Triplet II + BTS 24/8/2006 → 28/8/2006
- Survey Separator + Triplet II + BTS 29/8/2006 → 30/8/2006
- Install Steering Magnet + Collimator System + Degrader System + Vacuum System 31/8/2006
- BTS Cryogenic Connections LHe + $LN_2$ + pumping-down **5d** 26/8/2006 → 30/8/2006
- BTS Cool-down **3d** 31/8/2006 → 3/9/2006
- Beam Line Ready 4/9/2006

DC + TC data taking

to be joined by LXe

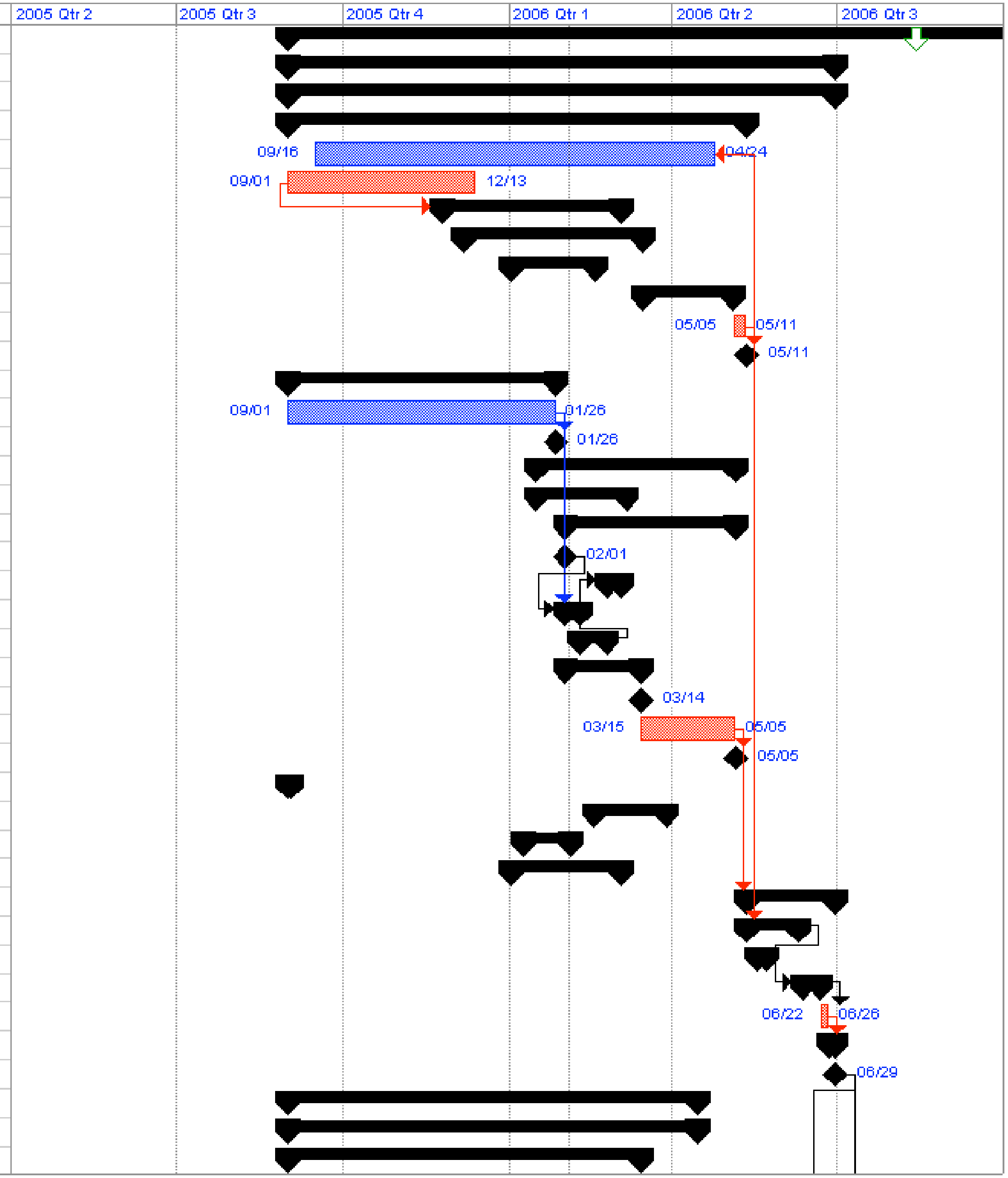
**Approximate Production Schedules:**

| System | Design Phase | Manufacture Phase |
|---|---|---|
| US COBRA End-Cap | → mid February | Mid Feb. → mid June |
| DS COBRA End-Cap | → mid March | Mid March → mid July |
| Insertion System | → End February | March → mid July |
| Target System | → End February | Beg. March → beg. June |


Task Name
March
April
May
June
July
August
September
October
November
B M E
MEG Beam Time 1
other expt at upstream?
MEG Beam Time 2
Beam setup
DC/TC Run
LXe Calibration Run
Full MEG Run
Beam Tuning
DC Beam Test
Remove Beamline
US TC Production
US TC Installation
US Endcap Production
US Endcap Setup
US Endcap Install
Target Production
DC Production
DC + Target Assemble
DC + Target Installation
DS TC Production
DS TC Installation
DS Endcap Production
DS Endcap Setup
Insertion Sys Production
DS Endcap & Insertion Install
LXe Cryostat Production & Test
LXe Assemble
LXe Setup
LXe Purification
DRS/DAQ
Trigger Installation
Trigger/DAQ/Splitter Integration
Online
Offline Production

# More detailed schedule available for each sub-project

| ID | Task Name |
|---|---|
| 1 | MEG |
| 2 | **Detector Systems** |
| 3 | **Liquid xenon (Satoshi Mihara)** |
| 4 | **LXe cryostat (Alessandro Baldini)** |
| 5 | Oversight of LXe cryostat production |
| 6 | Delivery of cryostat materials |
| 7 | **LXe cryostat cold vessel fabrication** |
| 27 | **LXe cryostat warm vesel fabrication** |
| 44 | **LXe cryostat window production** |
| 59 | **LXe cryostat final assembly** |
| 75 | Ship LXe cryostat to PSI |
| 76 | LXe cryostat received at PSI |
| 77 | **Phototube mounts** |
| 78 | Fabricate LXe phototube mounts |
| 79 | Lxe phototube mounts ready for installation |
| 80 | **Phototubes** |
| 81 | 4th PMT test (130 PMTs) |
| 90 | PMT Installation |
| 91 | Start PMT installation |
| 92 | Top/Bottom |
| 97 | Outer |
| 102 | Upstream/Downstream |
| 107 | Inner |
| 112 | Inner LXe tubes installed |
| 113 | Reserve |
| 114 | All PMTs mounted |
| 115 | HV system for the LXe phototubes (Stefan Ritt) |
| 119 | **Xenon storage** |
| 125 | **Gas phase purifier** |
| 128 | **Liquid Phase purifier** |
| 132 | **LXe Assembly** |
| 133 | LXe Assembly mechanical |
| 143 | LXe assembly cabling |
| 145 | LXe assembly check |
| 150 | Level meter installation |
| 151 | **Spacer installation** |
| 154 | LXe closed, ready to move |
| 155 | **Pi0 Calibration** |
| 156 | **Detector (Satoshi Mihara)** |
| 161 | **Hydrogen target (Fabrizio Cei)** |

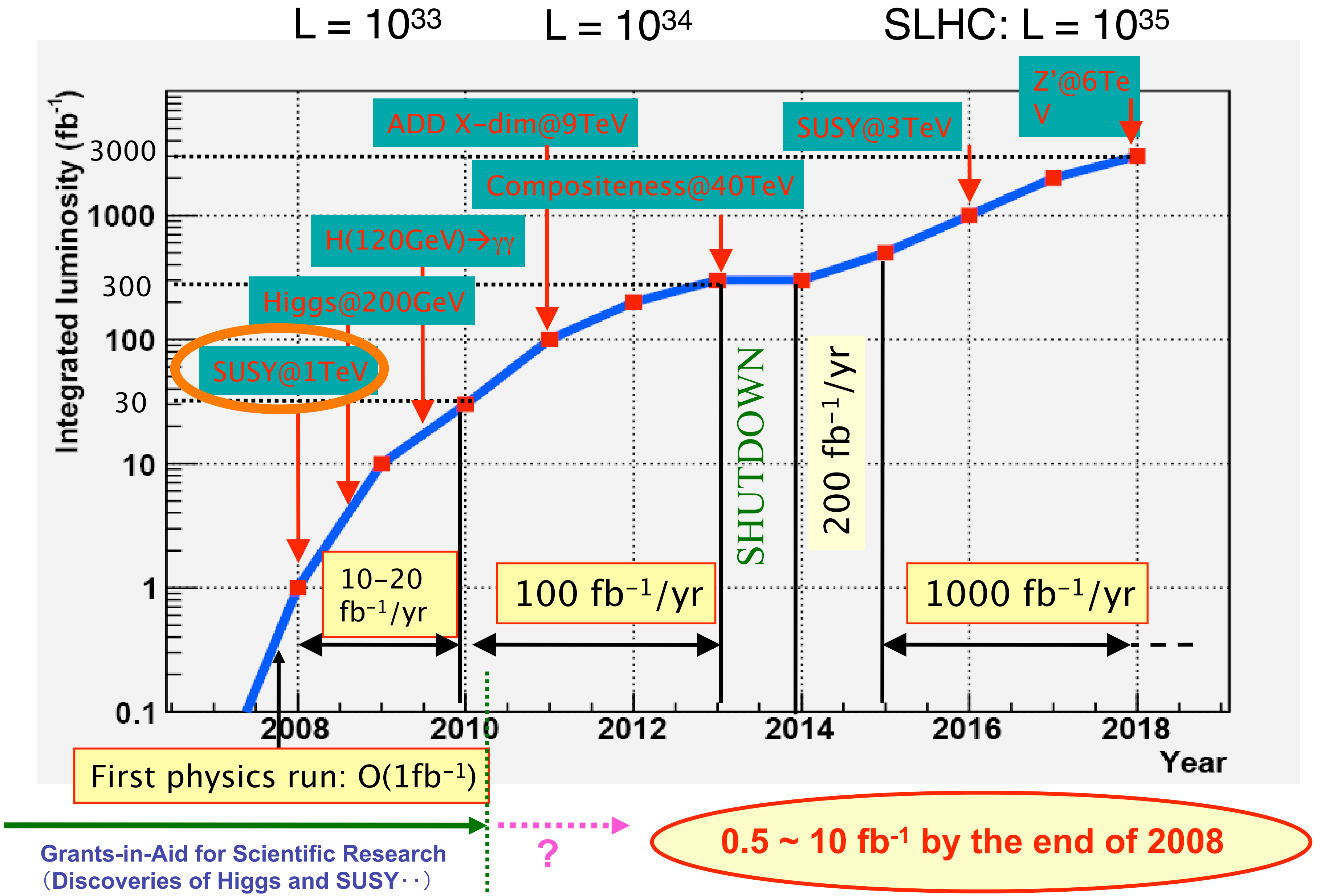


Our goal remains the same:

**A “significant” result before any LHC discovery**

# LHC Luminosity Profile

Michel Della Negra
CMS week (Sep.2005)



MEG

Publish in 2008
the “significant” result

⬇

Full data taking in 2007

⬇

**Start data taking in 2006**
**to fully test the whole experiment**