Installation and test of the MEG Cockroft-Walton accelerator

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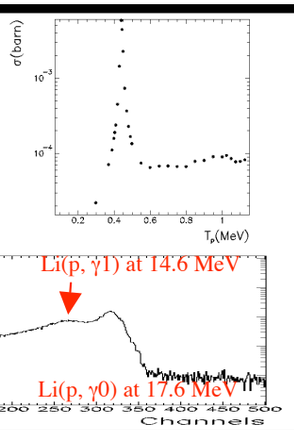
PSI - INFN Pisa - ICEPP Tokyo

MEG Experiment Review Meeting
July 18, 2007

Calibrations

- We are prepared for complementary and redundant calibration methods

Proton Accelerator



Li(p,γ)Be

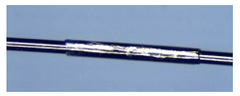
LiF target at COBRA center

17.6MeV γ

~daily calib.

also for initial setup

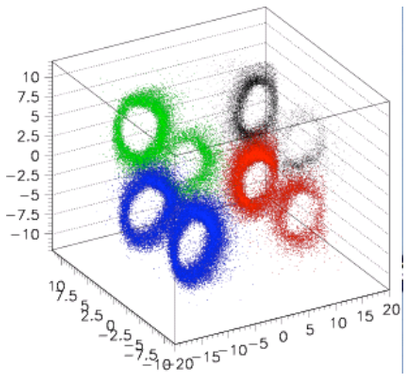
Alpha on wires



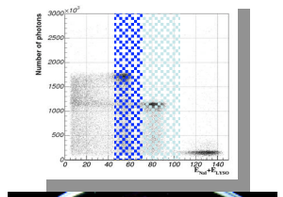
PMT QE & Att. L

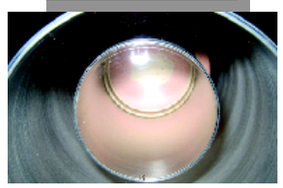
Cold GXe

LXe



$\pi^0 \rightarrow \gamma\gamma$



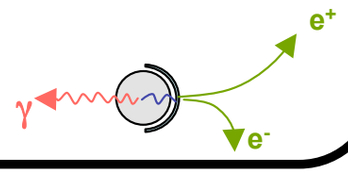


$\pi^- + p \rightarrow \pi^0 + n$

$\pi^0 \rightarrow \gamma\gamma$ (55MeV, 83MeV)

$\pi^- + p \rightarrow \gamma + n$ (129MeV)

LH_2 target

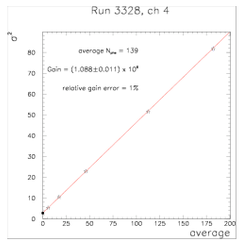


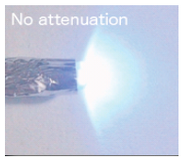
Xenon Calibration

LED

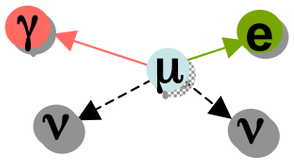
PMT Gain

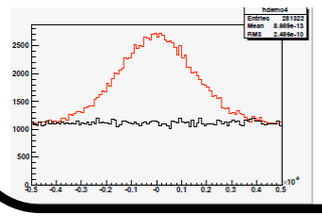
Higher V with light att.





μ radiative decay





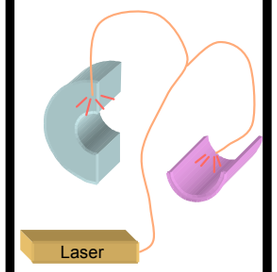
Lower beam intensity < 10^7

Is necessary to reduce pile-ups

A few days ~ 1 week to get enough statistics

Laser

relative timing calib.

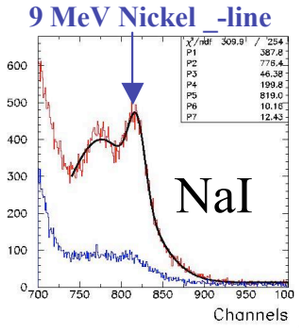


Nickel γ Generator

off on

Illuminate Xe from the back

Source (Cf) transferred by comp air → on/off

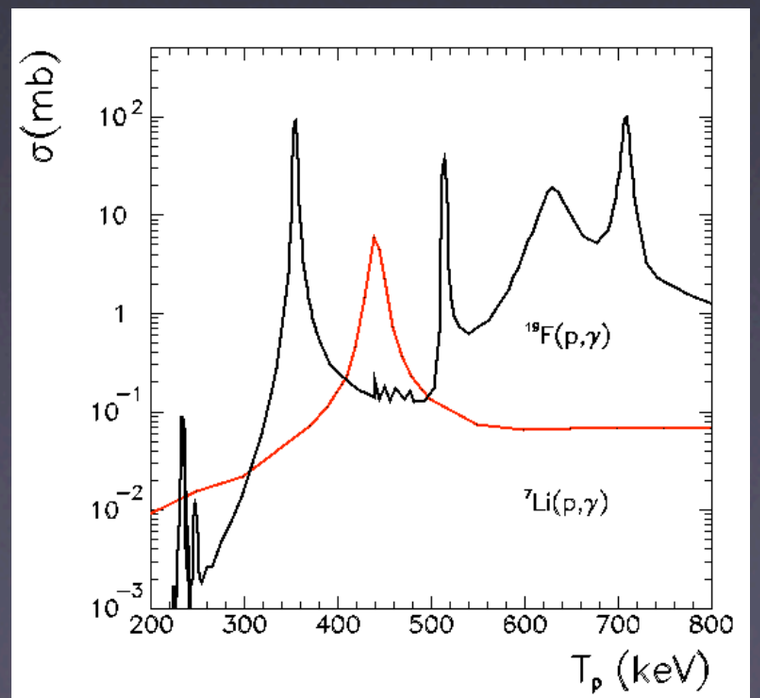


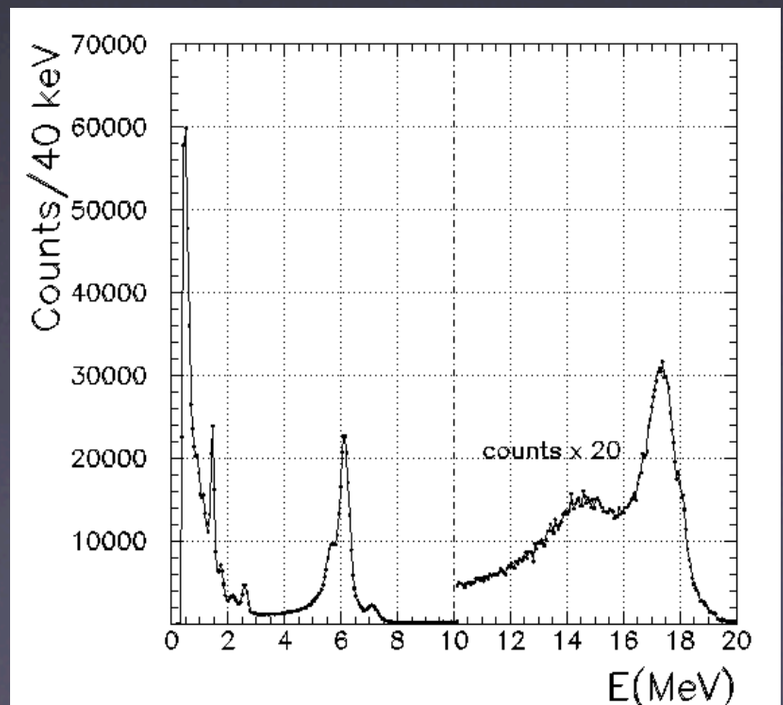
The MEG C-W accelerator

- γ-ray production by the reactions Li(p,γ)Be and B(p,γ)C
- Main method to check the energy scale and stability of the calorimeter on a daily basis

Reaction	*Resonance energy*	σ peak	γ-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

- LiF target is easier to prepare compared to Li alone but ^{19}F has other lines

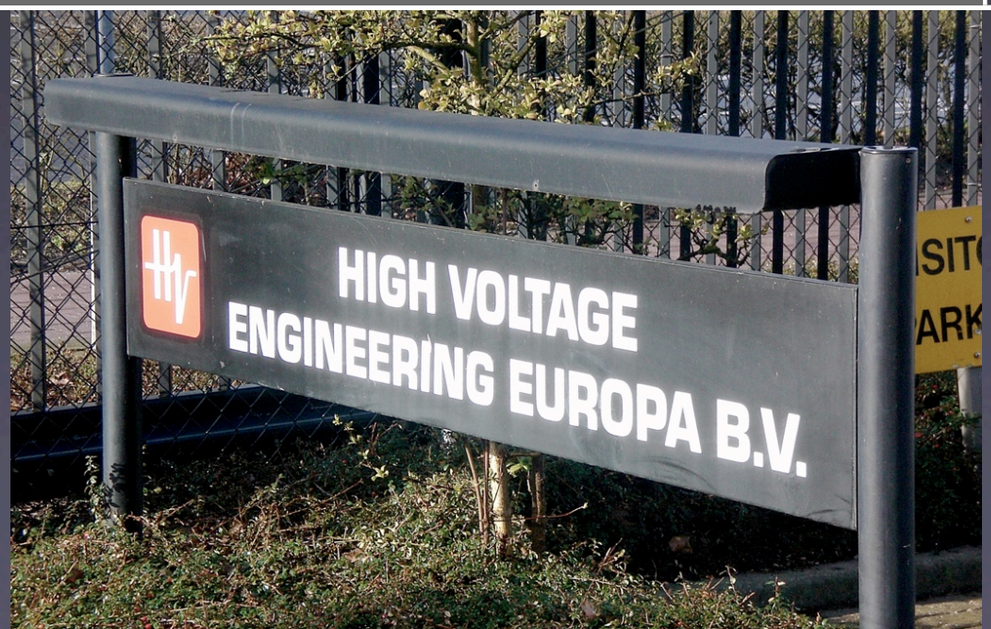




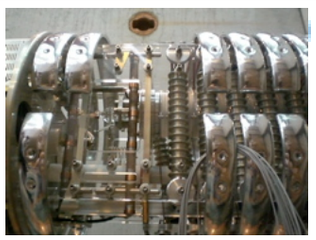
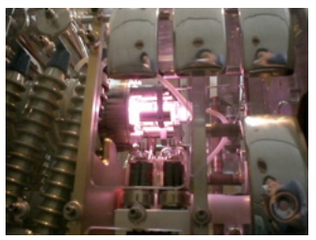
Machine Schedule

- We were almost on schedule with respect to what was shown at the february meeting

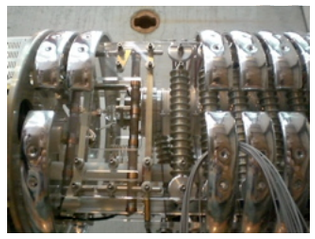
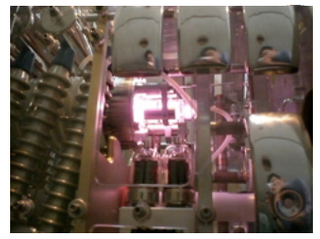
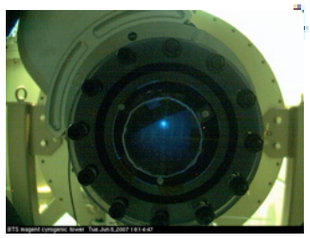
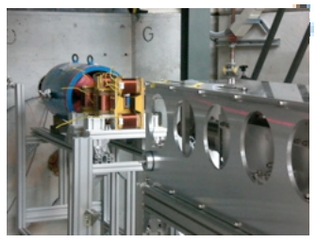
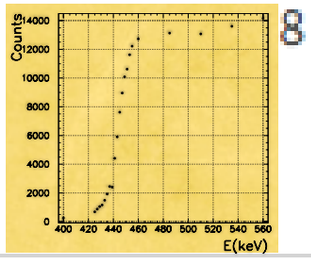
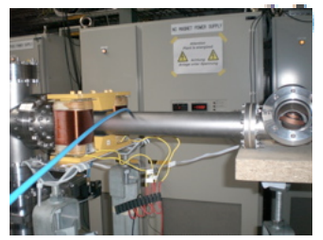
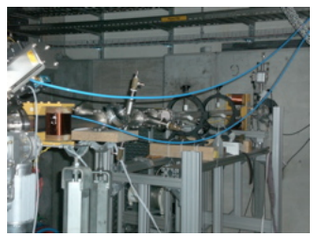
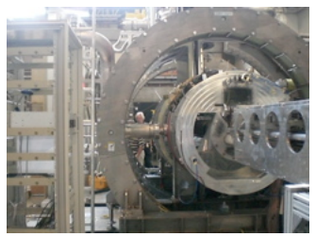
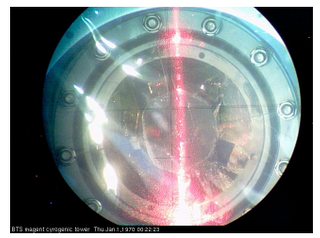
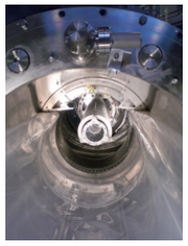
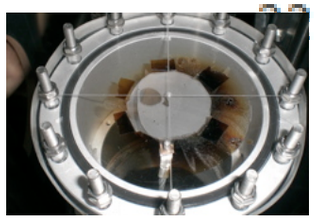
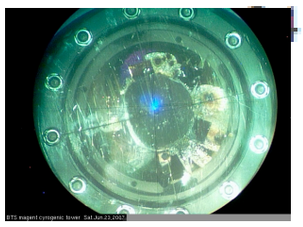
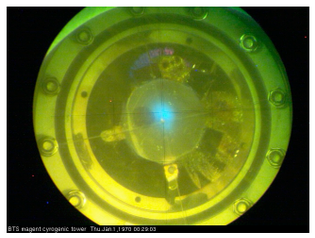
	Review 02/07	Present
Completion of manufacture	~ end-February 2007	end-February 2007
Acceptance Tests in Amersfoort NL with HVEE, INFN, PSI	~ mid-April 2007 ?	19-23 March 2007
Shipment to PSI	~ end-April ?	mid-May 2007
Machine Installation + Shipment/Guarantee Test	~ mid-April to mid-May 2007 ?	mid May to end June 2007



May 2007

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
30	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
	22		24		26	
28		30	 31	1		3

June 2007

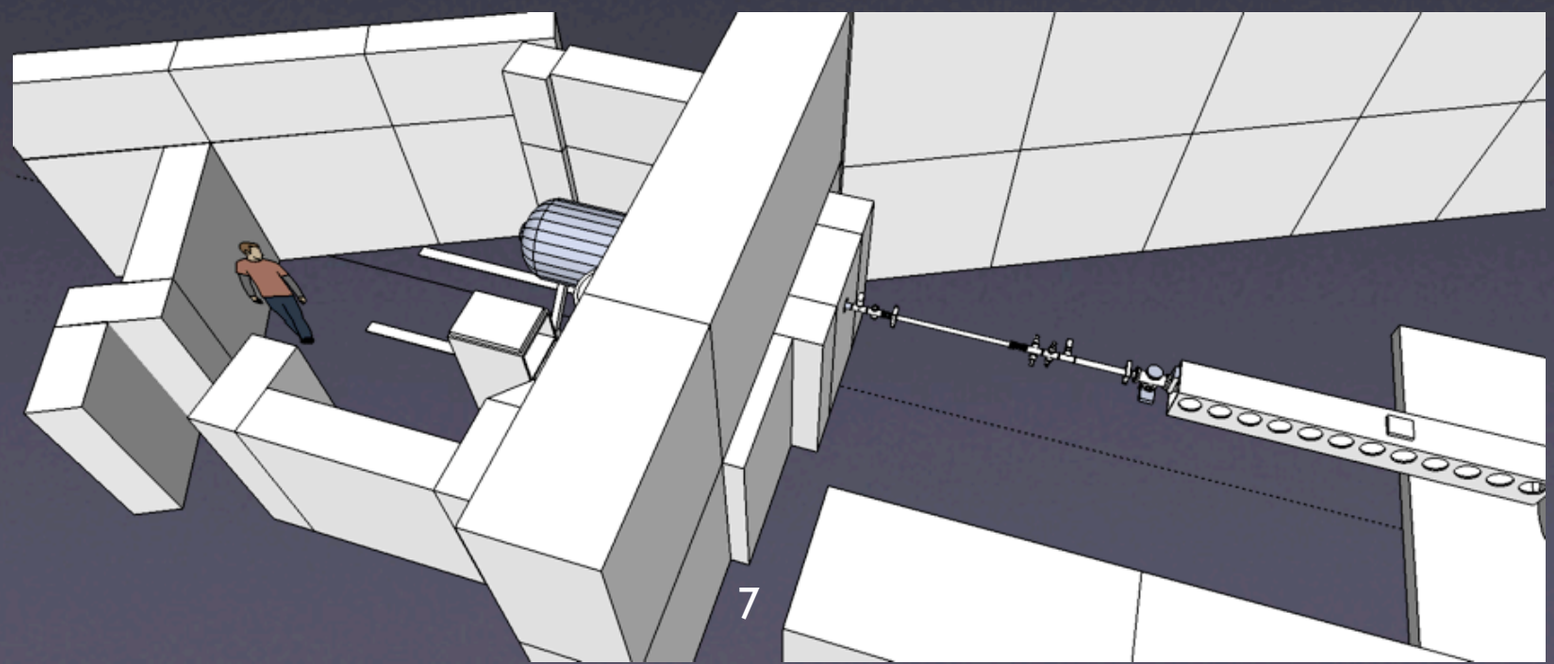
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
28		30	 31	1		3
	5		7	 8	9	
11		13		15		17
	19	 20	21	 22	23	 24
25		27		29	30	1

Ready!

- Less than two months from the C-W delivery at PSI the proton accelerator and beam line are ready to enter into operation
- We are able to deliver protons to a target at the center of COBRA to generate 17.6 MeV calibration photons

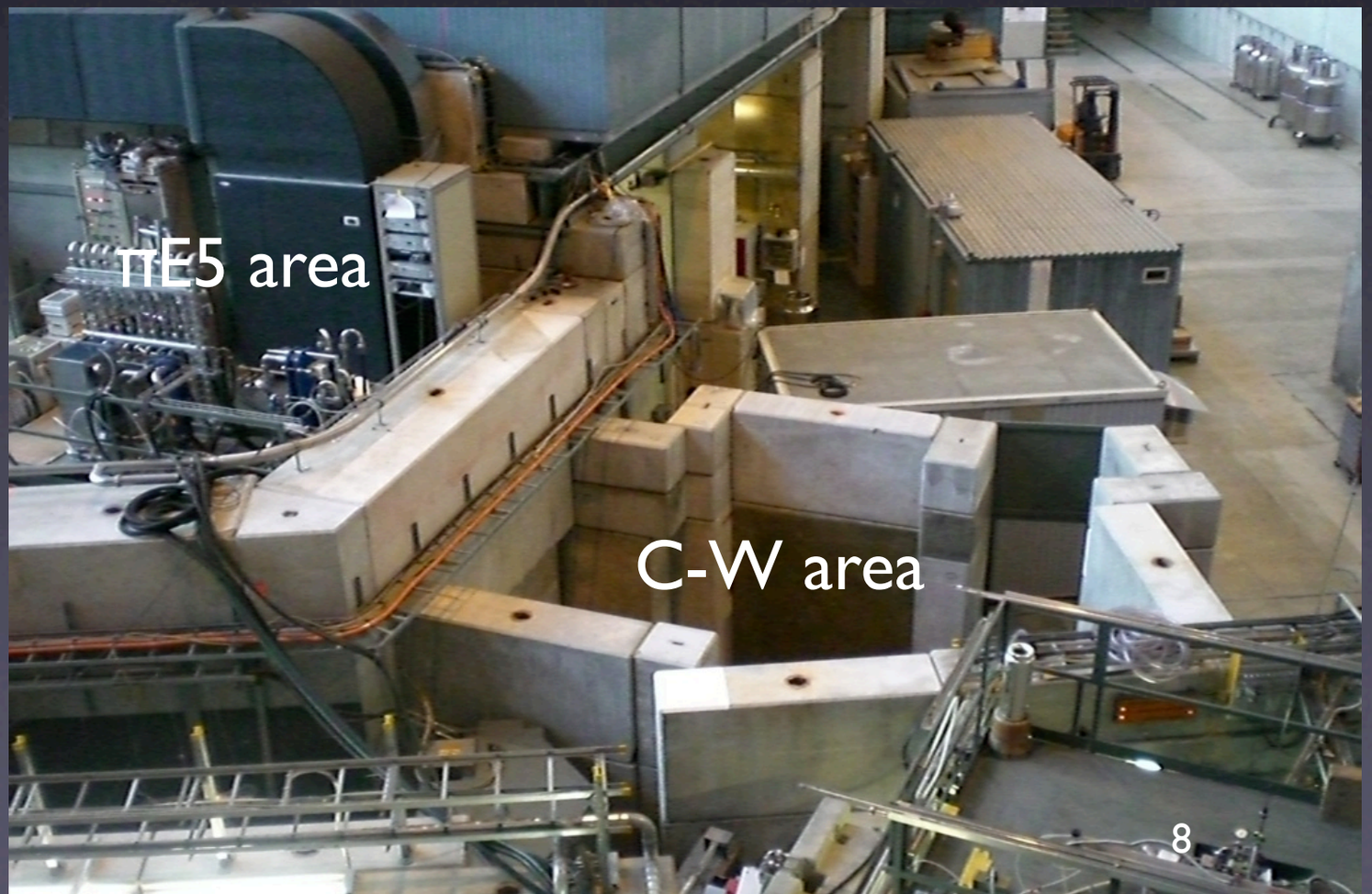
Two-fold

- Installation and acceptance test
- Beam line towards COBRA



Cockroft-Walton area

- The new area was completed and equipped
- Classification as Accelerator facility: subject to rules from:
  - BAG Rules (Swiss Ministry of Health)
  - PSI Health Physics & Safety Rules
- Strict Rules governing:
  - Facility usage, operational personnel
  - "Schooling" of personnel, maintainance & upkeep...



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Sachverständige für den technischen Strahlenschutz

Titel	Herr
Name	Wenni Christian
Beruf	Physiker
Bemerkung	Bevollmächtigter Sachverständiger für den Strahlens

Spezifikationen

1) Bewilligung für den Betrieb der Beschleunigeranlagen un Experimenten am Paul Scherrer Institut (PSI) in Villigen

Tätigkeit	Betrieb
Zweck	Forschung, Wissenschaft
Gegenstand	Anlagen nach unten aufgeführter Liste

Diese Bewilligung umfasst folgende Anlage und Areale:

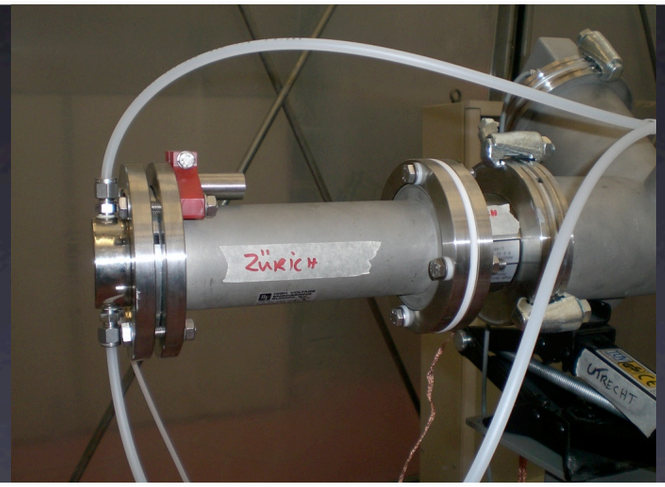
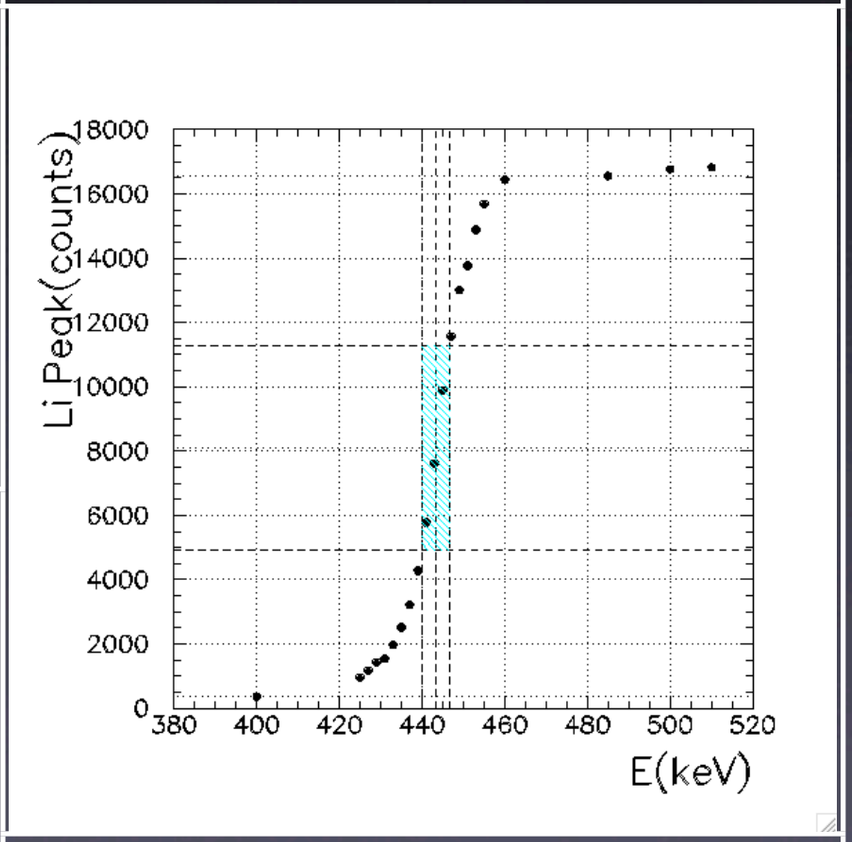
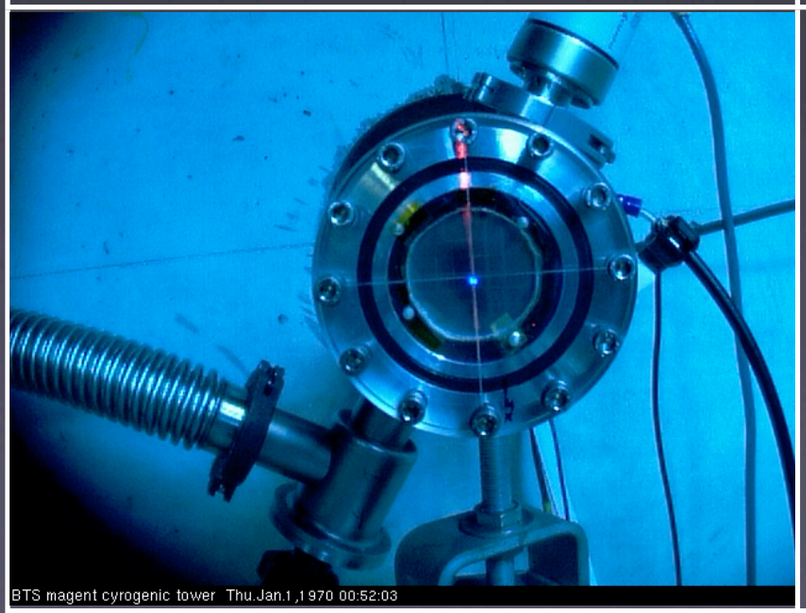
1. Cockroft-Walton Protonen Beschleuniger
   1 MeV Protonen
   von der Firma HV Engineering, Amersfoort, Netherlands
   im C-W Bunker (ehemaliger Vorplatz des pi-E-5 Areals)

2. Strahl im pi-E-5 Areal und im angrenzenden Areal mit den folg
   Protonen Energie: bis zu 1 MeV
   Strahlintensität: bis zu 1 µA

Certified Licence
for
Cockroft-Walton Facility

up to Energy: 1 MeV
Max. Current: 1 µA

Acceptance

Alignment	Current	Energy
	Measurement with an Aluminum Faraday cup	Li(p,γ)Be line excitation on thick target (5 μm) + NaI absolute energy calibration
The alignment was checked with the usage of a quartz crystal A most reliable, simple and sensitive method for beam tuning and diagnosis		
	Correlation of proprietary current meter and SCS2000 (nA!)	μ = (444 ± 1) keV Γ = (6.8 ± 0.5) keV

Acceptance test summary

	Nominal	Measured at PSI
Terminal energy range	300 - 900 keV	200 - 1100 keV
Energy ripple	< 500 V_{rms}	< 50 V_{rms}
Angular divergence	< (5 x 5) $mrad^2$	~ (4 x 4) $mrad^2$
Spot size at 3 m	< (3 x 3) cm^2	< 1 cm^2
Energy setting reproducibility	0.1 %	ok
Energy stability FWHM	0.1 %	ok
Range of current	(1 - 100) μA	(0.1 -135) μA
Current stability	3 %	ok
Current reproducibility	10 %	ok
Start-up time	< 20 min	< 15 min
X-ray level from the tank (500 keV)	< 2 μSv/hr @ 1 μA	< 0.1 μSv/h
	< 5μSv/hr @ 100 μA	< 0.1 μSv/h @ 50 μA
X-ray level in the πE5 area	-	0.5* - 3** μSv/h @ 1 μA
	-	14*** - 280* μSv/h @ 50 μA

* > 60 keV, on the Al Faraday cup
** > 10 keV, on the Al Faraday cup
*** > 60 keV, 3 cm from the beam line

Acceptance test summary

Term	
Energ	
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Range	
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Start-	
X-ray	µA
X-ray	I µA
	50 µA

araday cup
araday cup
the beam line

ACCEPTANCE PROTOCOL

1.0 MV SINGLETRON POSITIVE ION ACCELERATOR SYSTEM

Paul Scherrer Institute ref.: E 642950
INFN - Sez. di Pisa ref.: Pur. order n.110
HVEE ref. B6759 & B6760

Immediately after the successful completion of these tests at PSI the equipment will be accepted and the responsible representatives of both buying parties INFN & PSI and Seller will sign this acceptance protocol.

Warranty as per contract.

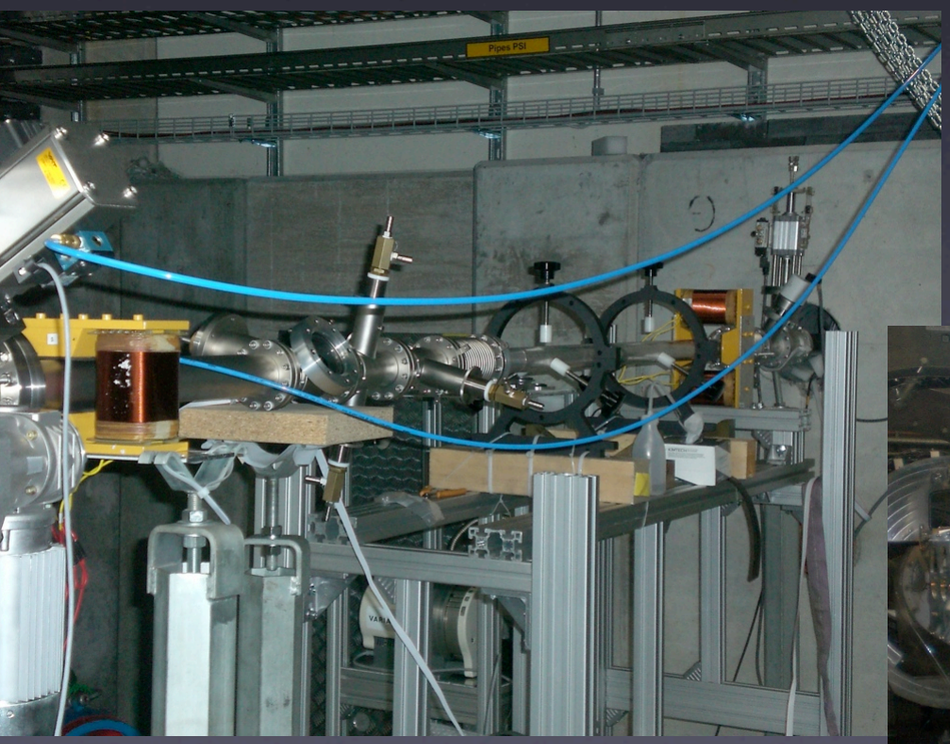
29 June 2007 by contract!

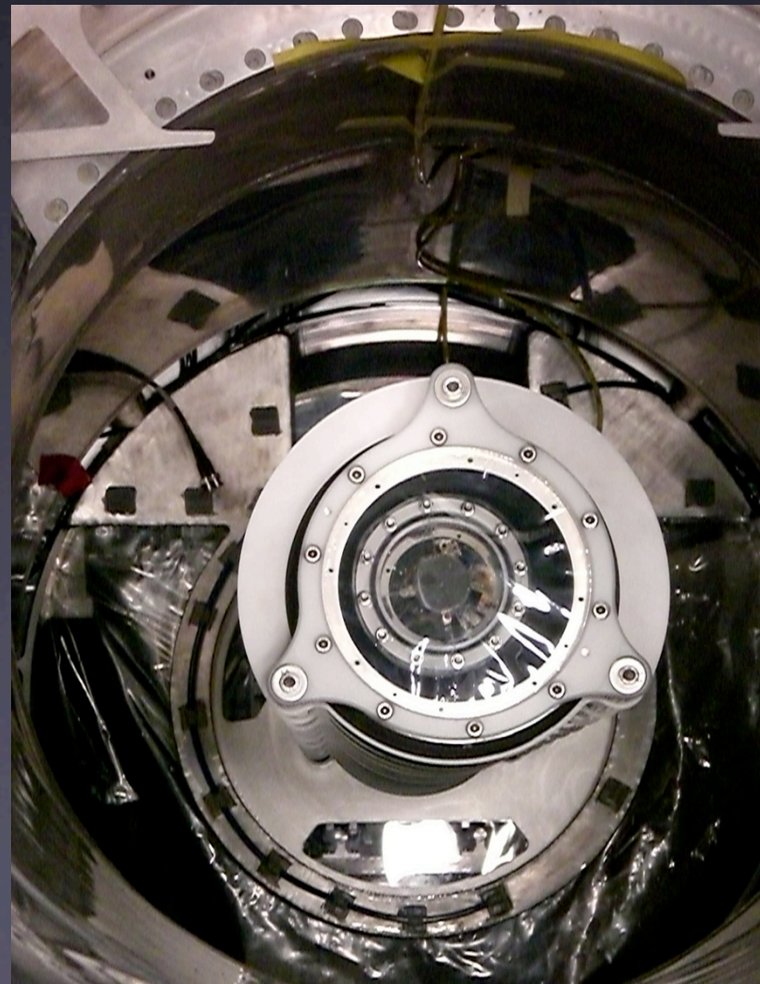
Zürich, 19. June, 2007.

Prof. C. Bemporad	P-R. Kettle	A.W. Terpstra
INFN	PSI	HVEE

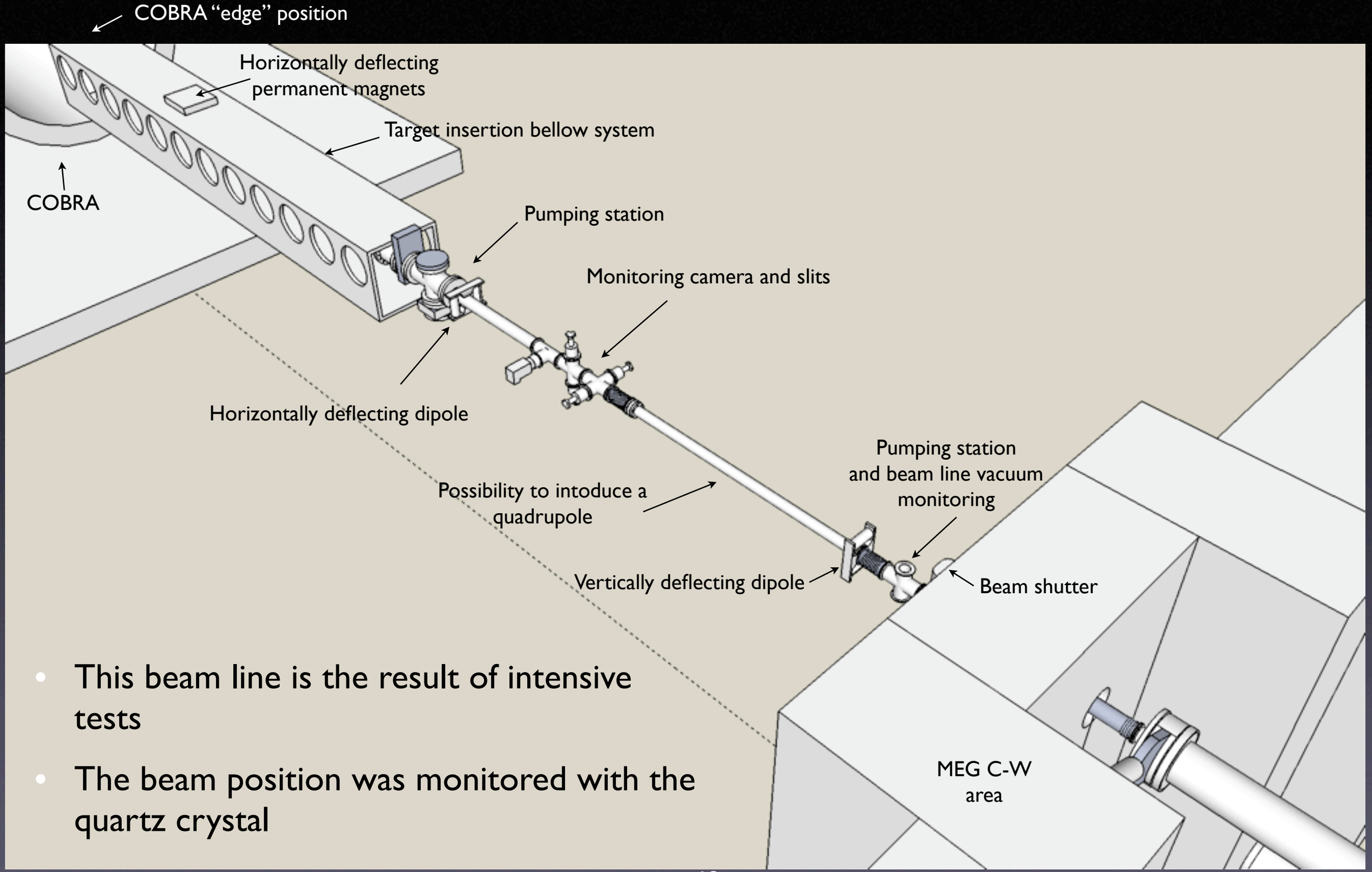
Towards MEG area

- After this date we operated the machine by ourselves
- Successful mounting and operation of the proton beam line elements
  - beam shutter - slits - collimators - straight insulated sections - gate valves
- Integration with the experiment slow control (SCS2000 - pressure, valve, currents, bellow system)
- Matching with the insertion system
  - we move 4 mm/s => need 10 minutes to insert the system (40 W)
  - to bo tested with the gas system in operation





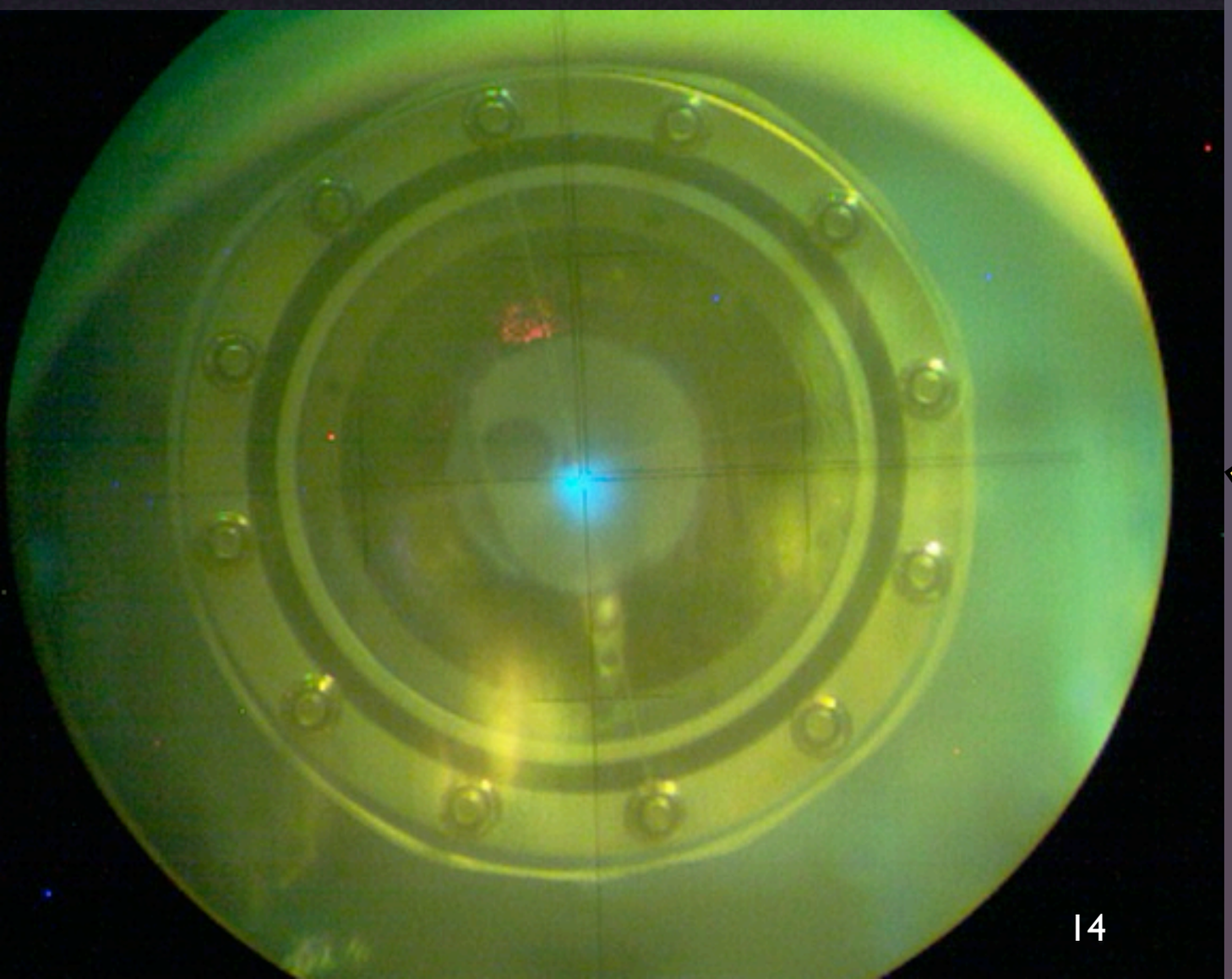
Final Beam Line schematics



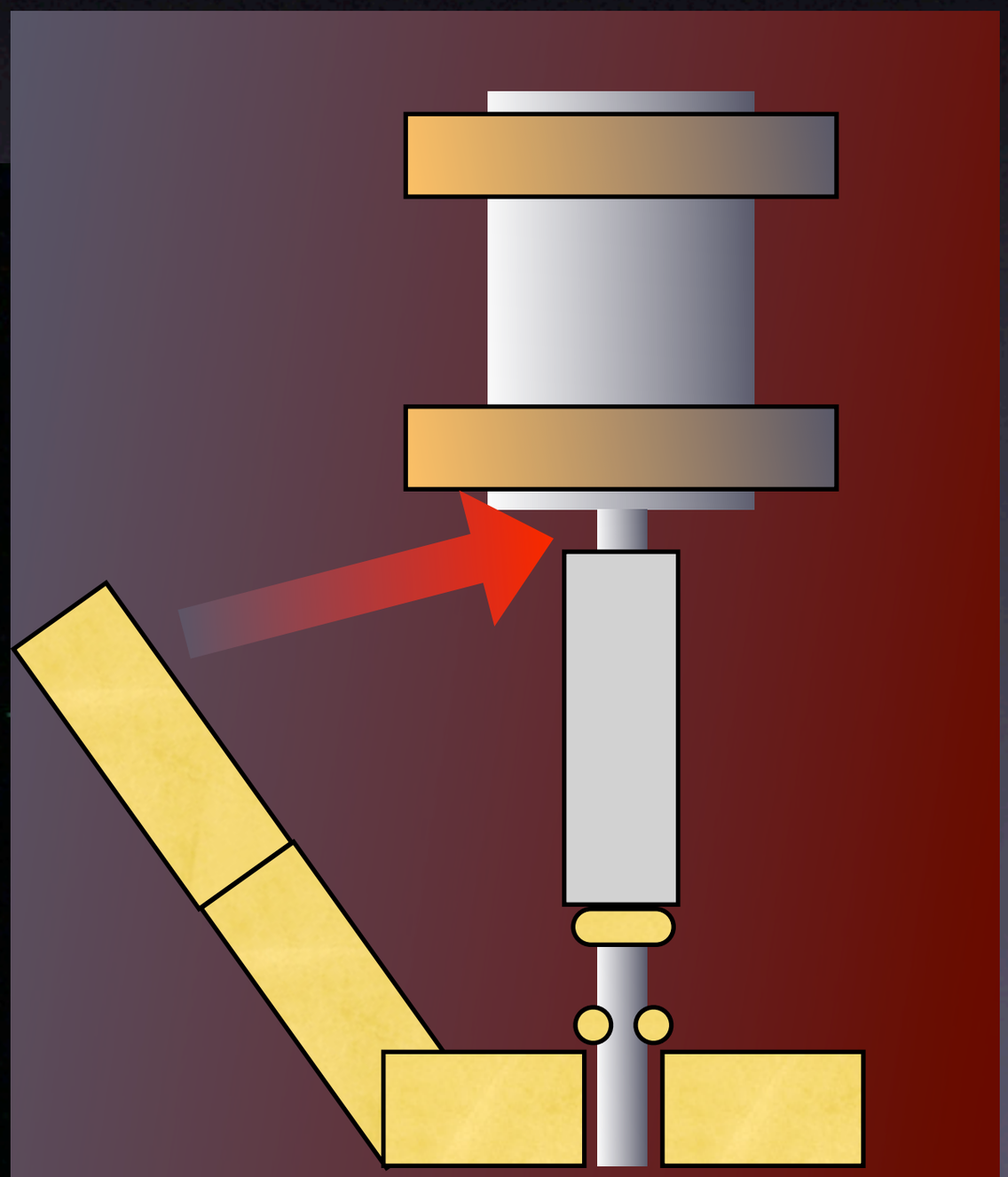
- This beam line is the result of intensive tests
- The beam position was monitored with the quartz crystal

At COBRA edge

- With the magnetic field on we have to adjust the horizontal and vertical position of the beam
- Horizontal ~ 1 A, Vertical ~ 100 mA (few 10s G)



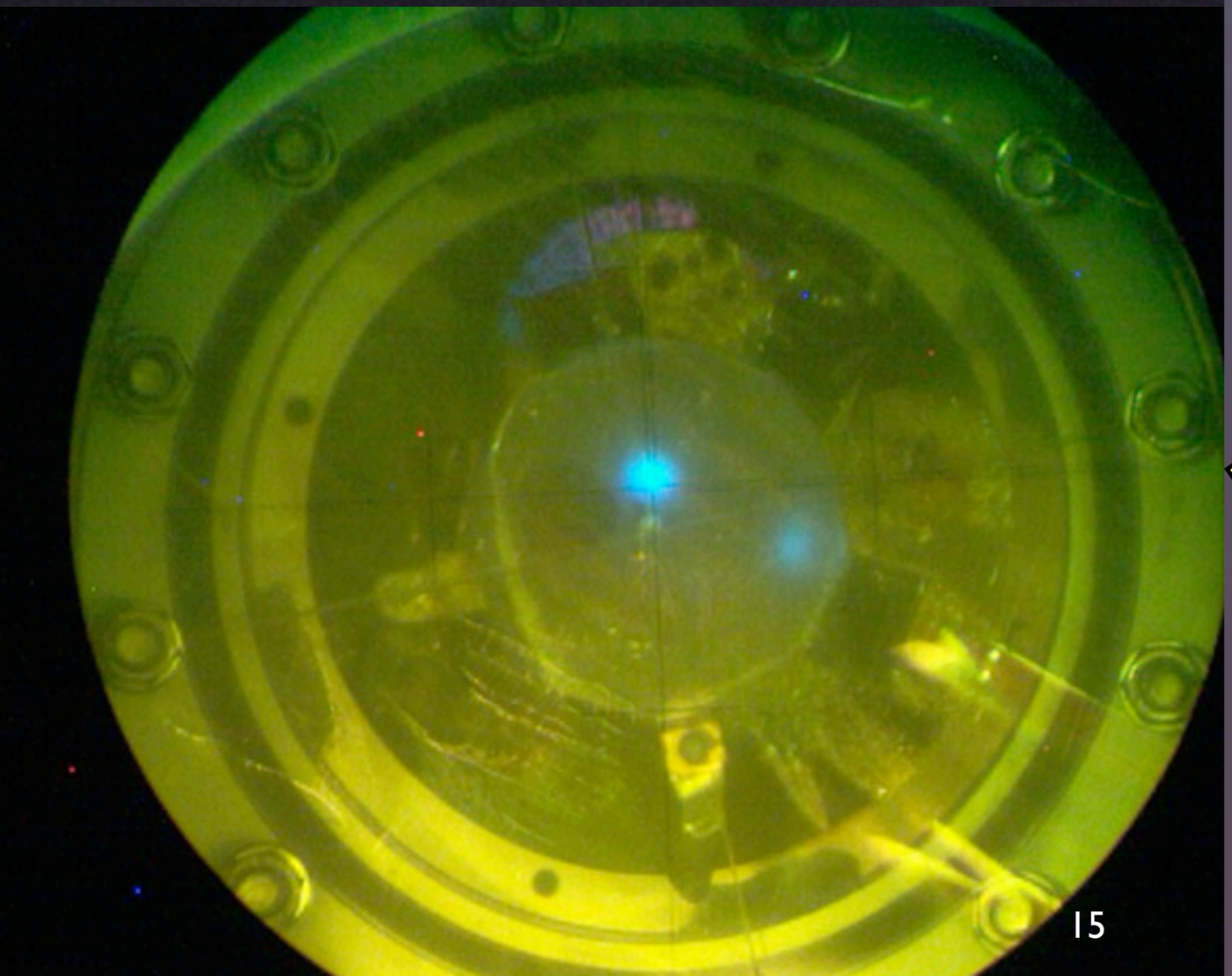
RED light = field ON

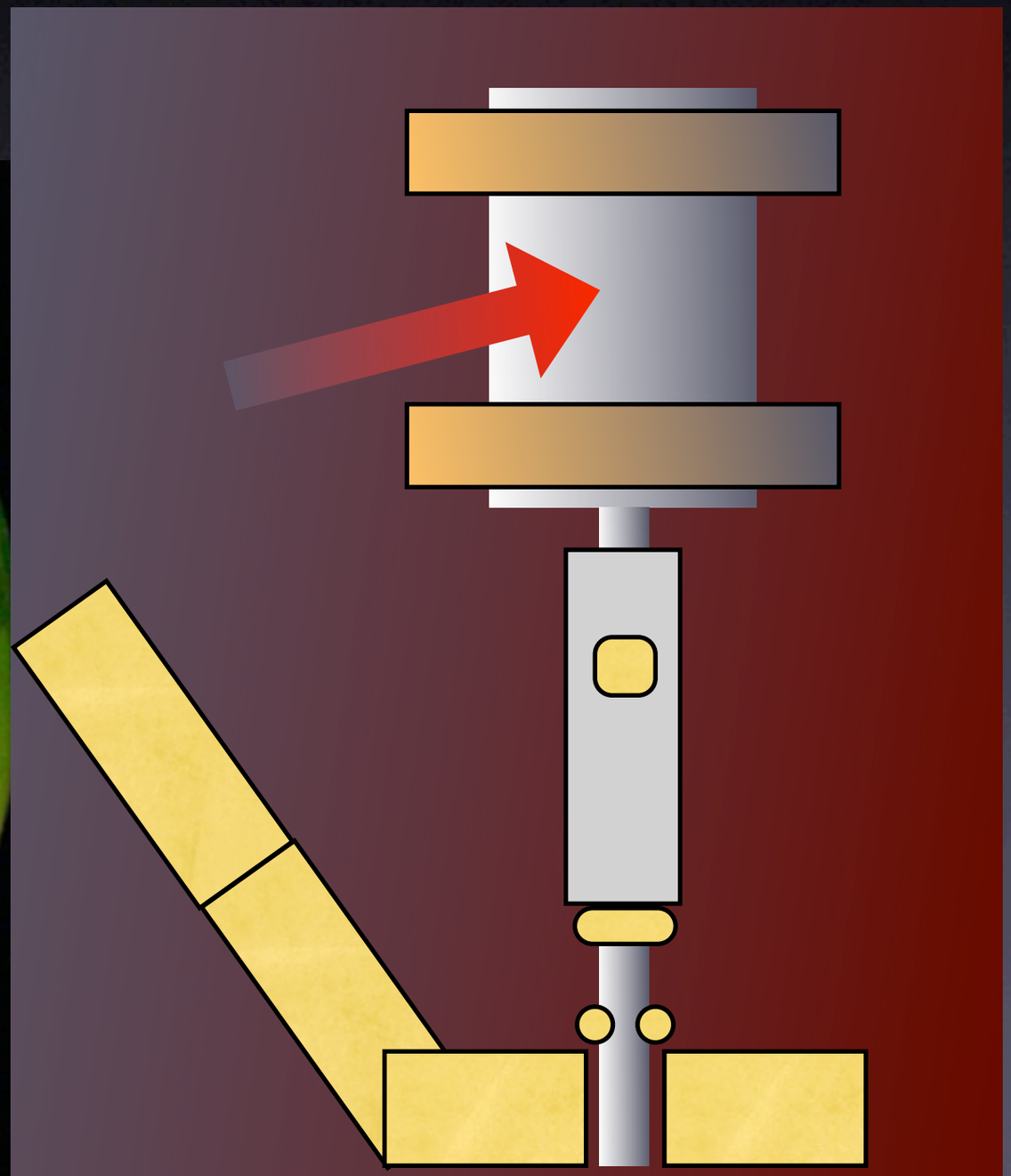


At COBRA center

~7 cm from the center

- We had a significant (~few cm) shift but with the help of dipoles and permanent magnets we could center the beam
- COBRA splits H^+ and H_2^+

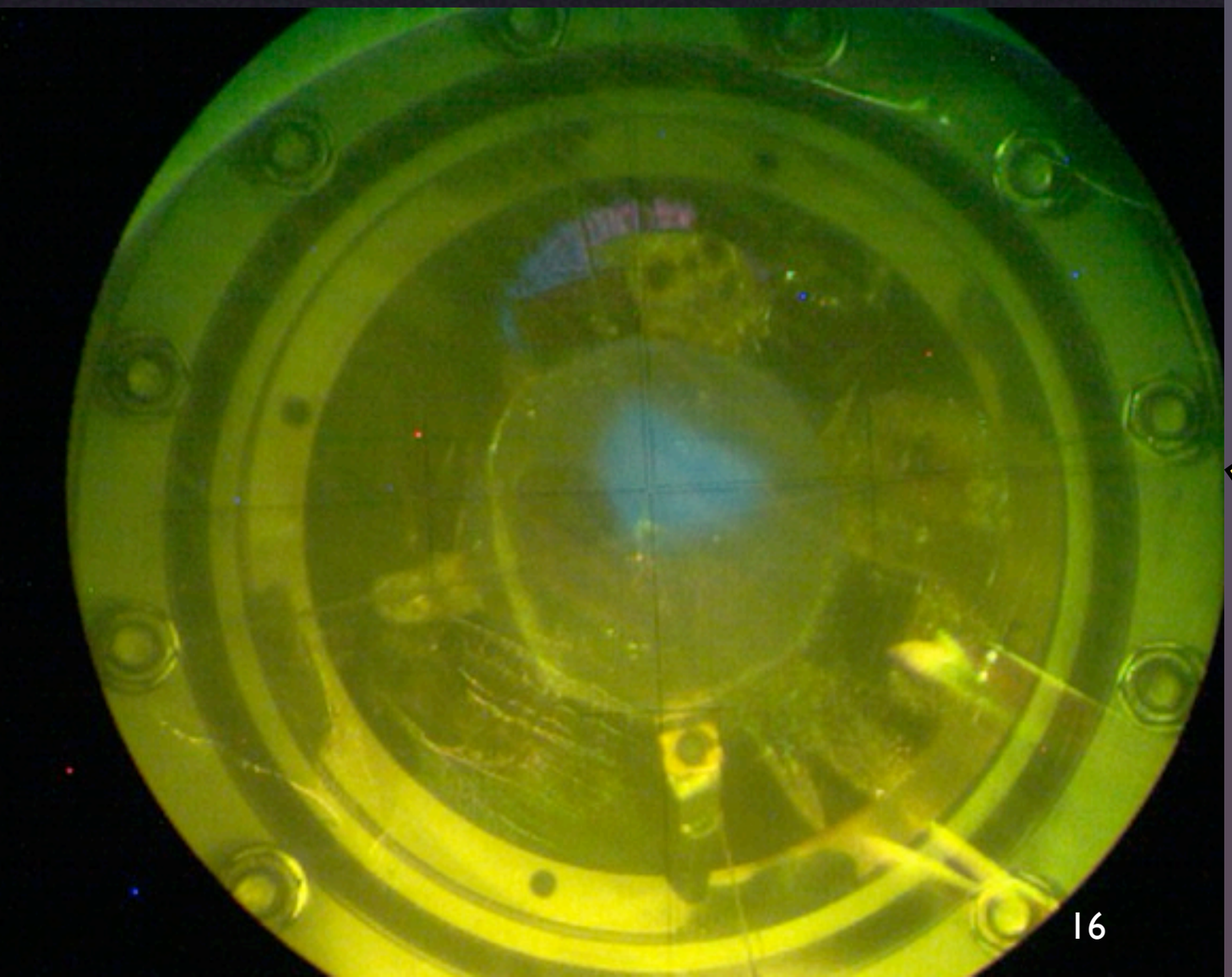


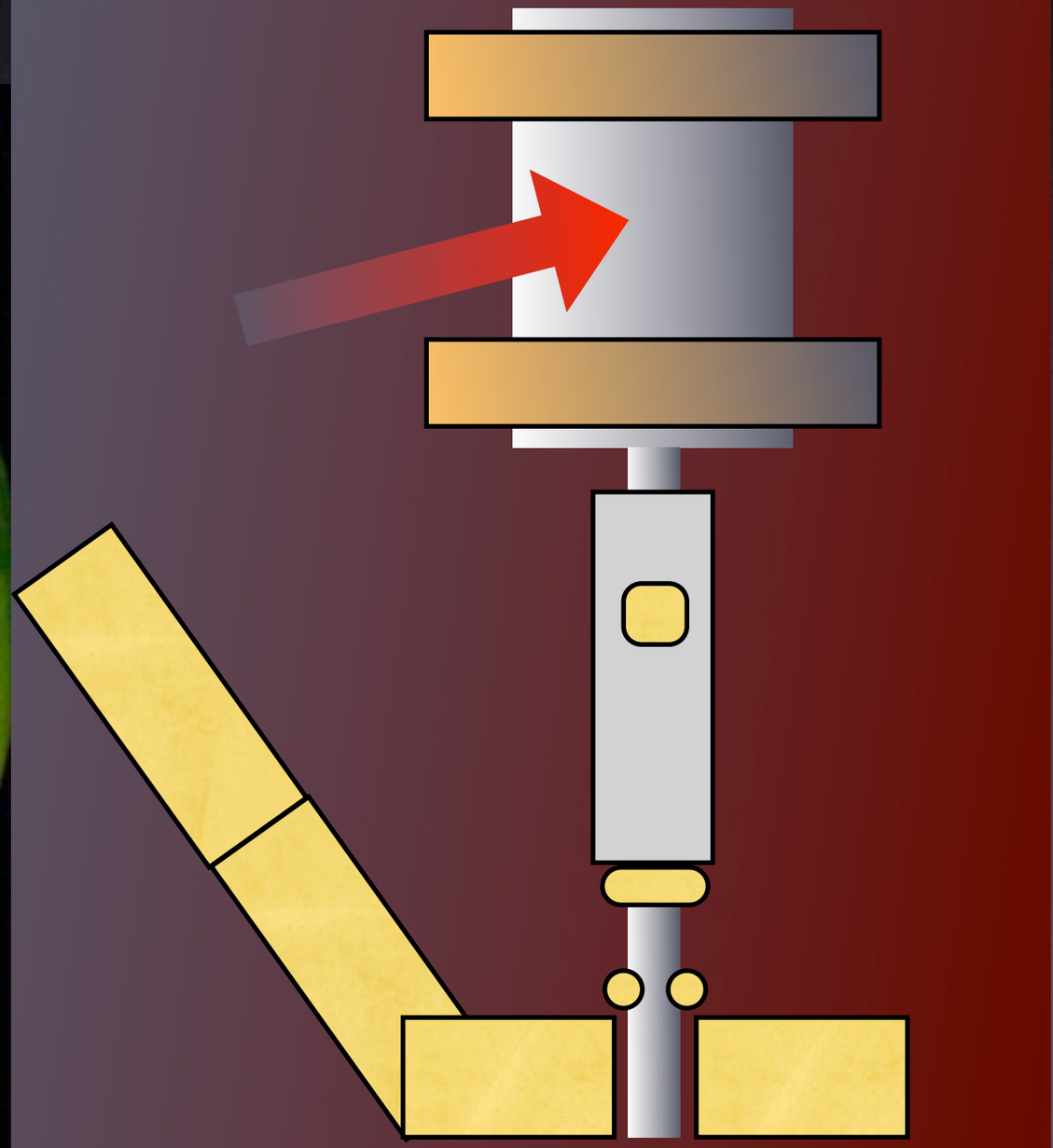


At COBRA center

~7 cm from the center

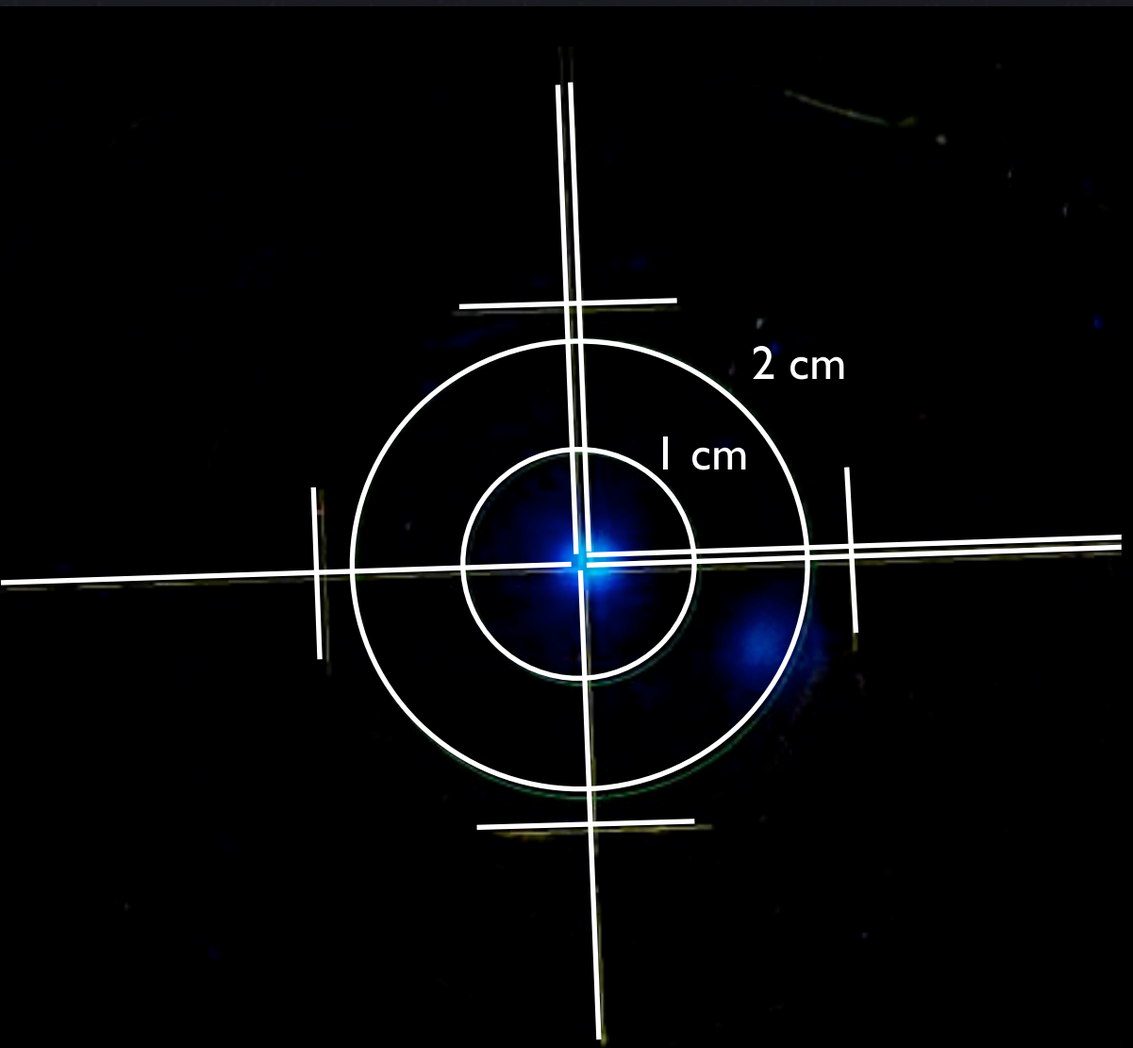
- A larger beam spot is more suitable for our case
  - uniform target illumination
  - less target consumption for delivered current
- Defocussing using accelerator extraction voltage we obtain a ~ 2 cm beam spot

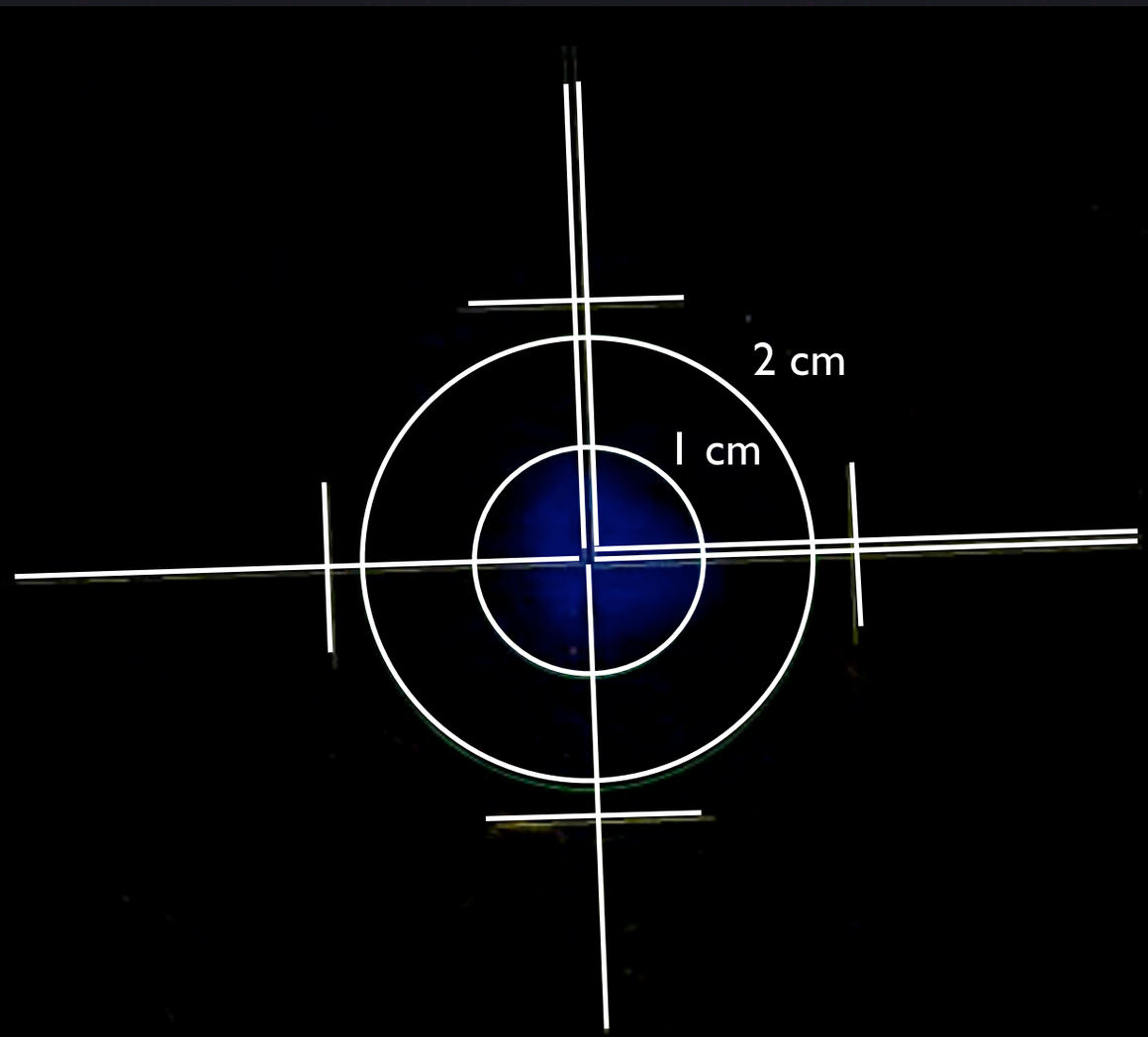




Beam spot measurement

- CW-source probe voltage changes the current
- CW-extraction voltage changes the focussing
- Camera picture through theodolite grid
  - Few mm at full focussing
  - ~ 2 cm at maximum CW defocussing





Centering and Focussing

- Some difference between COBRA off and COBRA on
  - Presence of stray fields
- Misalignment at COBRA of 2 mrad
- We have sufficient handles to compensate for this effect
- Usage of dipoles only
  - COBRA focuses the beam
  - Usage of C-W extraction voltage to defocus on target (to have a uniform distribution) at a sufficient level
  - We reserve the possibility to test the usage of a defocussing (!) quadrupole.
  - multiple scattering on thin foil
- ~1 week test planned

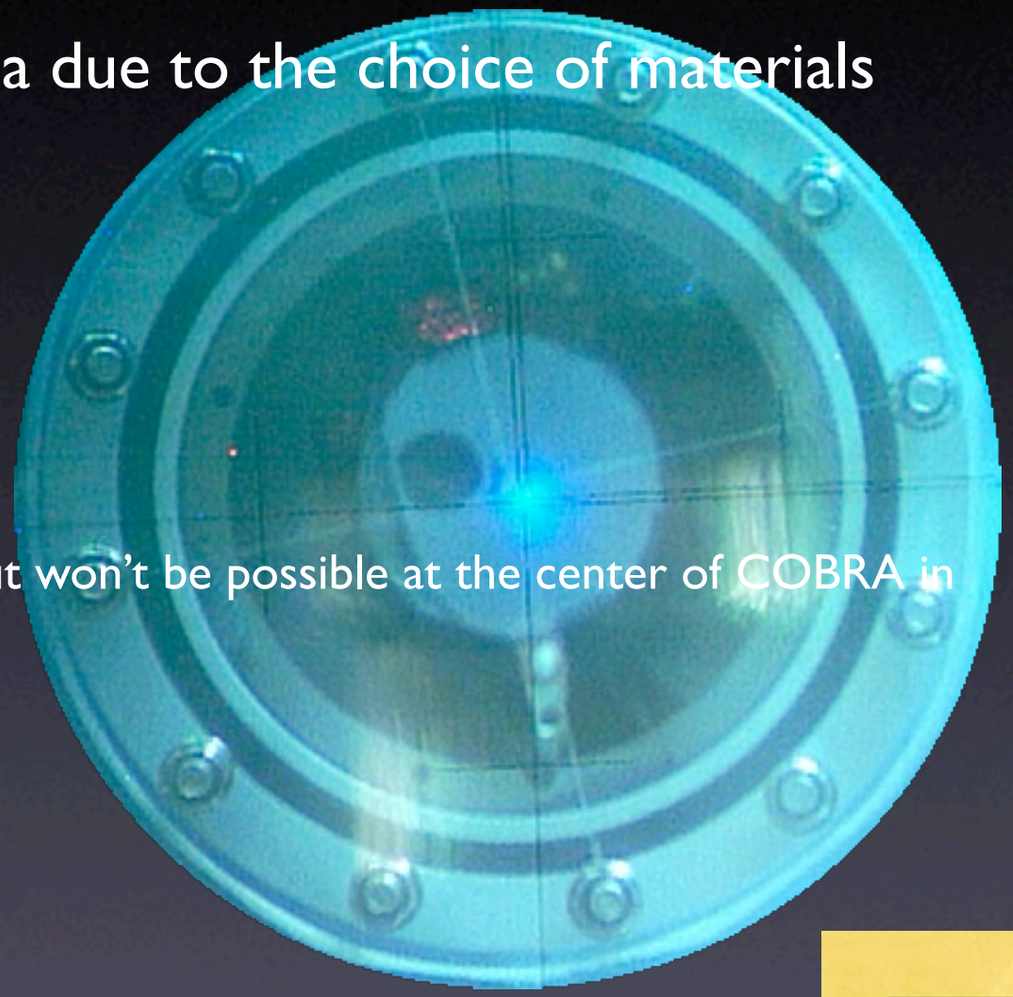
Time needed for Calibration

- 10 minutes inserting
  - 10 minutes conditioning can go in parallel
- O(10 minutes) data taking at 30 Hz
  - 20k events
  - Rate (17.6 MeV) on LXe = 1.8 kHz / μA
- 10 minutes extracting
- Alpha-source and LEDs can be done during extraction/insertion

Daily operations	Periodic Operations	Rare Operations
-Automatic or Manual turn-on procedure -Optimization of source parameters -Calibration procedure (Bellows + Insertion System introduction into COBRA beam-shutter manipulation & reverse procedure) -Target (LiF) change when required	Testing safety aspects (zone-interlocks etc.)	-Pressure SF6-vessel filling/emptying - N2 flushing + evacuation -Pressure-vessel opening/closing - Ion-source replacement - H2-bottle replacement -Intervention on internal parts
Trained Shifters + assistant	Member of the "C-W Group" + assistant	

Conclusion and perspectives

- The system is ready to deliver the desired beam at the desired intensity to calibrate the LXe calorimeter
- No dangerous radiation (x-rays) to the area due to the choice of materials
- Few things need to be investigated
  - optimize optics w/all detectors inside
  - test the usage of a quadrupole
  - check target duration
  - the usage of the crystal has been of invaluable help but won't be possible at the center of COBRA in the final beamline configuration
    - multi-pixel target
  - ~ One week "C-W" beam time
- Full integration with PSI safety interlocks
- Some new pneumatic elements foreseen (intermediate crystal, FCup)
  - Test independently thanks to the separate C-W area



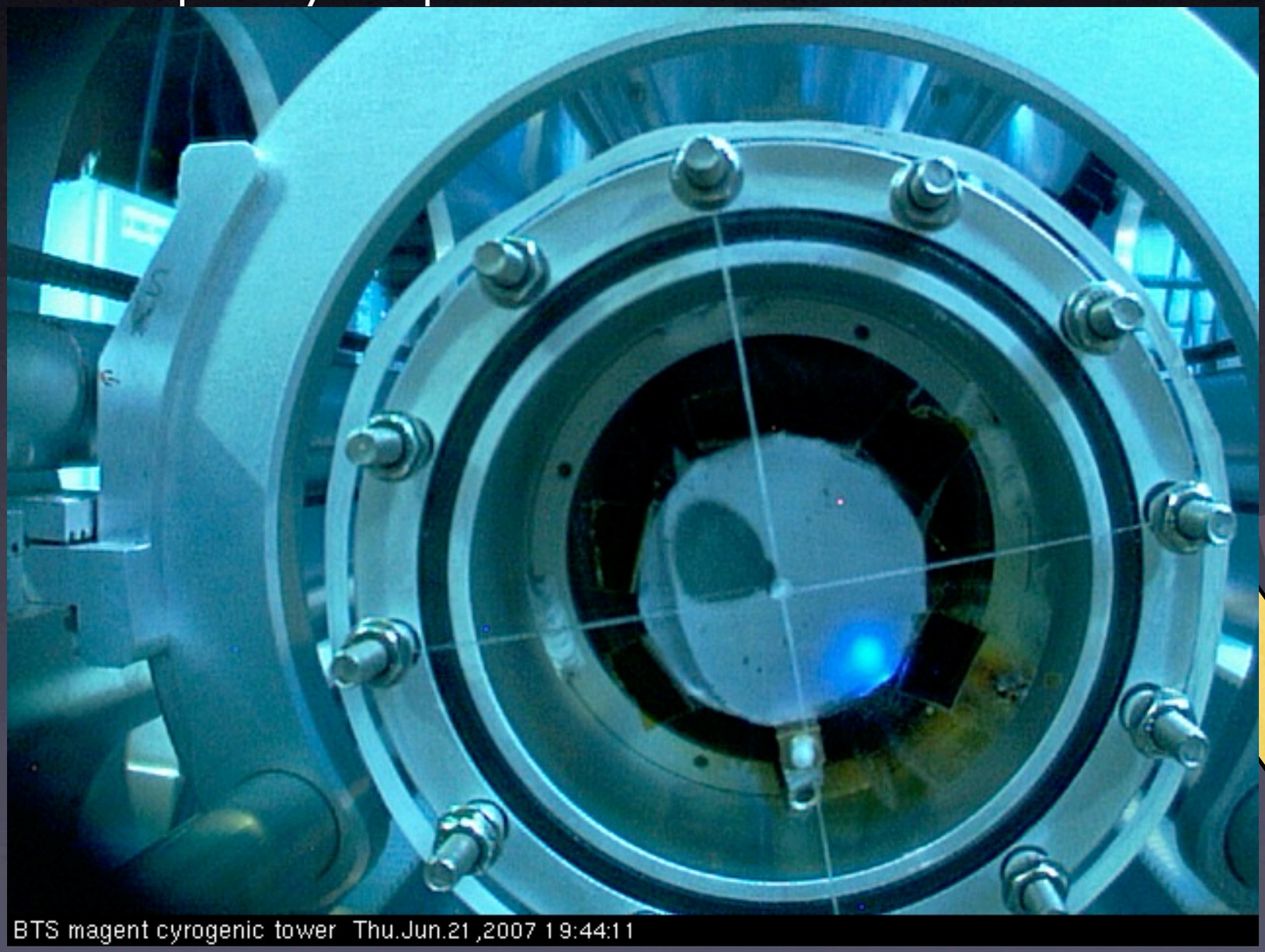
Back-up slides

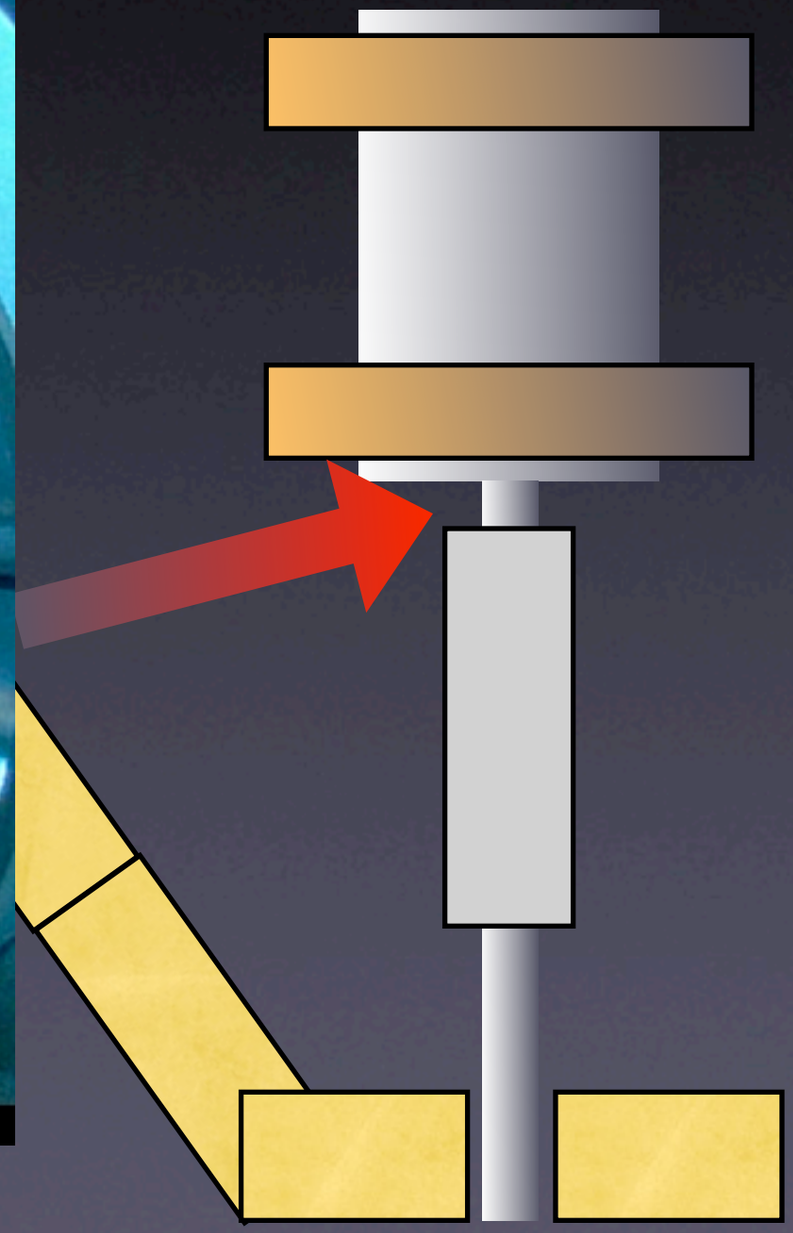
Next slides are only intended for back-up use.

Centering procedure

Beam centering

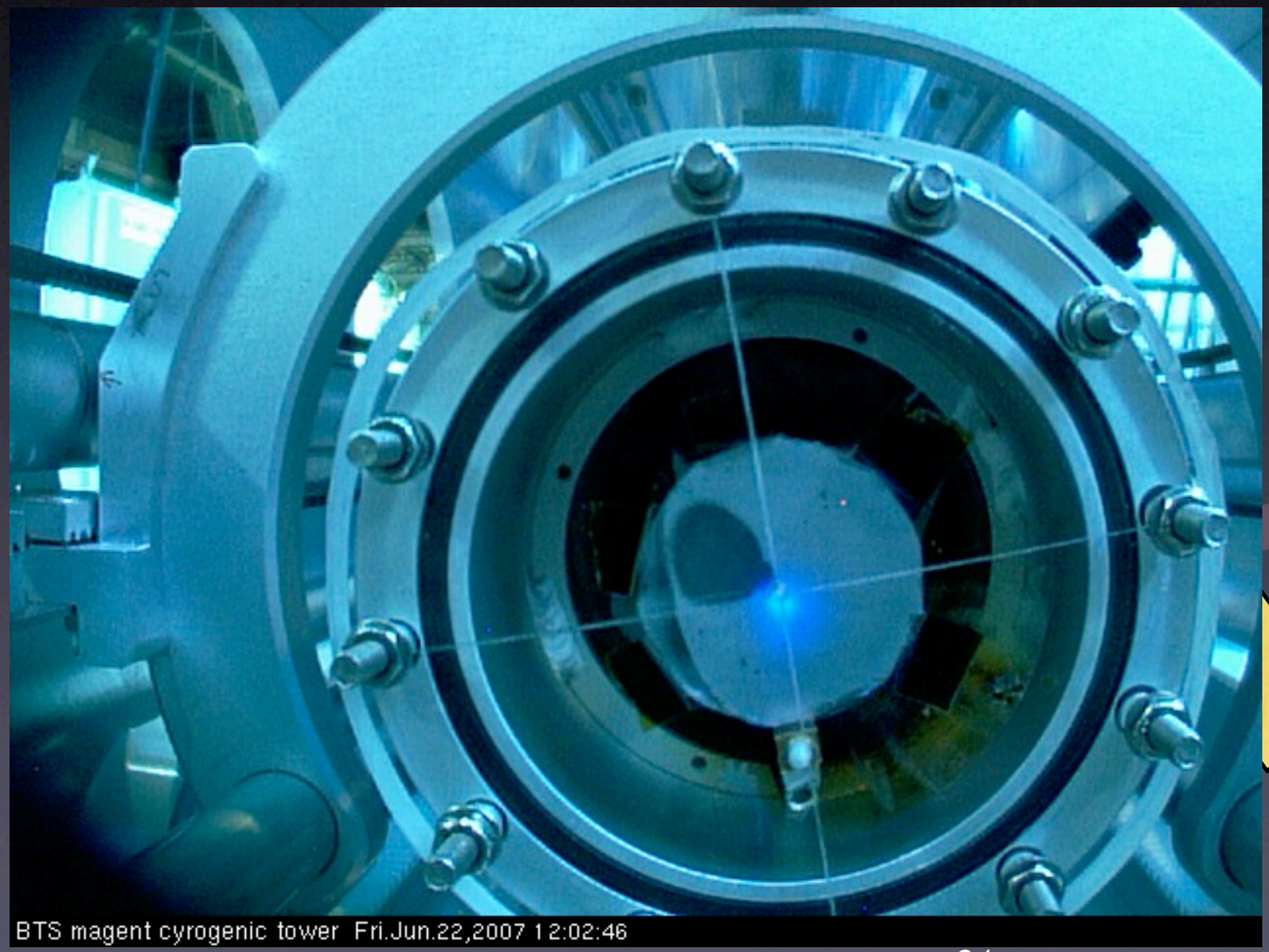
- misalignment of 1.2 mrad in x, and in y
- small accelerator misalignment and long lever arm (10 m)
- presence of residual fields (iron platform, neighbouring areas, steering magnets off...) partially compensates or masks

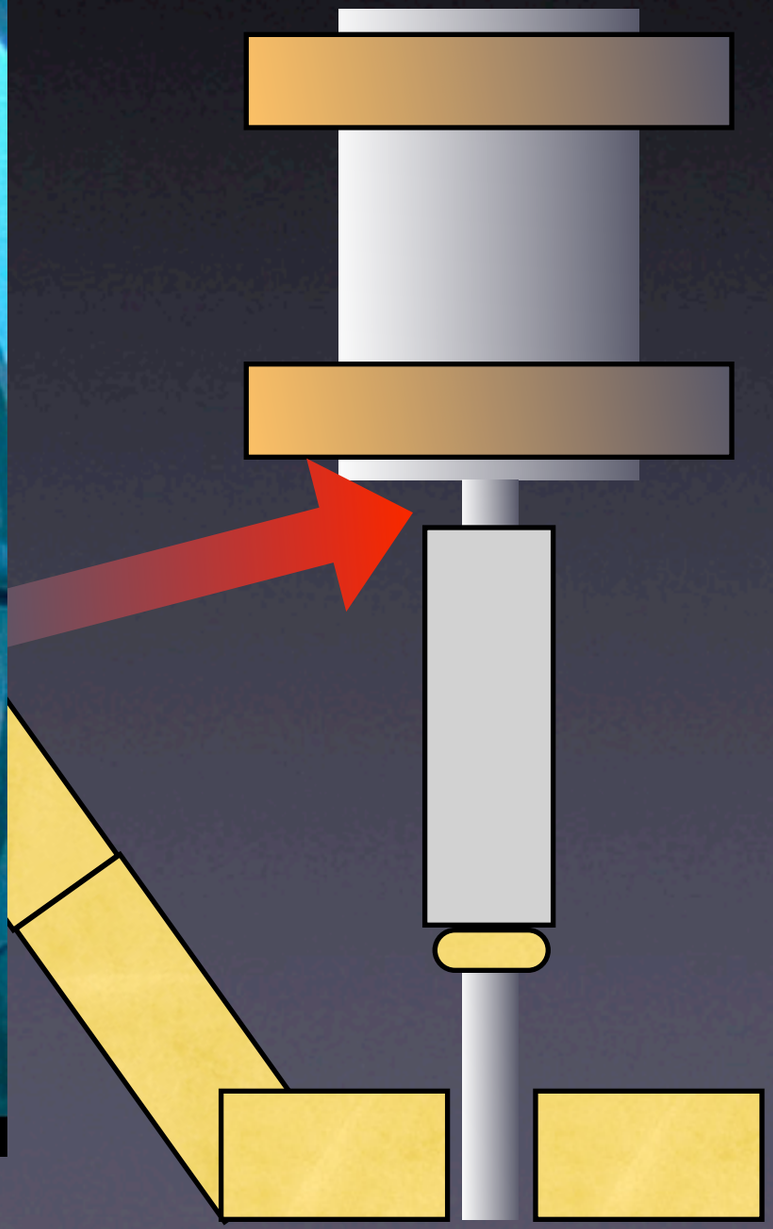




Dipoles in operation

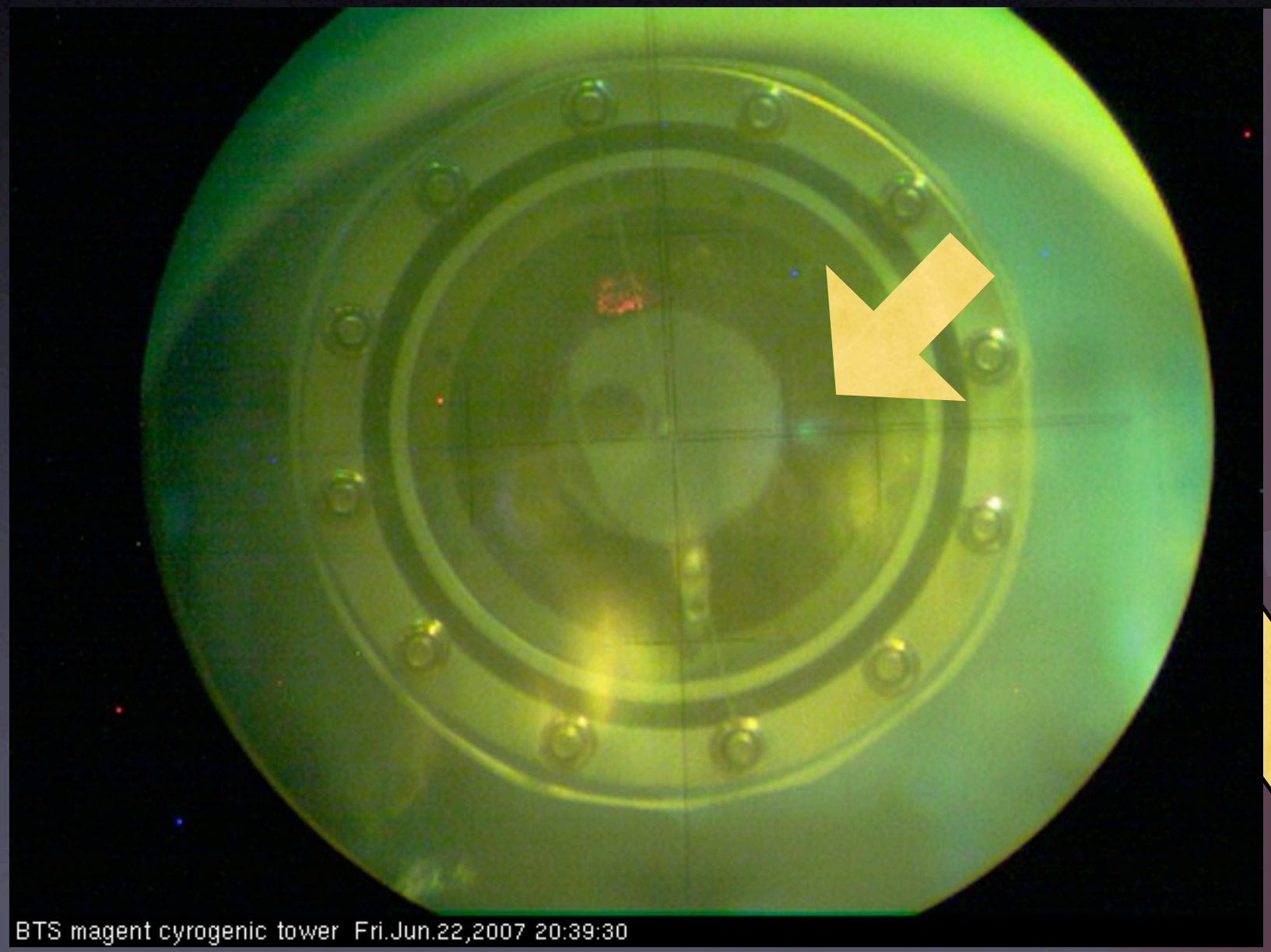
- cobra edge
- horizontal dipole at 0.3 V (=100 mA, ~ 20 Gauss) vertical 0.0 (residual fields on vertical magnet compensate y)



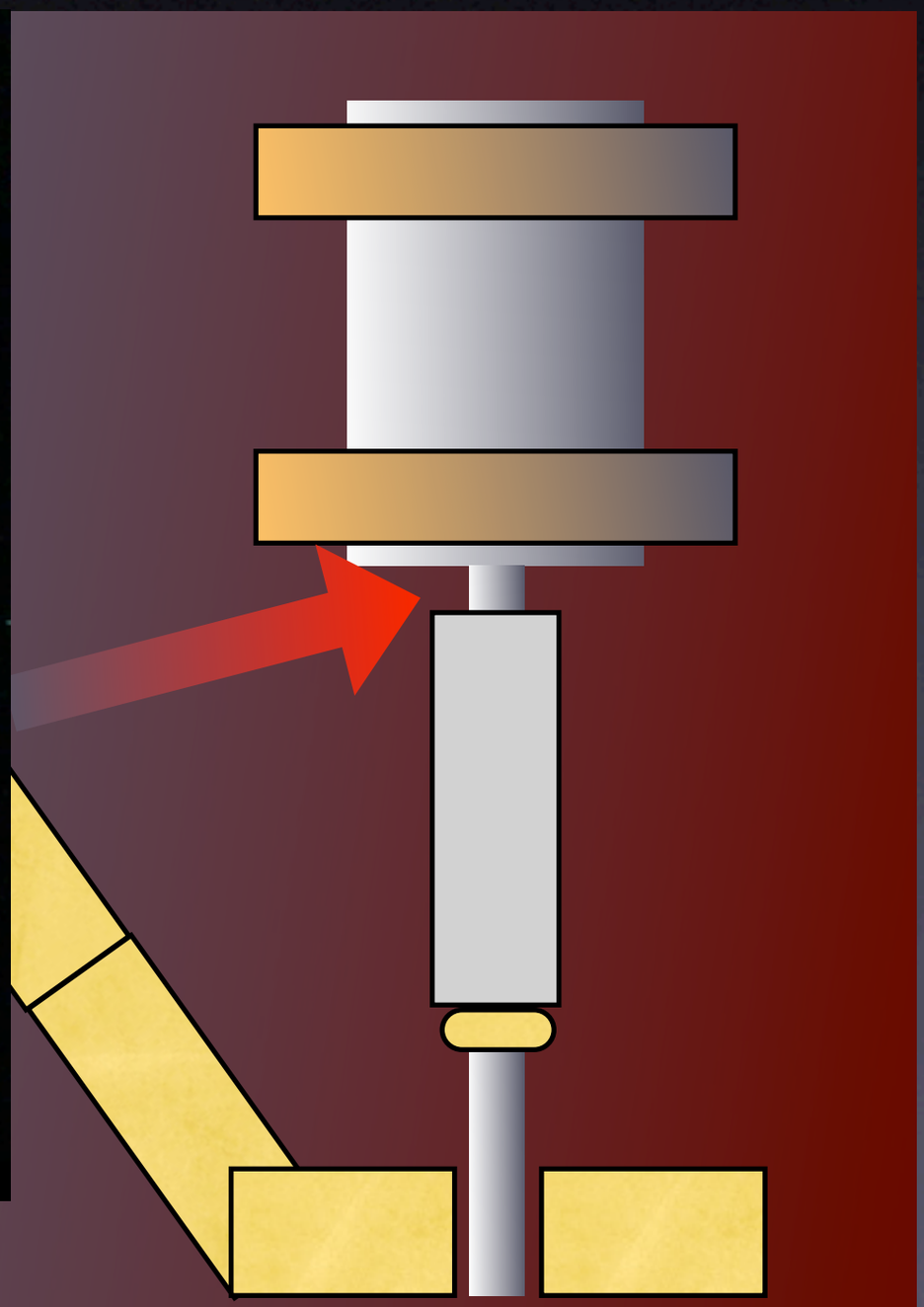


Switch COBRA on

- beam towards Berg
- Notice different camera position

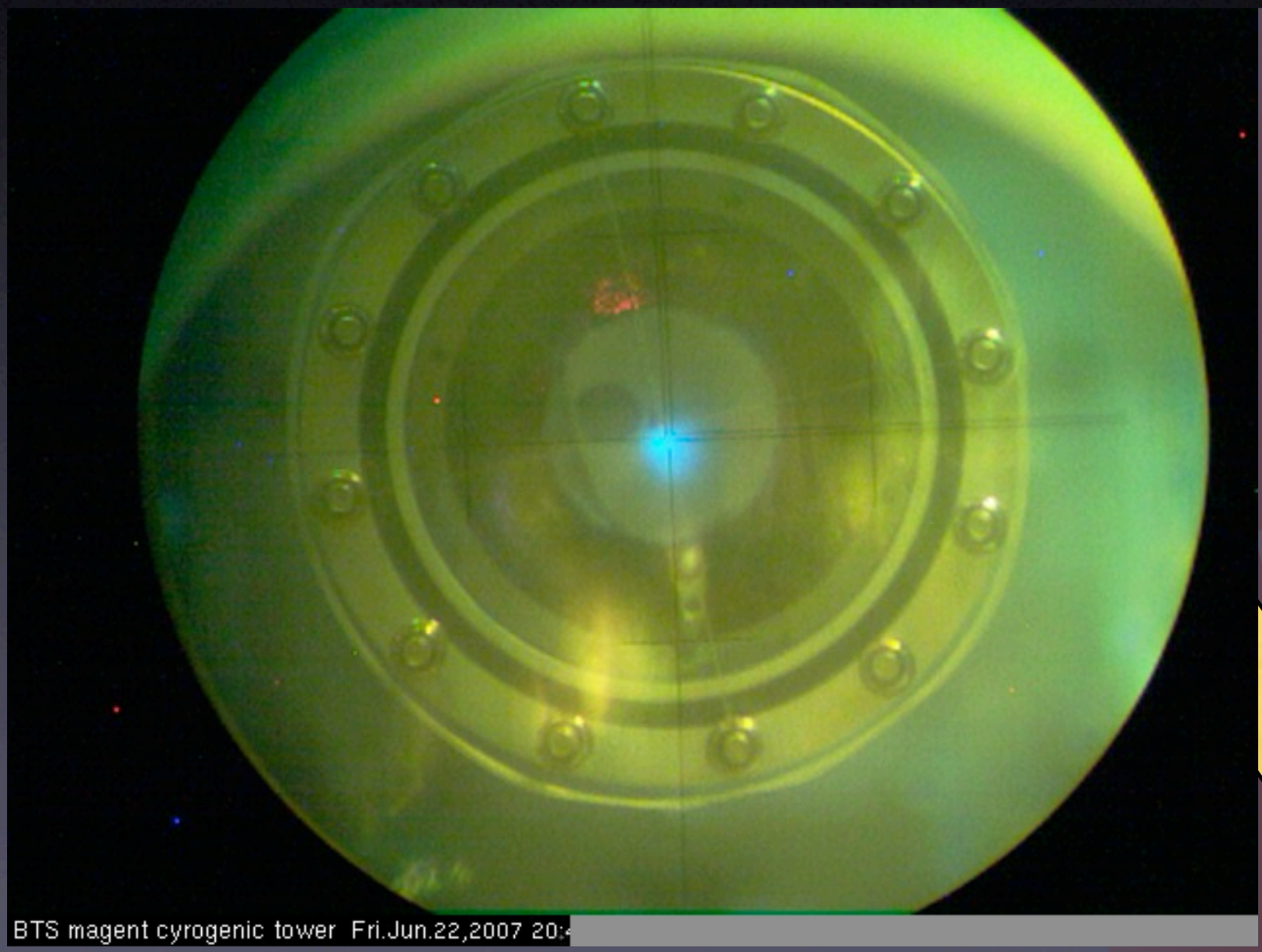


RED light = field ON

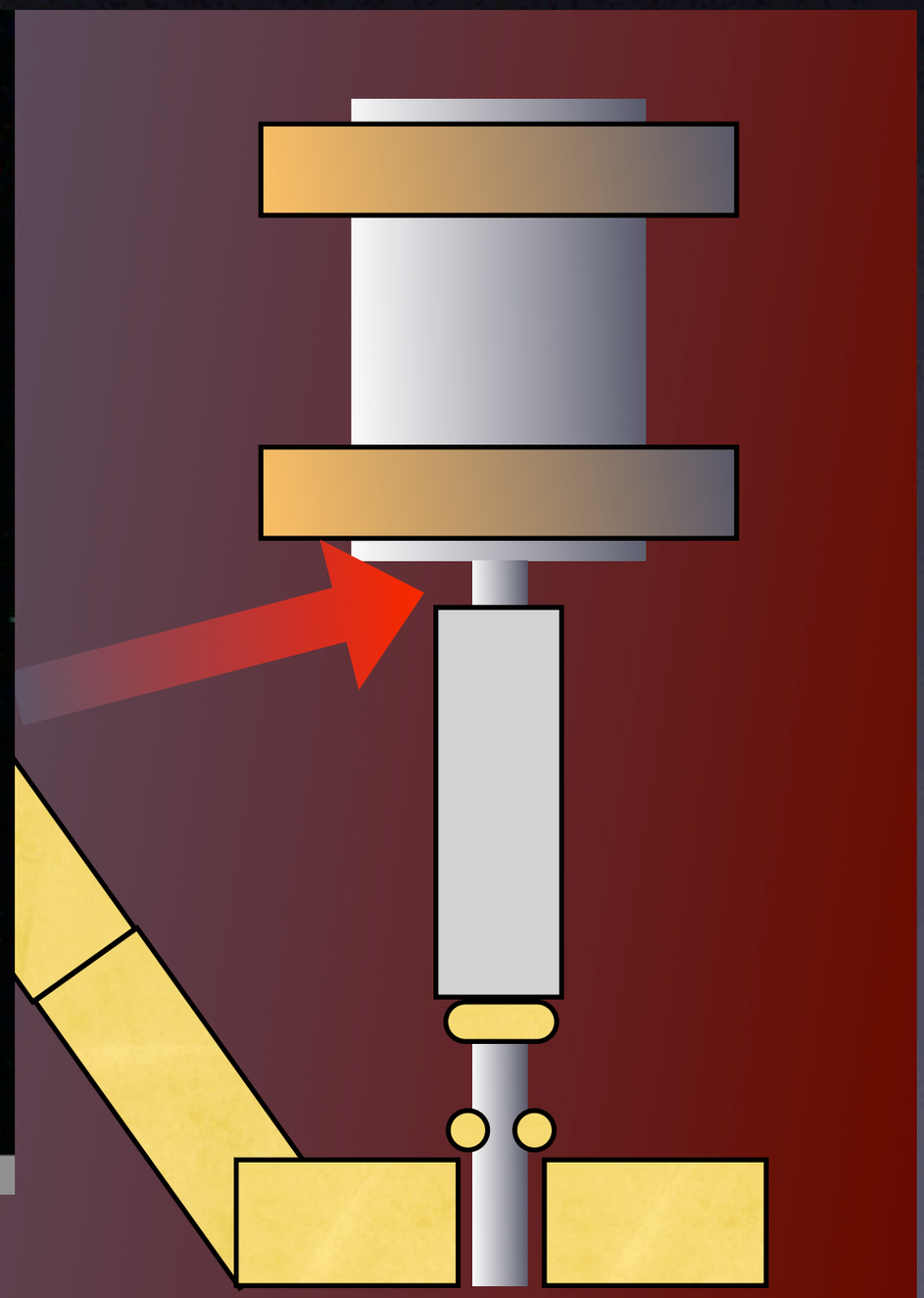


Re-adjust horizontal dipole

- Horizontal dipole = 1.5 V
- Vertical = 0.1 V



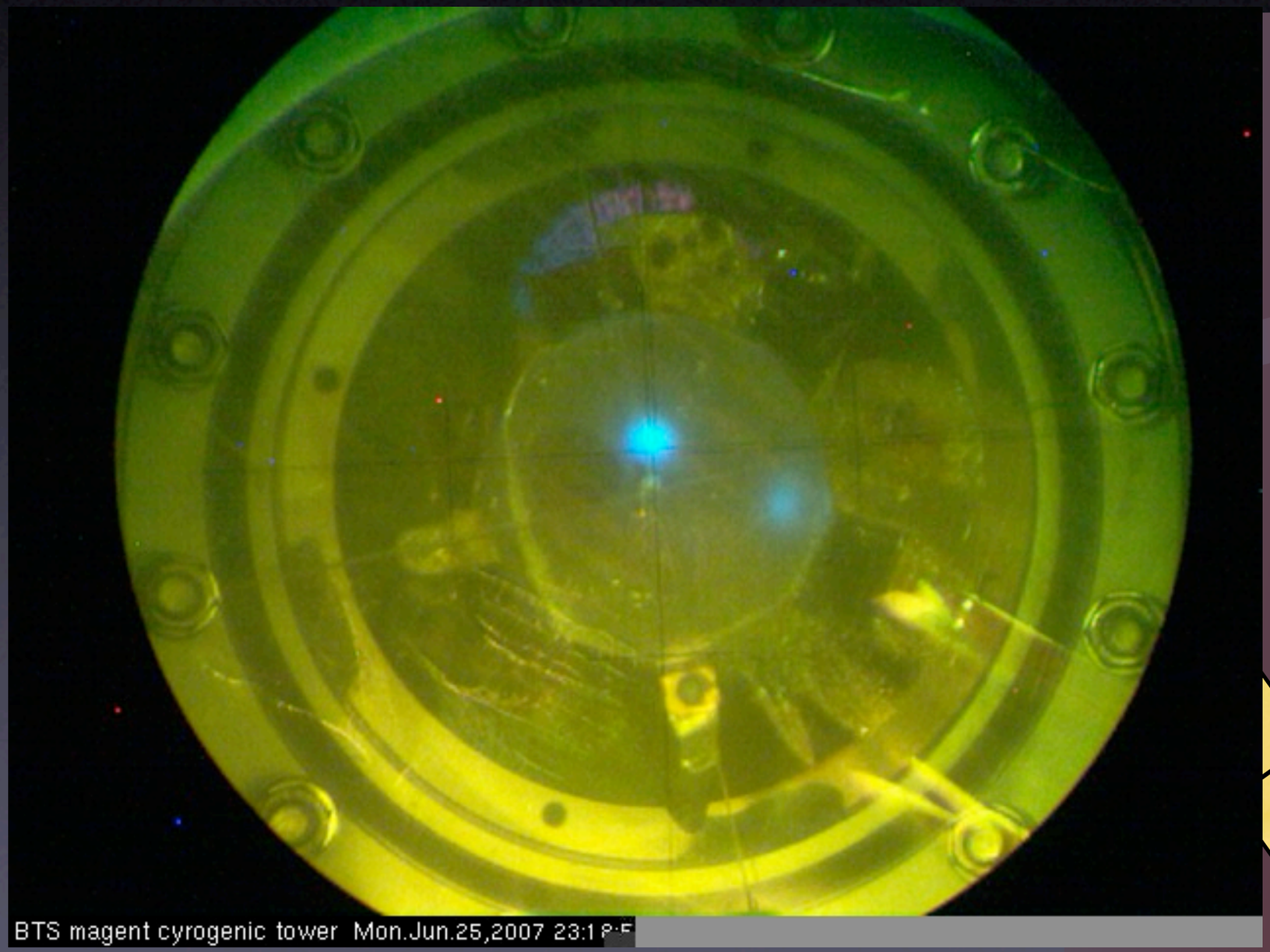
RED light = field ON

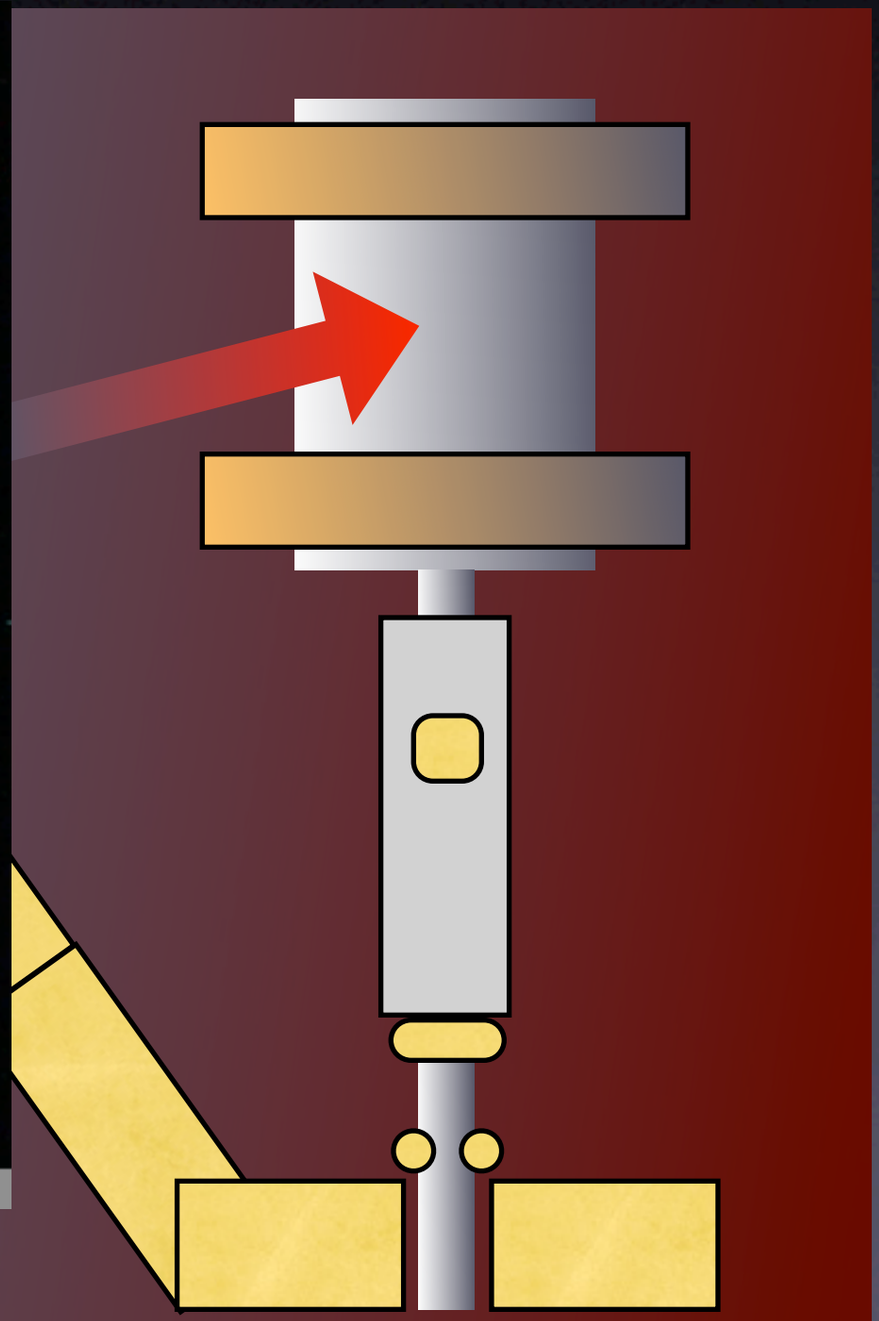


At COBRA center

~7 cm from the center

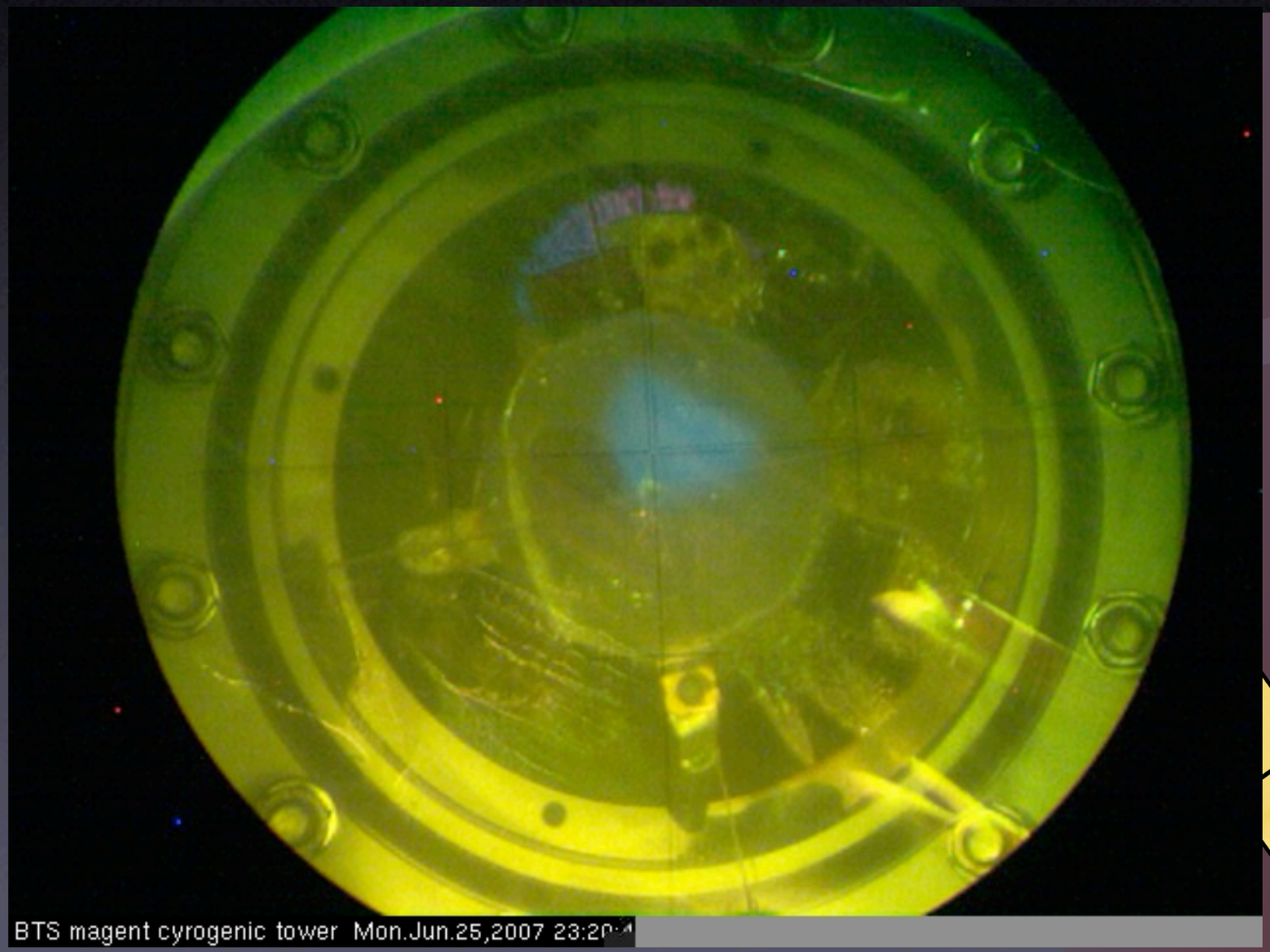
- We had a significant (~few cm) shift but with the help of dipoles and permanent magnets we could center the beam
- COBRA splits H^+ and H_2^+

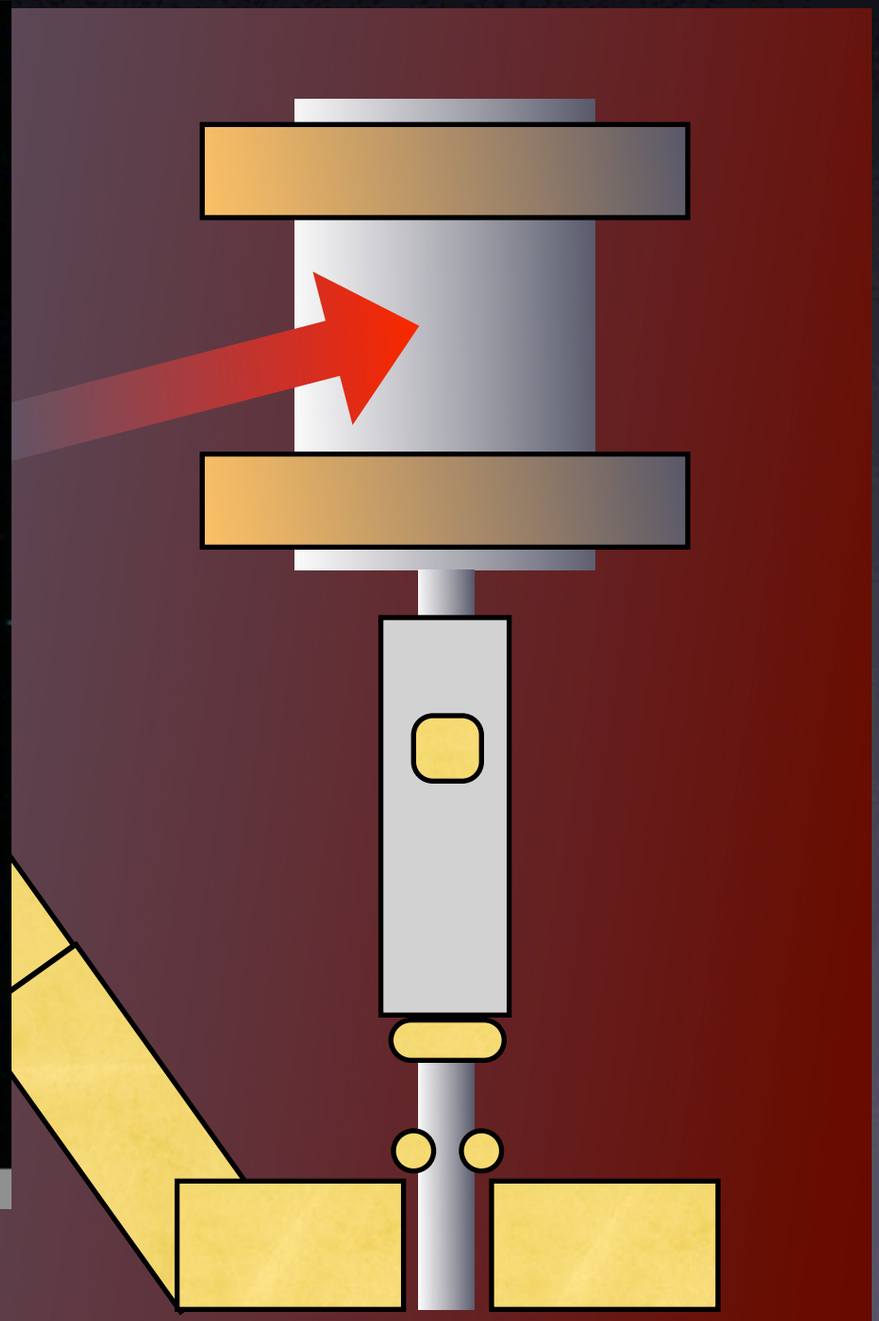




At COBRA center

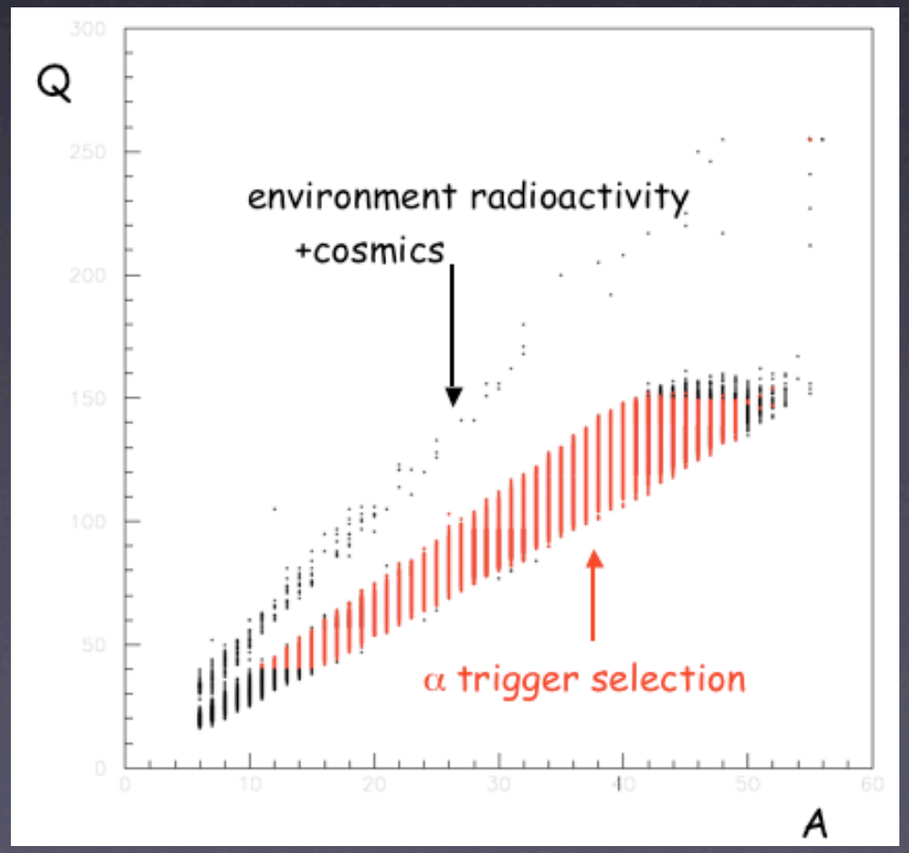
- Defocussing using accelerator extraction voltage
- ~ 2 cm beam spot





“in-run” calibration

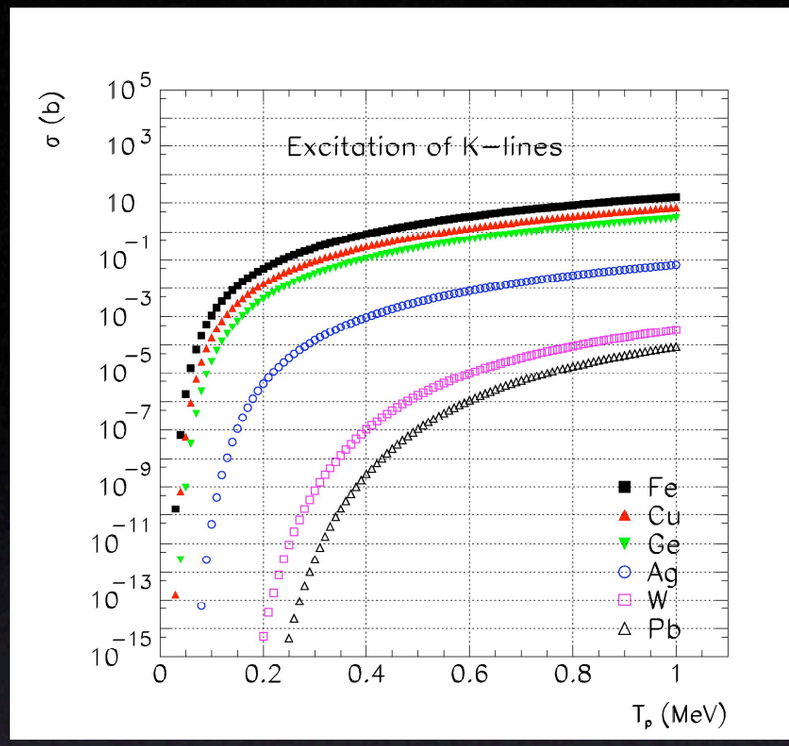
- It is possible to have a simultaneous μ & photon run
  - check of the gamma line behaviour in true experimental condition
- Not exactly at the center of the detector
- Also alpha-sources
  - trigger pulse shape discrimination
  - tested w/real trigger boards at the Pisa PMT test facility

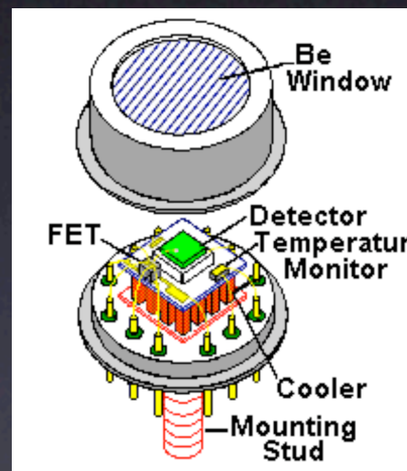


X-rays from the C-W

- Proton Induced X-ray Emission
  - Each element emits caracteristics X-rays
  - Medical Physics, geology, etc...
  - small brehmsstrahlung background
- Independent p-current normalization
  - Nuclear reaction detected by dedicated hardware
- Sub-detector calibration
- Check of safe radiation level ok!
  - MEG TN041

$$\sigma_k \propto \frac{T_p^4}{Z^{12}}$$





$$n_X = n_p \frac{N}{M} \int_{T_0}^{0} \frac{-dT_p}{S(T_p)} \sigma_X(T_p)$$

Particle Induced X-ray Emission (PIXE)
associated with the MEG Cockcroft-Walton

June 26, 2007

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Transport simulation

- Beam simulation with Transport