La Beam-Test Facility: una linea di fascio per molti usi

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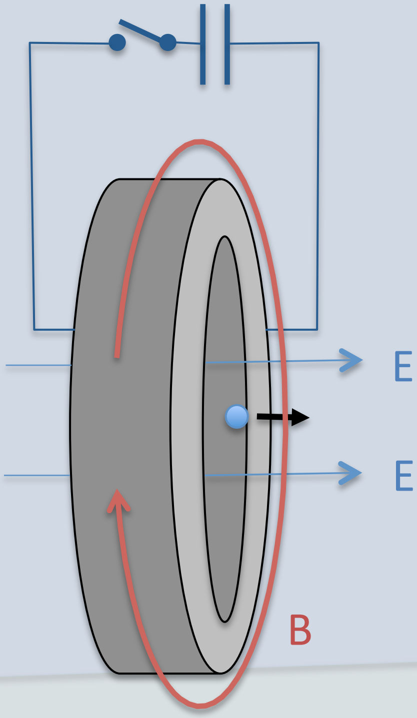
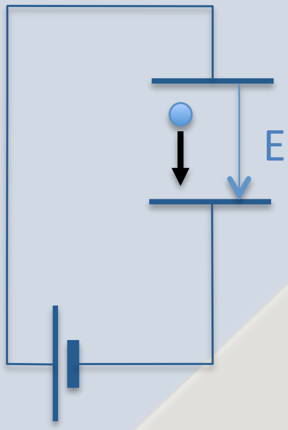
LINAC: tutto comincia da qui

Accelerare le particelle cariche

- Acceleratori elettrostatici (Cockroft-Walton, Van de Graaff): limitati dal **breakdown elettrostatico** (poche decine di MeV)
- Acceleratori a induzione

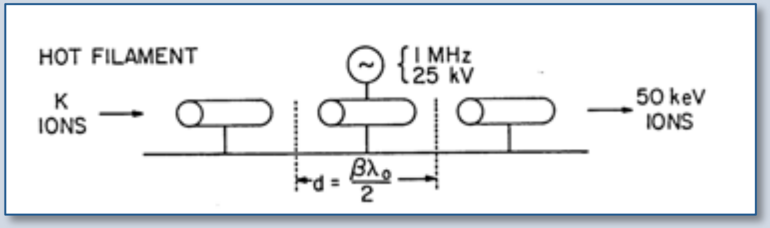




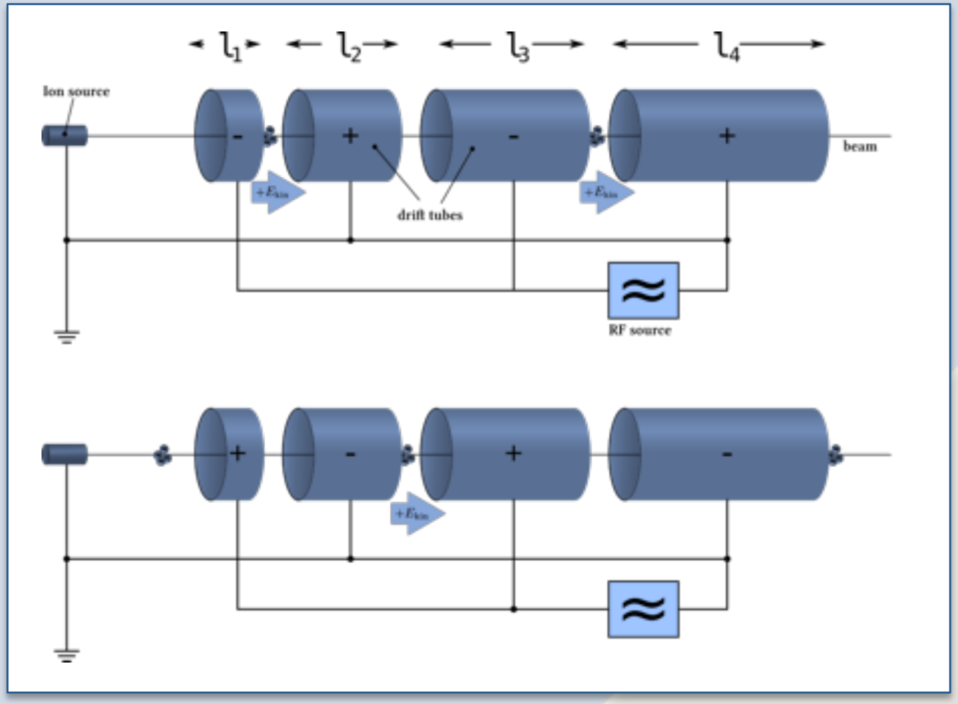
- Acceleratori a **radio-frequenza**: le particelle sono accelerate in modo risonante da un campo elettrico RF

Acceleratore lineare

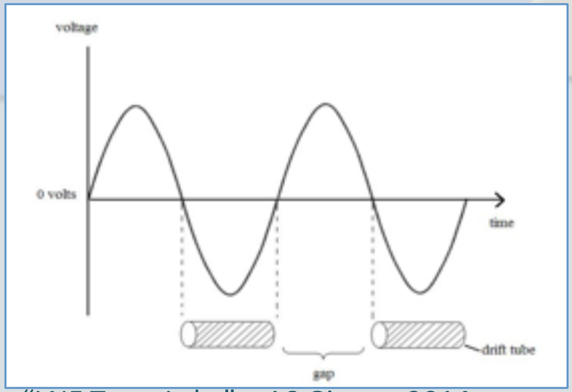
LINAC di Wideroe (1928)

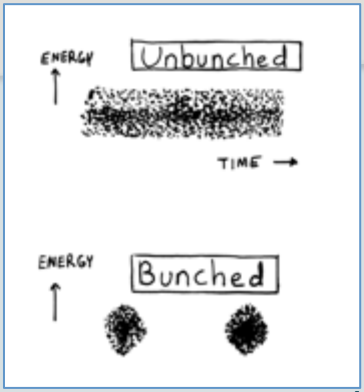


β=v/c
λ=lunghezza d'onda del campo RF

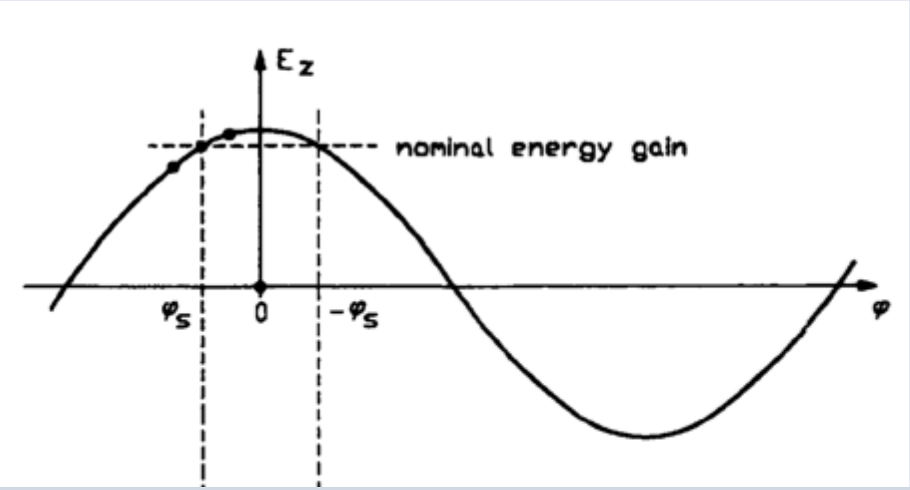


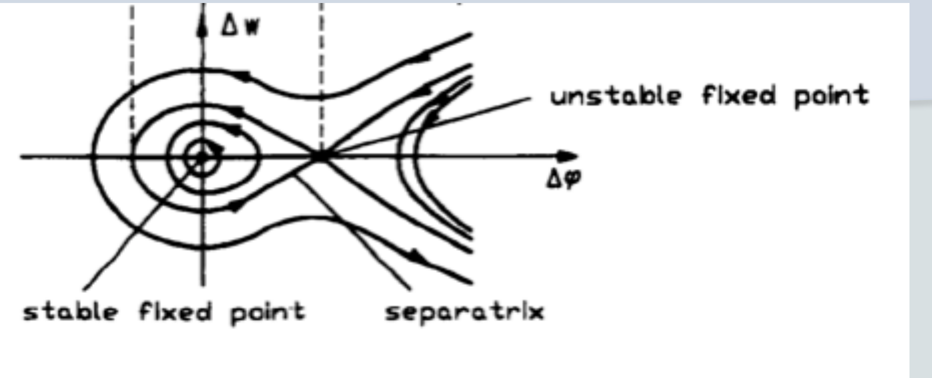
I tubi successivi sono più lunghi per mantenere il sincronismo della fase della tensione alternata





Stabilità di fase





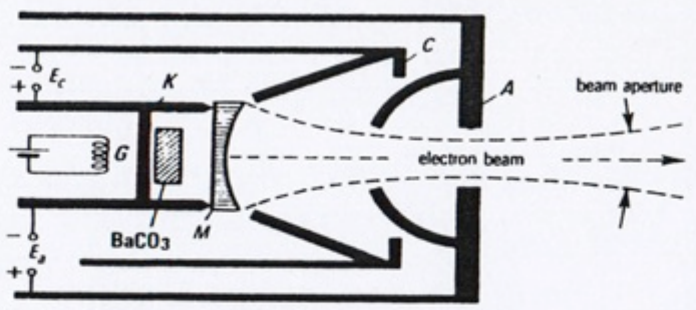
Gun

- Produrre elettroni
- Pre-accelerare fino al centinaio di keV.
- Produrre un fascio:
  - intenso
  - piccola divergenza angolare (beam-emittance)
  - grande durata e stabilità

Gli elettroni sono prodotti sulla superficie di un catodo caldo che può essere fatto di filamenti di tungsteno. Se un filamento del diametro di 1 mm è riscaldato a 2600 K, è prodotta una corrente di circa 0.8 A su cm^2.
La vita media di tale dispositivo è relativamente lunga ~ 400 h.

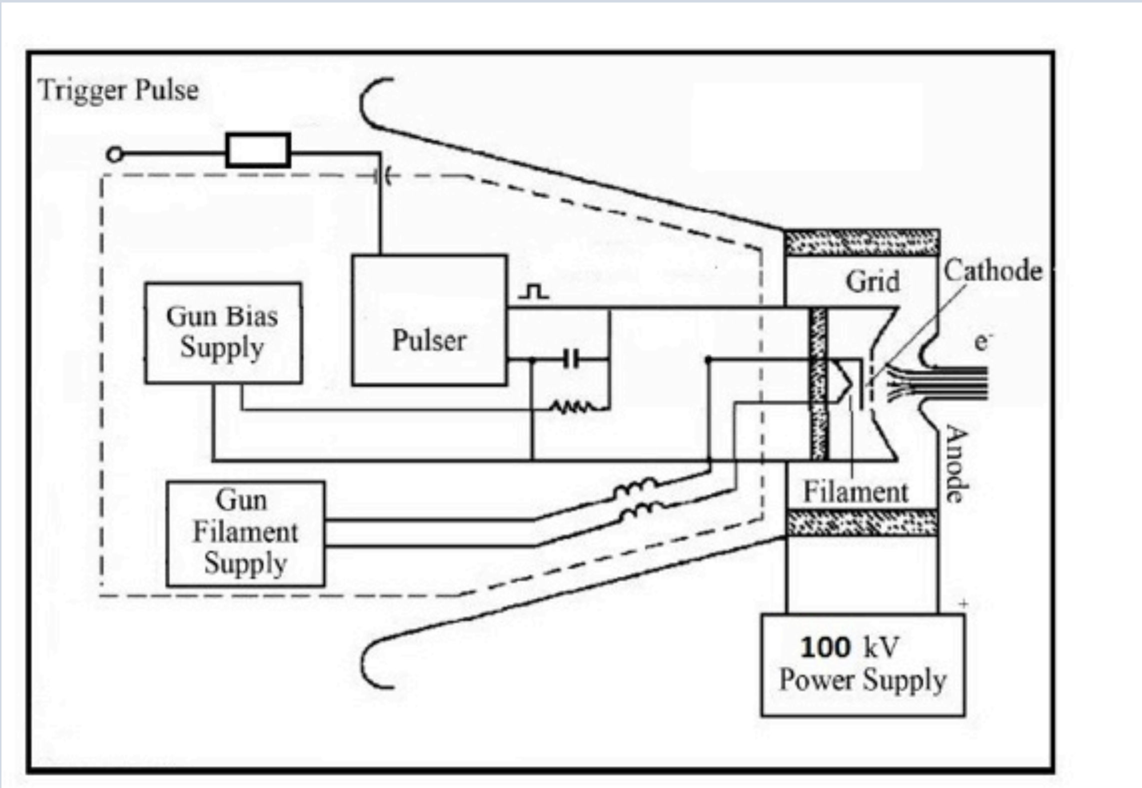
Se la temperatura del medesimo catodo raggiungesse 3000 k, la corrente aumenterebbe di un fattore 20 ma la durata sarebbe appena 20 ore.

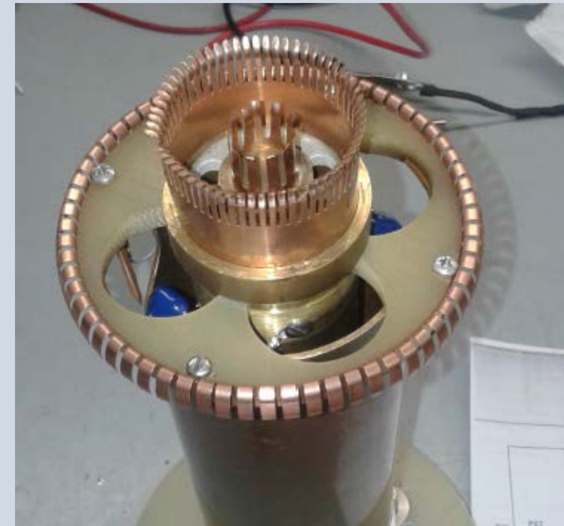
Va fatta una scelta di compromesso.



Pierce electron source used in linear accelerators: H—cathode heater; K—cathode; A—anode; C—control electrode; M—mirror; E_a—anode voltage; E_c—control voltage

Gun electronics





Cathode parameters

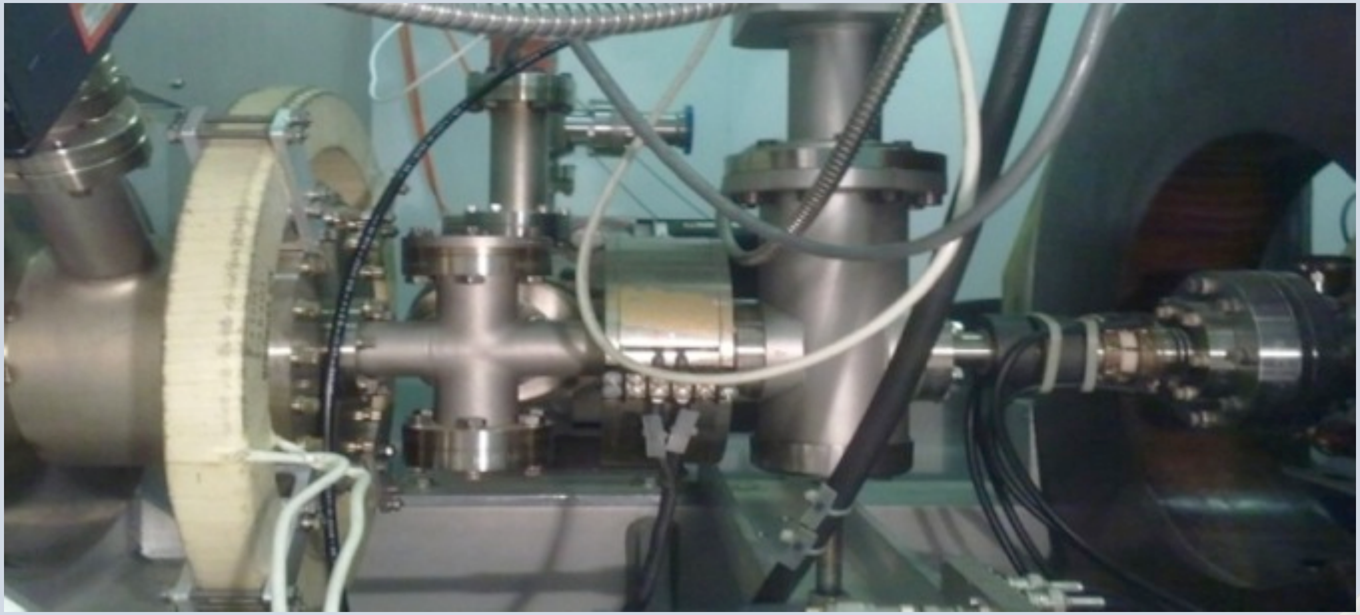
Cathode Area 2.0 cm^2

Max emission current 12 A

Heater 5.8 A, 6 V

With a gun current of 7 A,
80% can be captured and accelerated

Parameters	Characteristics
Gun type	Thermionic triode electron gun
Cathode	Y796 (EIMAC) dispenser
Filament heating power	35 W
Acceleration potential	120 kV
Beam current	12 A
Emission current density	10 A/cm2
Grid bias voltage	0 - 500 V



Buckling coil

Focusing coil

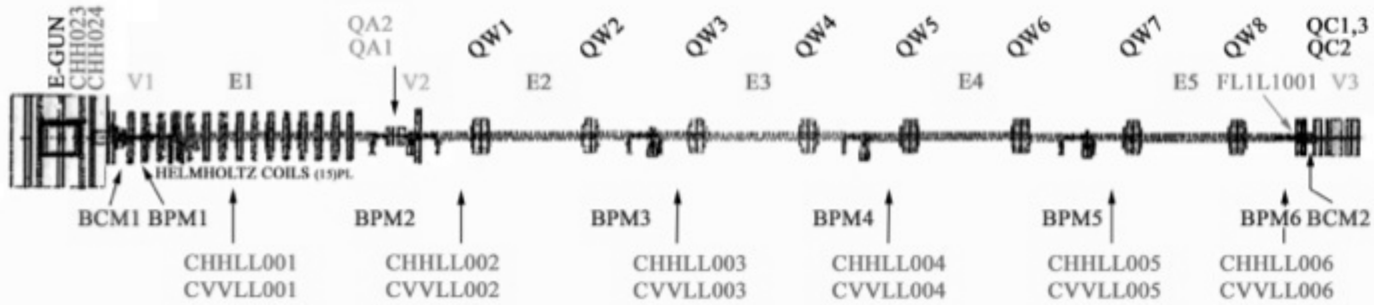
Helmholtz coil (×14)

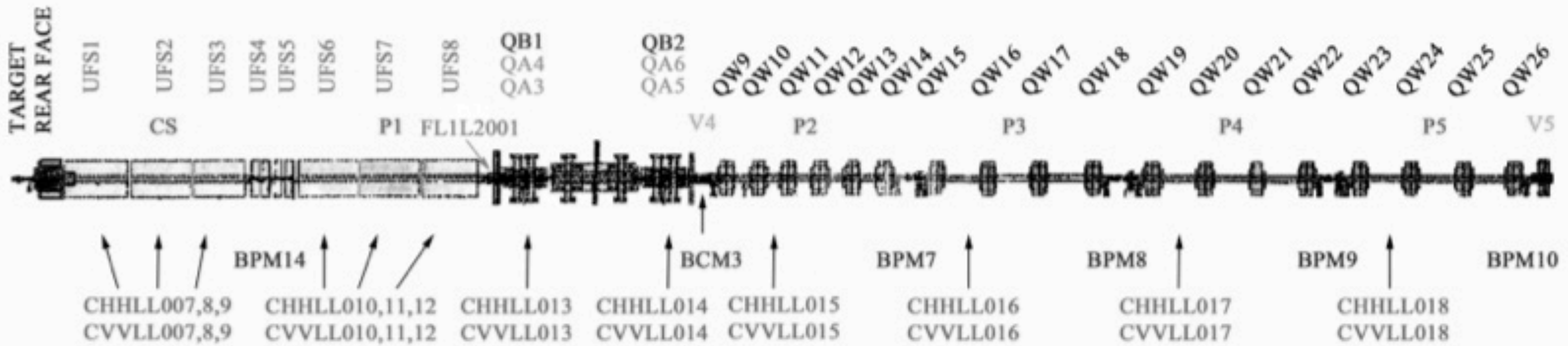
Compensa l'effetto delle bobine successive in modo di avere B=0 in prossimità del catodo

Consentono il trasporto degli elettroni ancora di bassa energia nonostante la forte carica spaziale

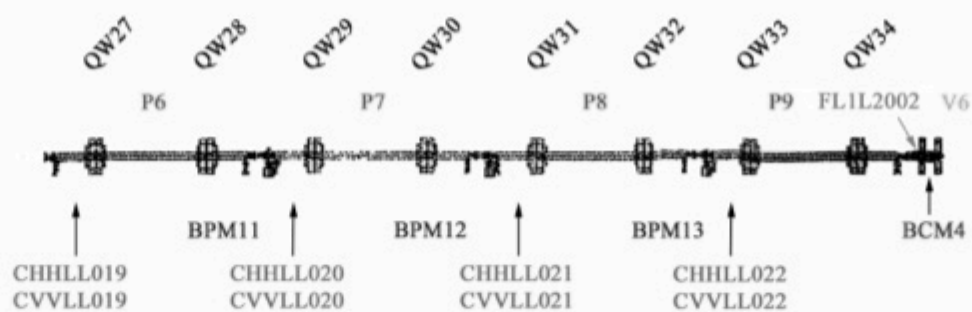
Schema generale

High current

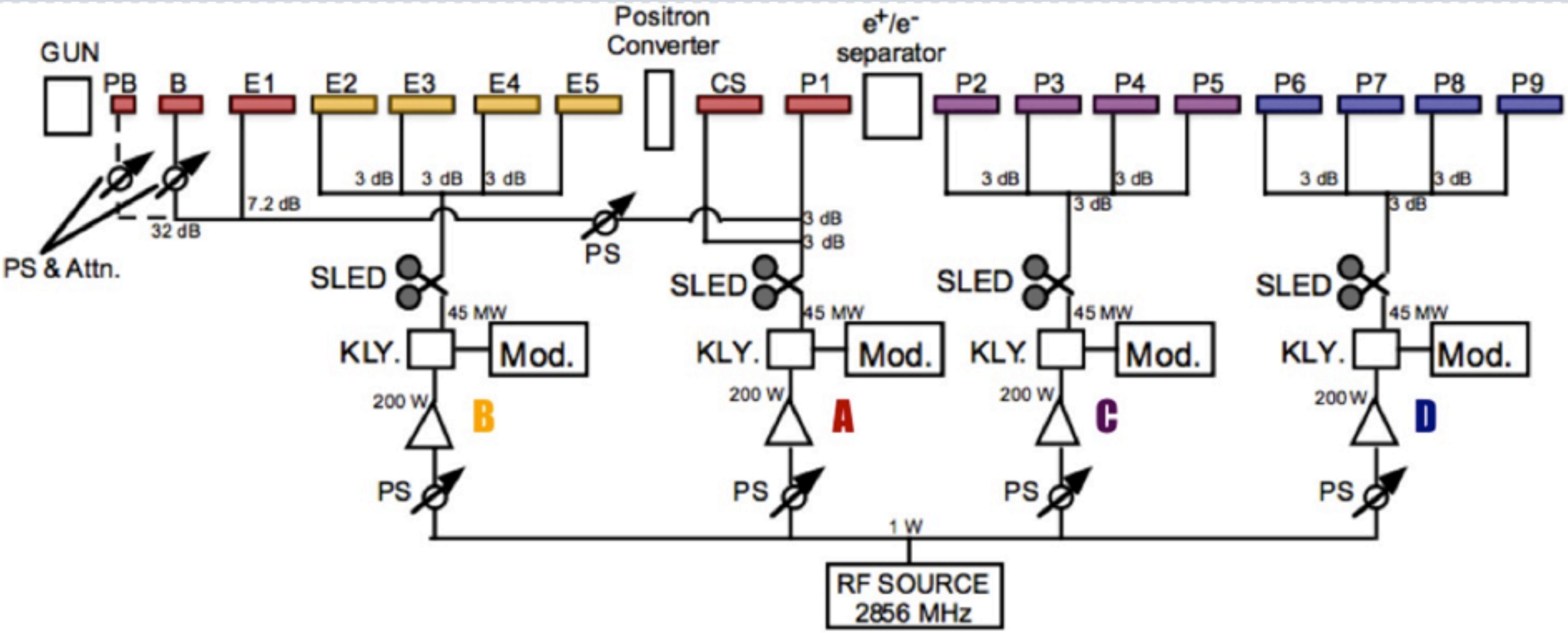




High energy



Distribuzione RF



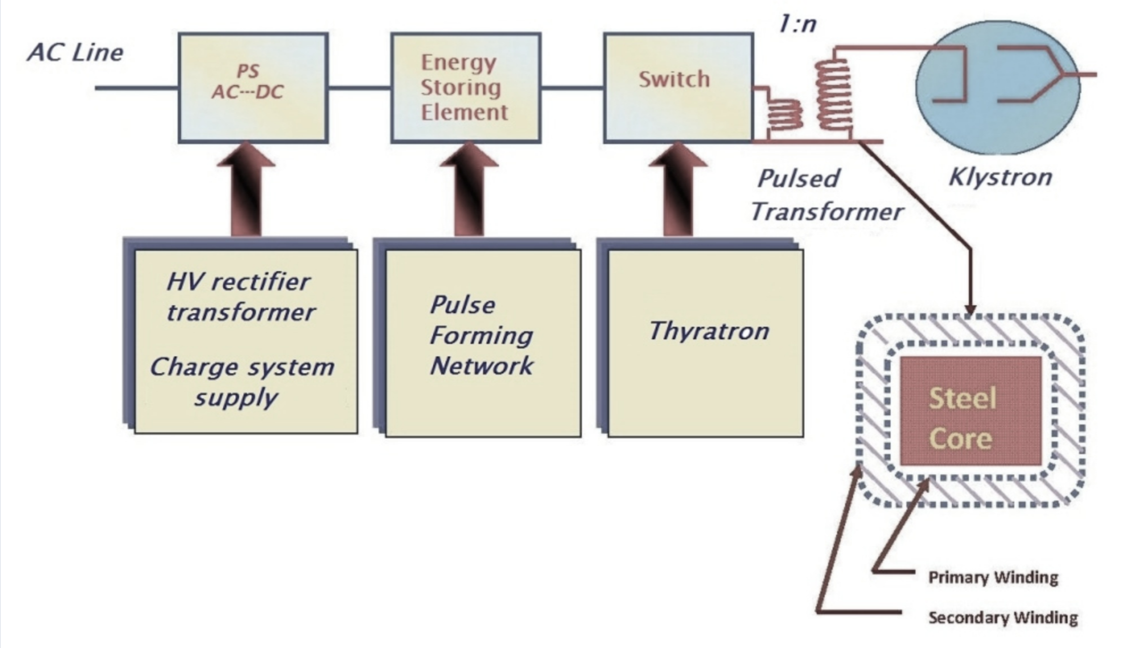
Componenti RF

RF Components:

Driver amplifier to power klystron
Klystron is used to generate high peak power (A small accelerator)
Need to transport power to the accelerating structure
Waveguide is used (under vacuum) to propagate and guide electromagnetic fields
Windows (dielectric material, low loss ceramic) are used to isolate sections of the waveguide
Termination loads (water loads) are used to provide proper rf match and to absorb wasted power
Power splitters are used to divide power in different branches of the waveguide run

Line type Modulators layout

The modulator is the DC power supply which drives the klystron beam.



Typically it cannot reach the klystron drive voltage directly.
A transformer is needed to reach the desired voltage.

Modulatori

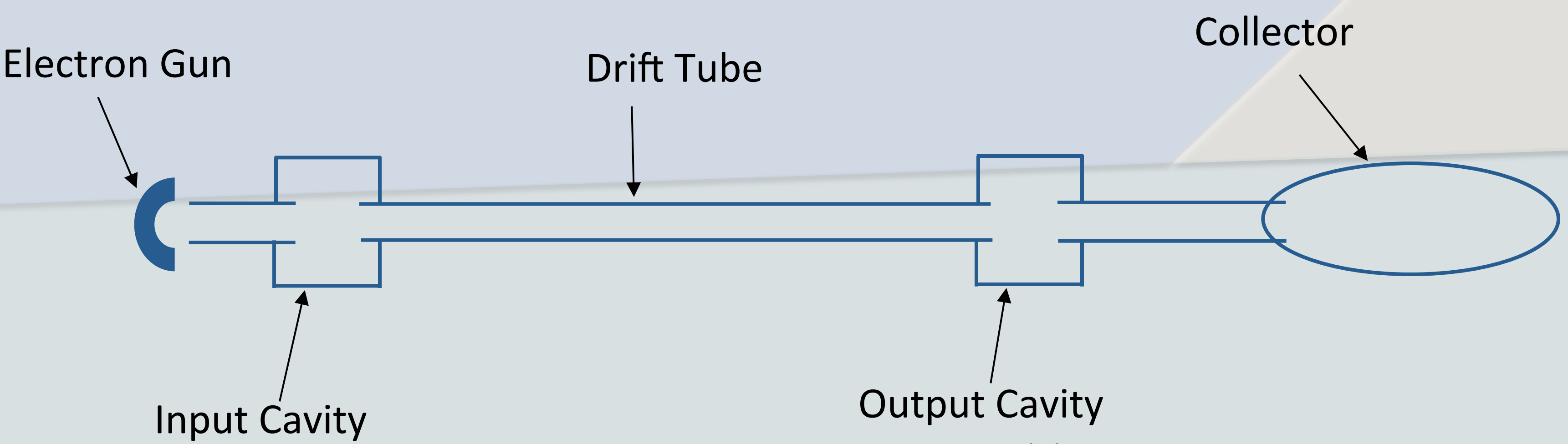
Klystron	TH2128C
PFN voltage pulse width(μs)	4,5
PFN Cell capacitance (nF)	68
PFN Cell inductance(μH)	2
Pulse transformer ratio	1:12
Thyratron peak current (A)	4300
Thyratron Peak voltage (kV)	50
Beam voltage flat top(μs)	4.5
Pulse rise time (10%-90%) (μs)	0.4
Pulse fall time (10%-90%) (μs)	0.5
Pulse voltage variation (%)	±0.1
Pulse repetition rate (Hz)	50
Modulator charging time (ms)	10

Klystrons

Klystrons have been the principal source of high-power (>1 MW) RF since the beginning of time, and no alternative technology appears poised to replace them.

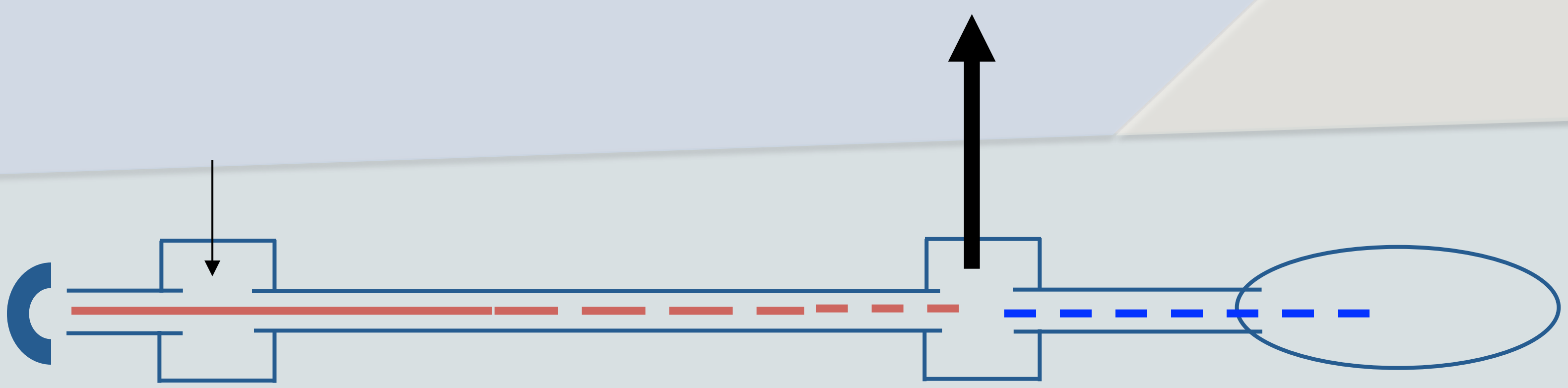
What are klystrons?

A klystron is a narrow-band vacuum-tube amplifier at microwave frequencies (an electron-beam device).



How the Klystron works

- DC Beam at high voltage (<500 kV, < 500 A) is emitted from the gun
- A low-power signal at the design frequency excites the input cavity
- Particles are accelerated or decelerated in the input cavity, depending on phase/arrival time
- Velocity modulation becomes time modulation in the long drift tube (beam is bunched at drive frequency)
- Bunched beam excites output cavity at design frequency (beam loading)
- Spent beam is stopped in the collector.



Klystron data sheet

PARAMETER	Unit	TH2128C	5045
Center Frequency	MHz	2856	2856
Peak output power	MW	45	65
Peak average power	KW	10	90
RF pulse width	µs	4.5	3.5
Peak beam voltage	kV	320	350
Peak beam current	A	360	414
Microperveance	µA/V3/2	2.0	2.0
Heater voltage	V	20~30	15
Heater current	A	20~28	35
Focusing currents	A	40	15
Peak driver power	W	200	350
Gain	dB	54	53
Efficiency	%	43	45
Pulse repetition rate	Hz	50	120

Pulse compression

Room-temperature accelerator structures require a short pulse of high RF power to reach their desired gradients.

Klystrons run efficiently when they produce a long pulse of relatively low power (minimize inefficiency from modulator rise/fall time etc).

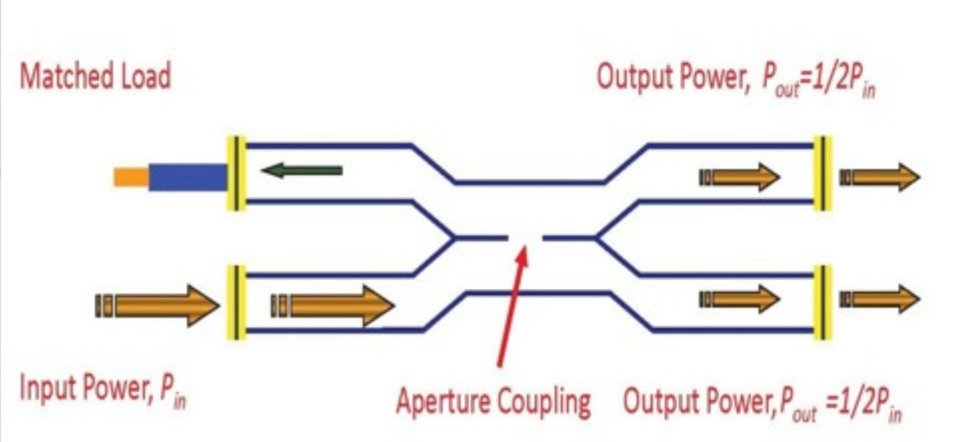
Matching these different time structures is done by pulse compression.

Pulse compression in turn relies on the magic of the 3-db directional coupler to succeed.

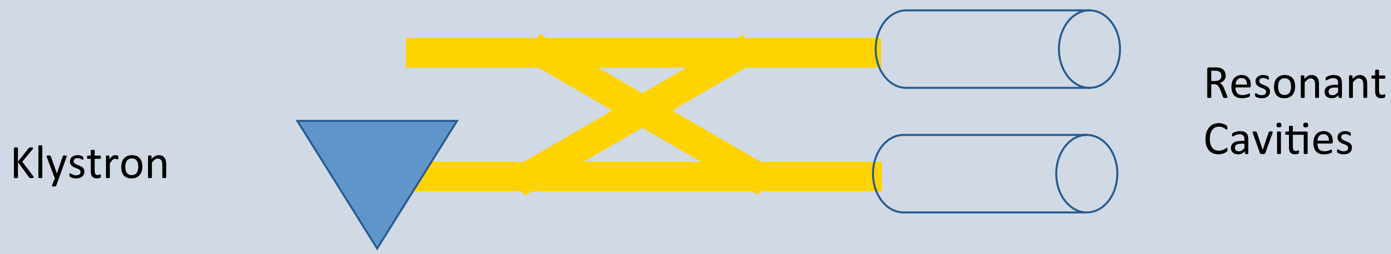
The 3-db coupler is a passive device with 4 input/output ports passing thru a central nexus:

The key feature of the coupler is that the diagonal pathways are longer by 90° than the straight pathways.

What does that do for us?



SLED pulse compression



Power from port 1 will be split and flow equally to ports 2 and 3, but with a phase shift.

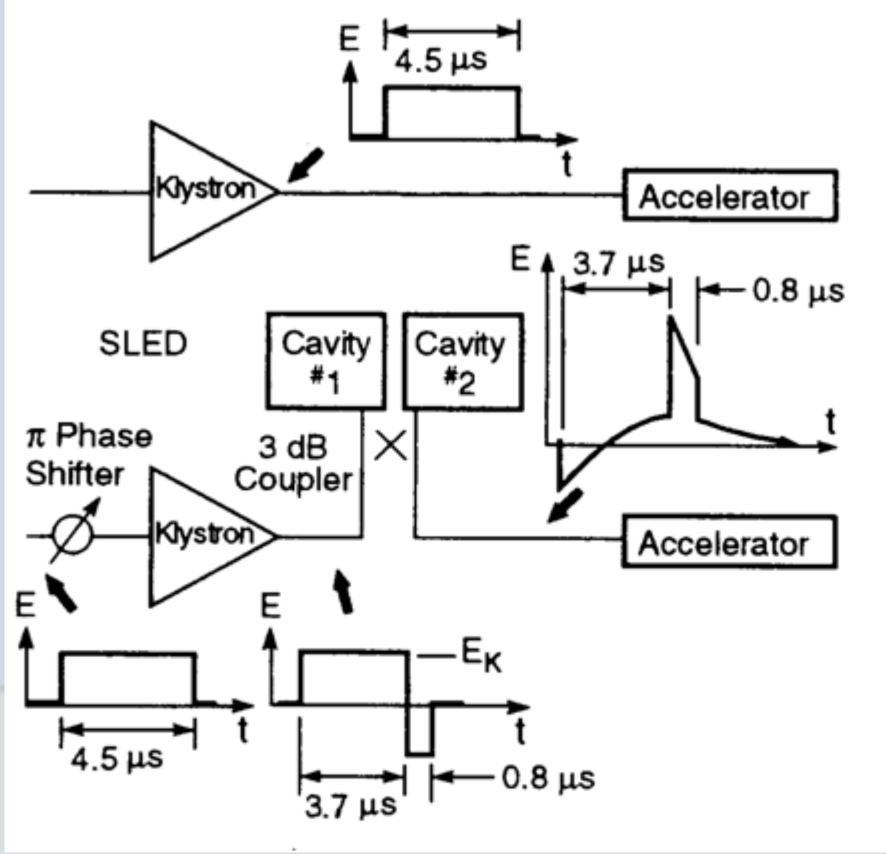
If equal power is introduced at ports 1 and 4, but with a 90° phase shift between them, it will flow entirely to either port 2 or port 3.

If power is introduced at port 1, and perfect reflectors are placed at the end of lines 2 and 3, the reflected power will recombine constructively at port 4 (if the reflectors are placed the same distance from the center of the coupler.

SLED pulse compression

Power from the klystron goes to 2 resonant cavities for storage
because the cavity coupler reflects almost all power, there's a surge of reflected energy which goes to the accelerator.

As the SLED system fills, its emitted power destructively interferes with the klystron reflected power.
At some point in the klystron pulse, the phase of the klystron is reversed so that the stored energy interferes constructively…



SLED limitations

- Factor of 3 amplitude limit (factor of 9 power limit)
- For large amplitude gains, efficiency is low
  - Large value of t_1 required w.r.t. t_c
  - Long time when most RF power is reflected, not stored
- Output pulse not flat
  - Exponential character due to standing-wave SLED character

The SLAC structure

Parameter	Symbol	Unit	Value
Frequency	$\omega/2\pi$	MHz	2856
Length	L	m	3.048
Cell Radius	b	cm	4.17--4.09
Iris Radius	a	cm	1.31--0.96
Cell Length	d	cm	3.50
Phase Advance per Cell	ψ	-	$2\pi/3$
Disc Thickness	h	cm	0.584
Quality Factor	Q	-	13,000
Shunt Impedance per Meter	r_l	MΩ/m	52--60
Filling Time	t_f	nsec	830
Group Velocity	v_{gr}	% c	2.0--0.65
Attenuation	τ	"nepers"	0.57
Typical Unloaded Gradient	G_0	MV/m	21
Typical Input Power	P_0	MW	45

DAFNE LINAC

	Design	Operational
Electron beam final energy	800 MeV	510 MeV
Positron beam final energy	550 MeV	510 MeV
RF frequency	2856 MHz	
Positron conversion energy	250 MeV	220 MeV
Beam pulse rep. rate	1 to 50 Hz	1 to 50 Hz
Beam macropulse length	10 nsec	1.4 to 40 nsec
Gun current	8 A	8 A
Beam spot on positron converter	1 mm	1 mm
norm. Emittance (mm. mrad)	1 (electron) 10 (positron)	< 1.5
rms Energy spread	0.5% (electron) 1.0% (positron)	0.5% (electron) 1.0% (positron)
electron current on positron converter	5 A	5.2 A
Max output electron current	>150 mA	500 mA
Max output positron current	36 mA	85 mA
Trasport efficiency from capture section to linac end	90%	90%
Accelerating structure	SLAC-type, CG, 2π/3	
RF source	4 x 45 MWp sledded klystrons TH2128C	

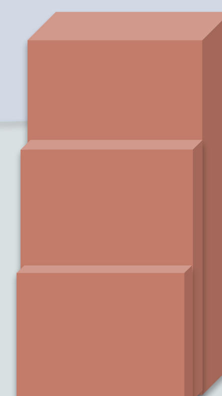
Produzione di positroni

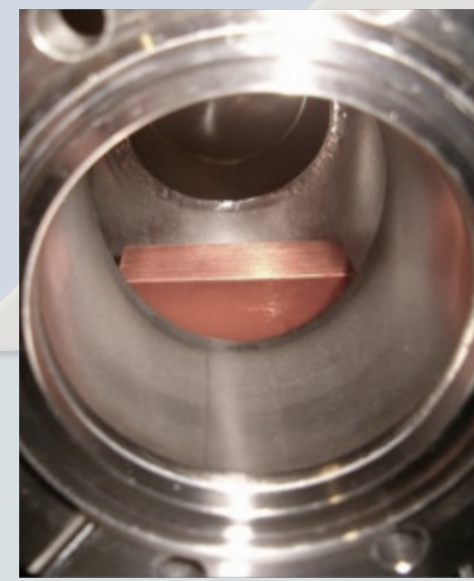
LINAC **positron converter**
- Target: tungsten (Z=74)-rhenium(Z=75), L=2 $x_{0ù}$
- Positrons by pairs production
- flux concentrator, jointly with DC solenoid magnets, generate a strong magnetic field (5 T peak) necessary for the positron capture.

BTF target
- Copper (Z=29) variable depth (1.7, 2 or 2.3 radiation lengths)

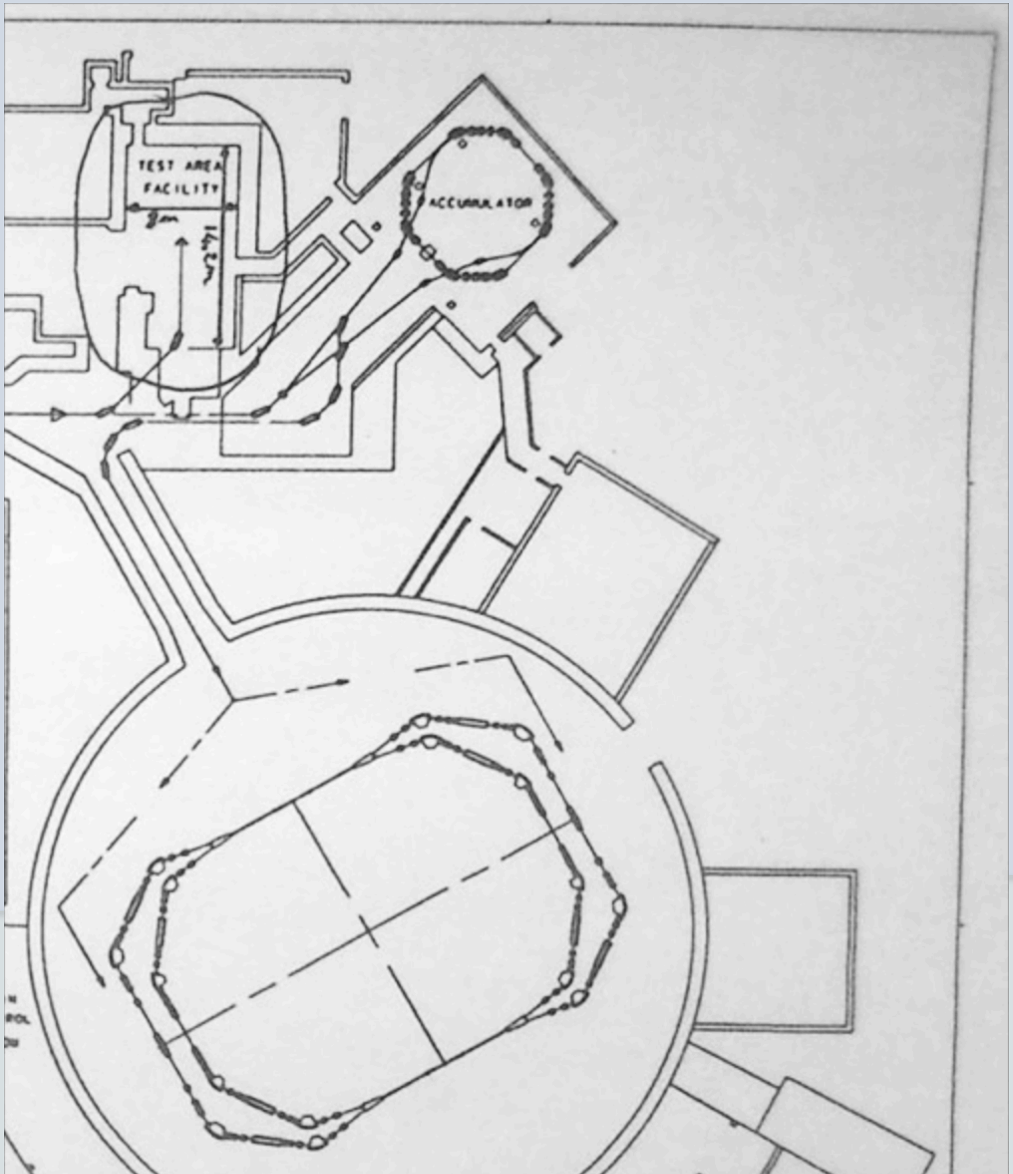
$$\frac{\left(\frac{\partial E}{\partial x}\right)_{RAD}}{\left(\frac{\partial E}{\partial x}\right)_{ION}} \approx \frac{ZE_0}{800}$$

- Copper critical energy at E_0=0.5 GeV ≈ **18 MeV** (≈ **46 MeV** for W/Re)

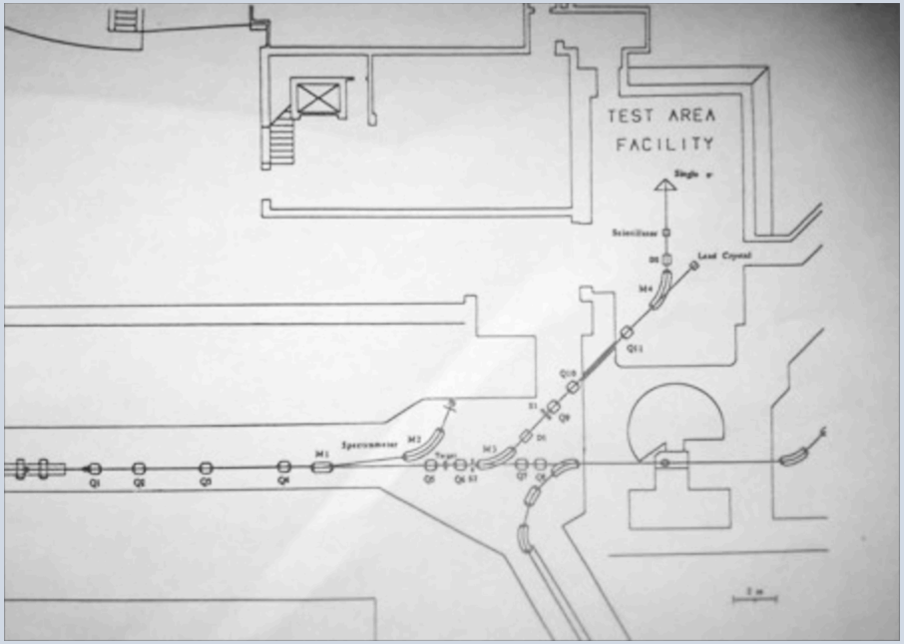


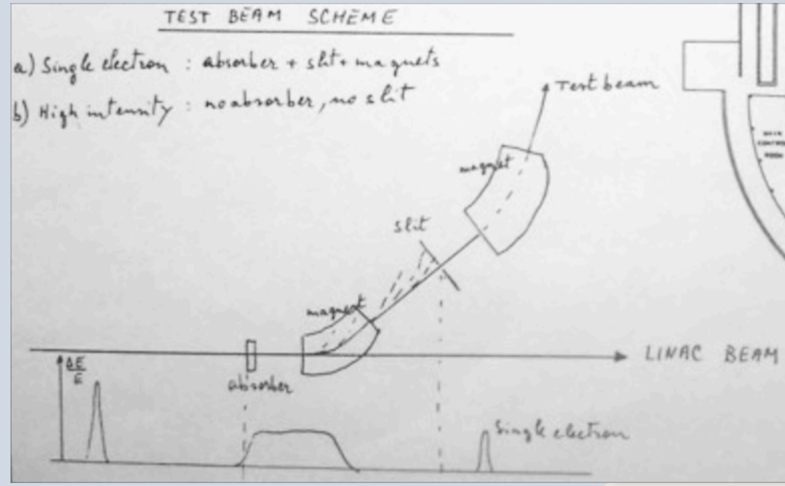


La linea BTF



The concept





The original idea of the BTF was already to have **two distinct operation modes**:

a) Single particle mode
b) Full extraction of the primary beam

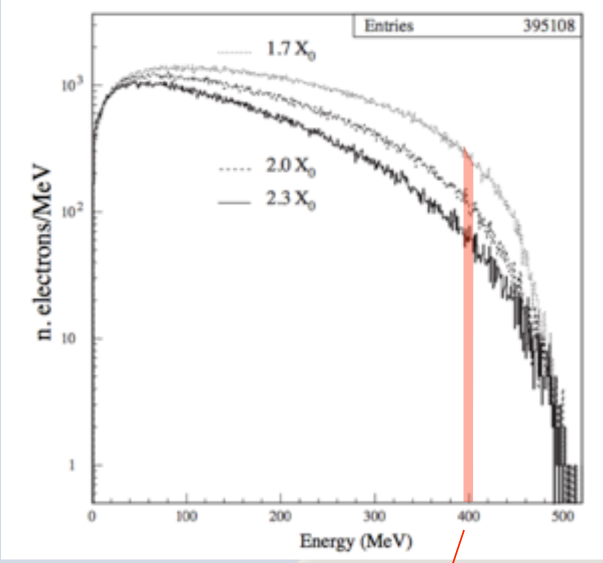
The idea was to use the LINAC beam **only when not injecting**, thus sharing the same transfer line to the damping ring

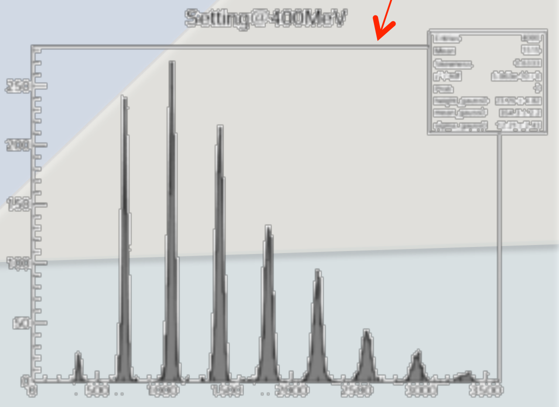
BTF operation modes

- Starting from 10^{7}-10^{10}(10^{9}) electrons (positrons) from the DAFNE LINAC, with E_{max}=550/750 MeV and Δt=1.5-40 ns, it operates mainly in **two different intensity regimes**:
  - **High intensity**: primary beam driven to the experimental hall, between 250 MeV and E_{max}, tuned with collimators
  - **Single particle/bunch** (Poisson distribution) between few tens of MeV and E_{max}, created intercepting the beam with a variable depth Cu target, **selecting the energy** and **collimating**.

  Intermediate intensity ($<10^{5}$ particles/bunch) is also achievable with target at low energy

  [Primary beam fixed to E=510 MeV and Δt=10 ns during operations of DAFNE collider]
- **1% momentum resolution**
- Spot size down to 2×2 mm^{2},
- **2 mrad divergence**
- S-band gives 2856 MHz micro-bunching



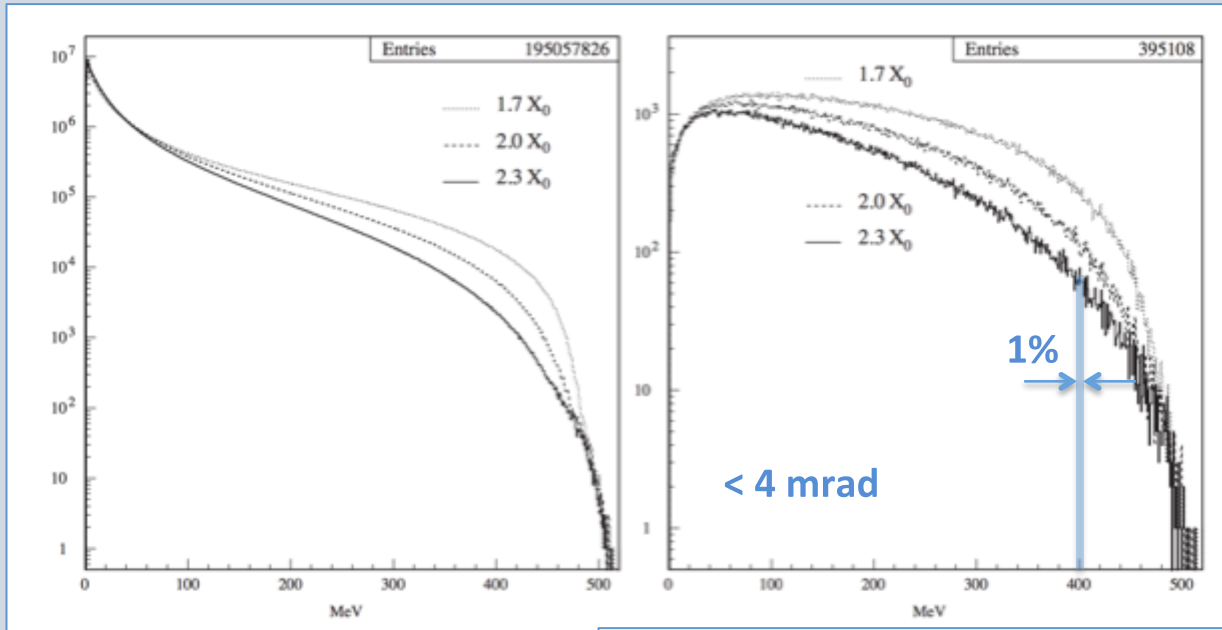


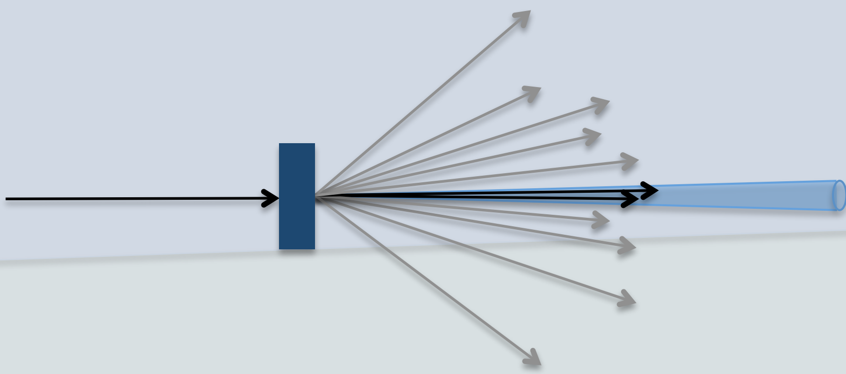
$N = I \times t \cong 6.24 \times 10^{7}$ particles/mA (10 ns pulses)

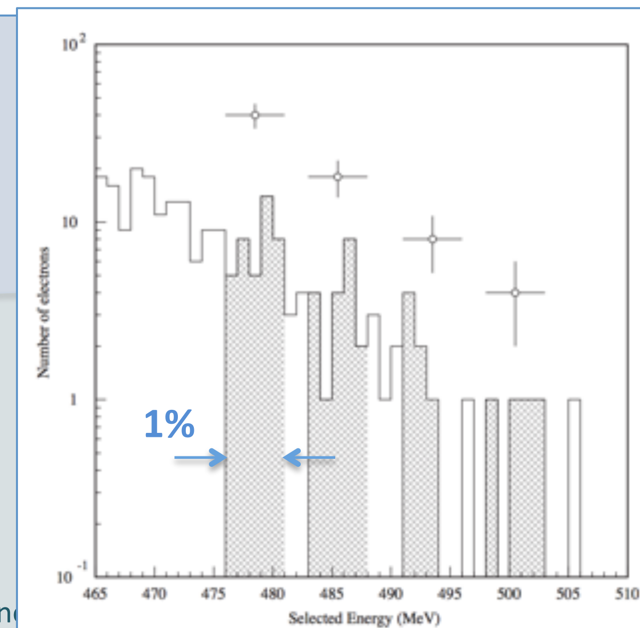
Attenuare fino alla singola particella

B. Rossi model of e.m. shower

$$w\,(E_o\,,\,\alpha,\,E\,)=\frac{1}{E_o}\,\frac{\left[\ln\left(\frac{E_o}{E}\right)\right]^{\frac{\alpha}{\ln\,2}-1}}{\Gamma\left(\frac{\alpha}{\ln\,2}\right)}$$

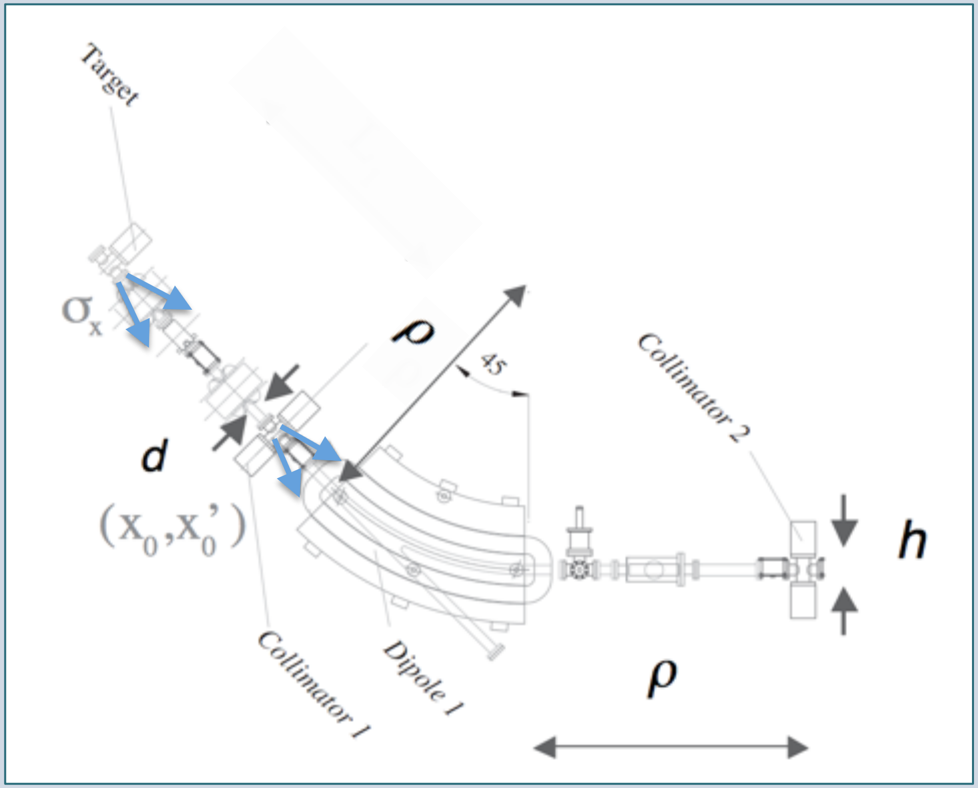






$$P=\frac{1}{2\,\Gamma\left(\frac{\alpha}{\ln\,2}\right)}\left(\frac{\Delta E}{E_o}\right)^{\frac{\alpha}{\ln\,2}}$$

Risoluzione in impulso



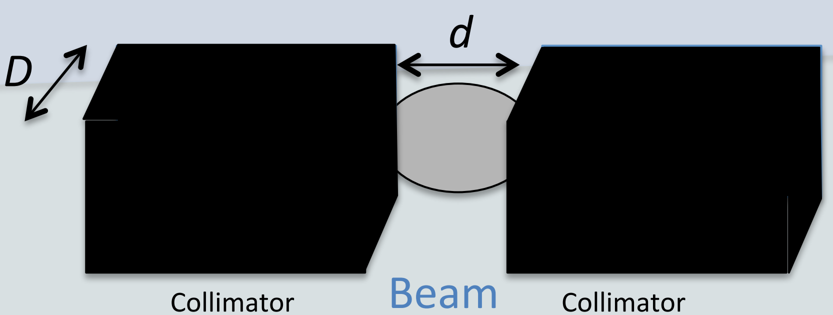
Energy resolution:

$$\left|\frac{\Delta E}{E}\right| = \frac{h}{2\rho} + \sqrt{2}\left|x_0'\right|_{MAX}$$

Maximum input divergence:

$$\left|x_0'\right|_{MAX} = \frac{d}{D}$$

Aperture *d*, Thickness *D*



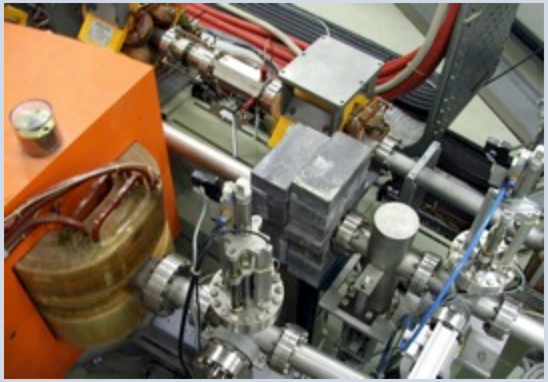
2004 upgrade: an independent BTF line

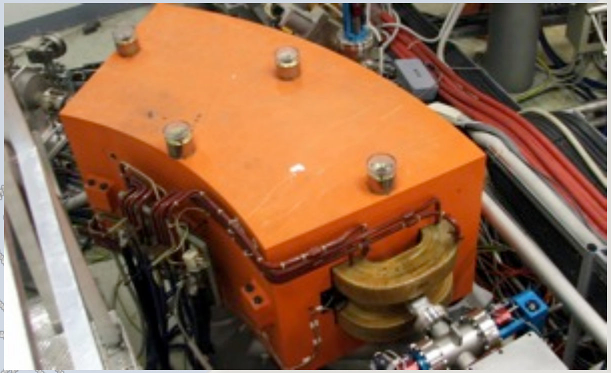
2006:

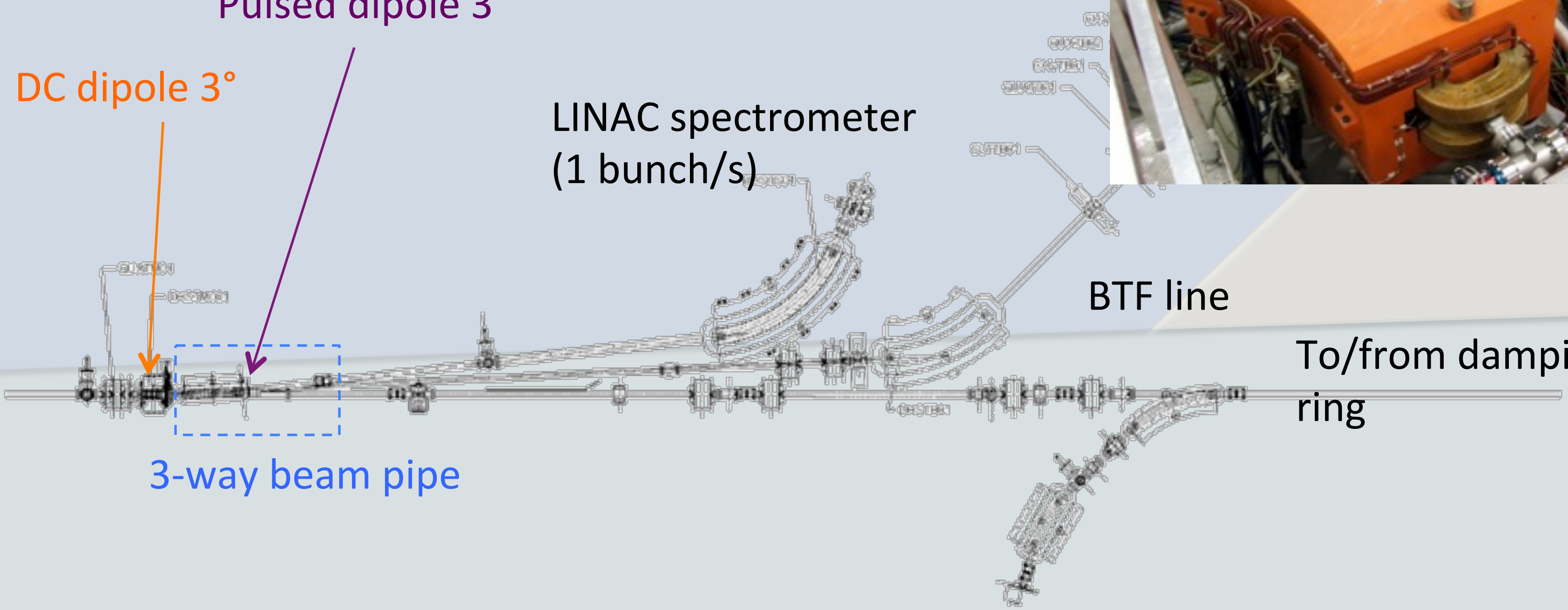
DC/pulsed power converter
Ramp up <10 ms
Flat top [5, 960 ms]

3-way beam-pipe

BTF line







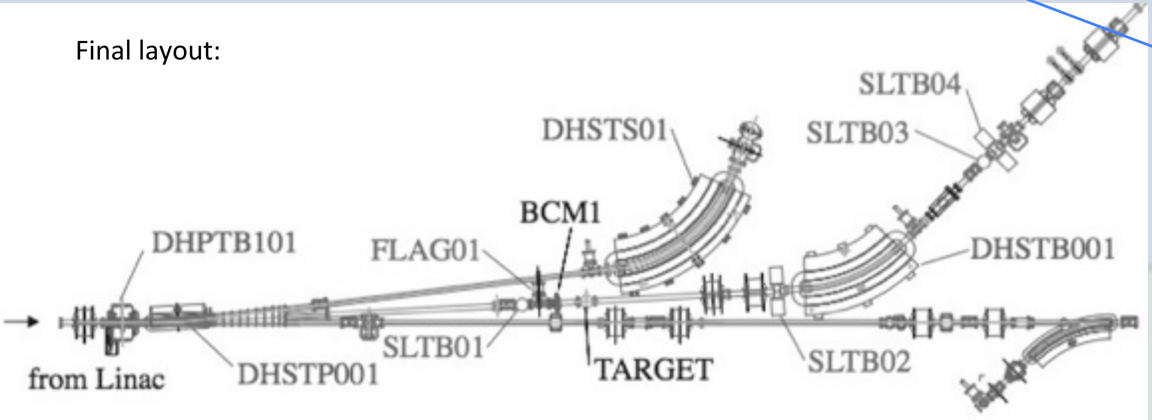
Pulsed dipole 3°
DC dipole 3°
LINAC spectrometer (1 bunch/s)
BTF line
To/from damping ring
3-way beam pipe

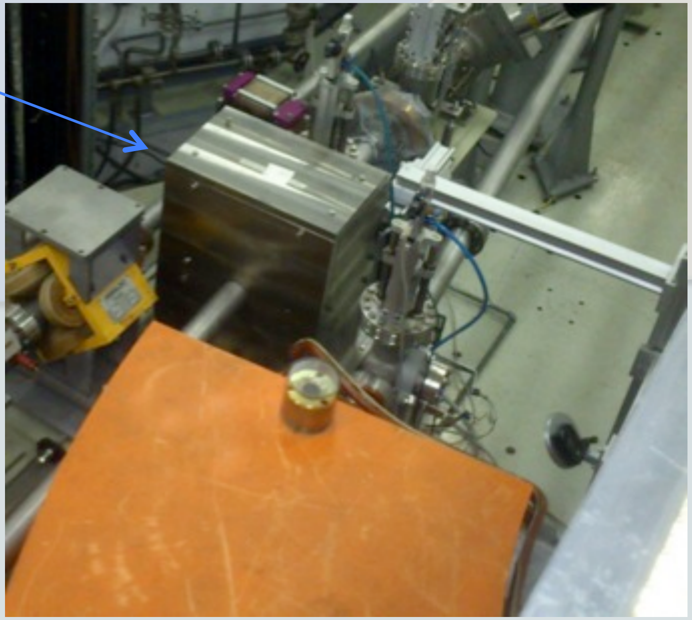
BTF line

- Added new slits for vertical collimation **after** energy selection (for better beam definition): SLTB03
- Added new slits for horizontal collimation **before** the energy selection (for improving the resolution): SLTB02

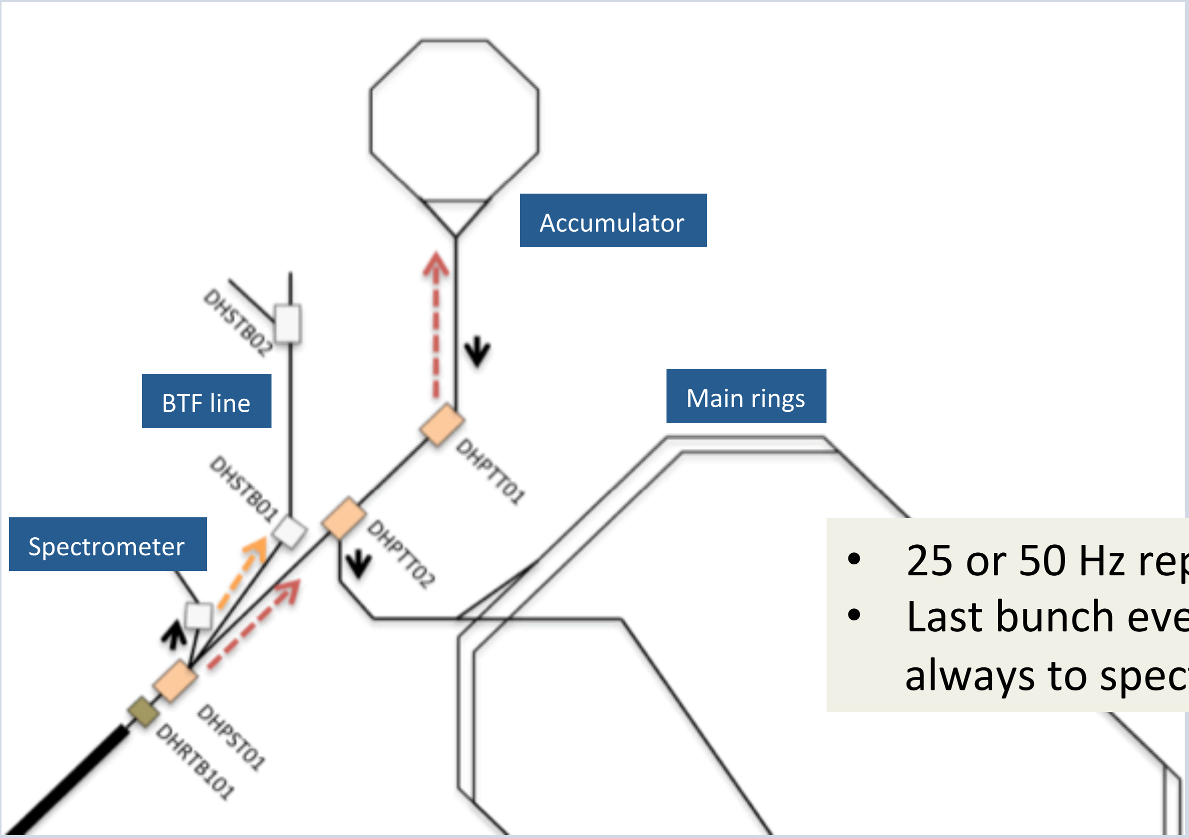
- Target moved to the BTF line (and shielded)

Final layout:





Timing

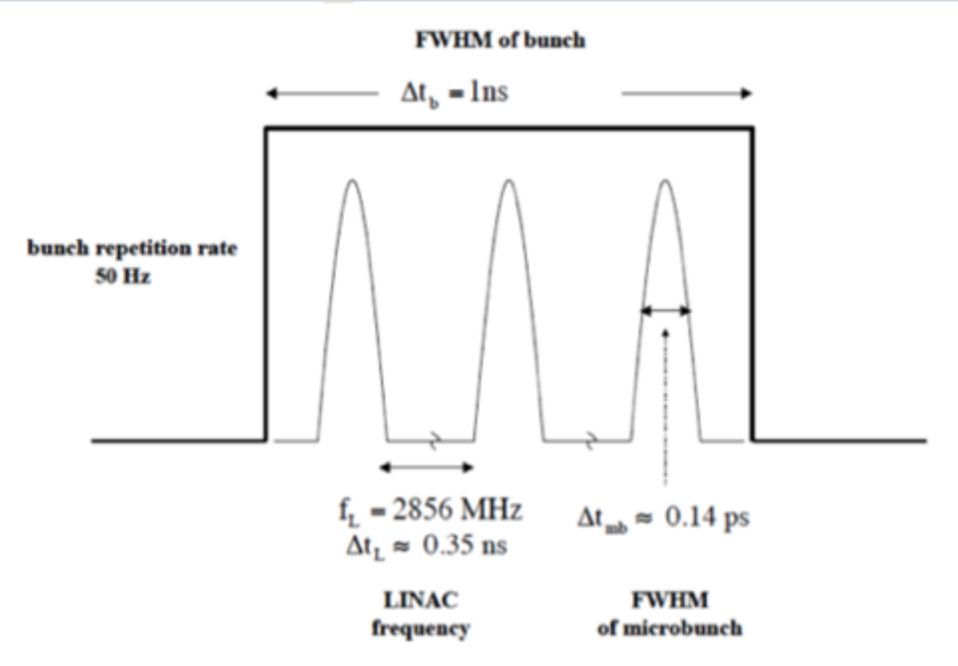


- 25 or 50 Hz repetition rate
- Last bunch every second always to spectrometer line

DAΦNE phases of the complex LINAC, BTF and DAΦNE:

- **LINAC** = LINAC shots are delivered at 25(50) pulse per second and dumped at the end of TL
- **LINAC+BTF** = LINAC shots are delivered with a selectable duty cycle to BTF from 1 to 24(49) pulse per second. The remaining are dumped at the end of the TL
- **GLOBAL** = LINAC shots are delivered with a variable duty cycle to BTF in dependance of the injection parameter in ACCUMULATOR
  - ➢NO INJECTION => SELECTABLE from 1 to 24(49) pulse per second
  - ➢INJECTION => the injection needs are DAΦNE CR controlled. Tipically an injection sequence pulses at 2Hz, taking from 1 up to 7 LINAC bunches per sequence. BTF delivers 22 down to 10 bunches per second

Fascio dal LINAC



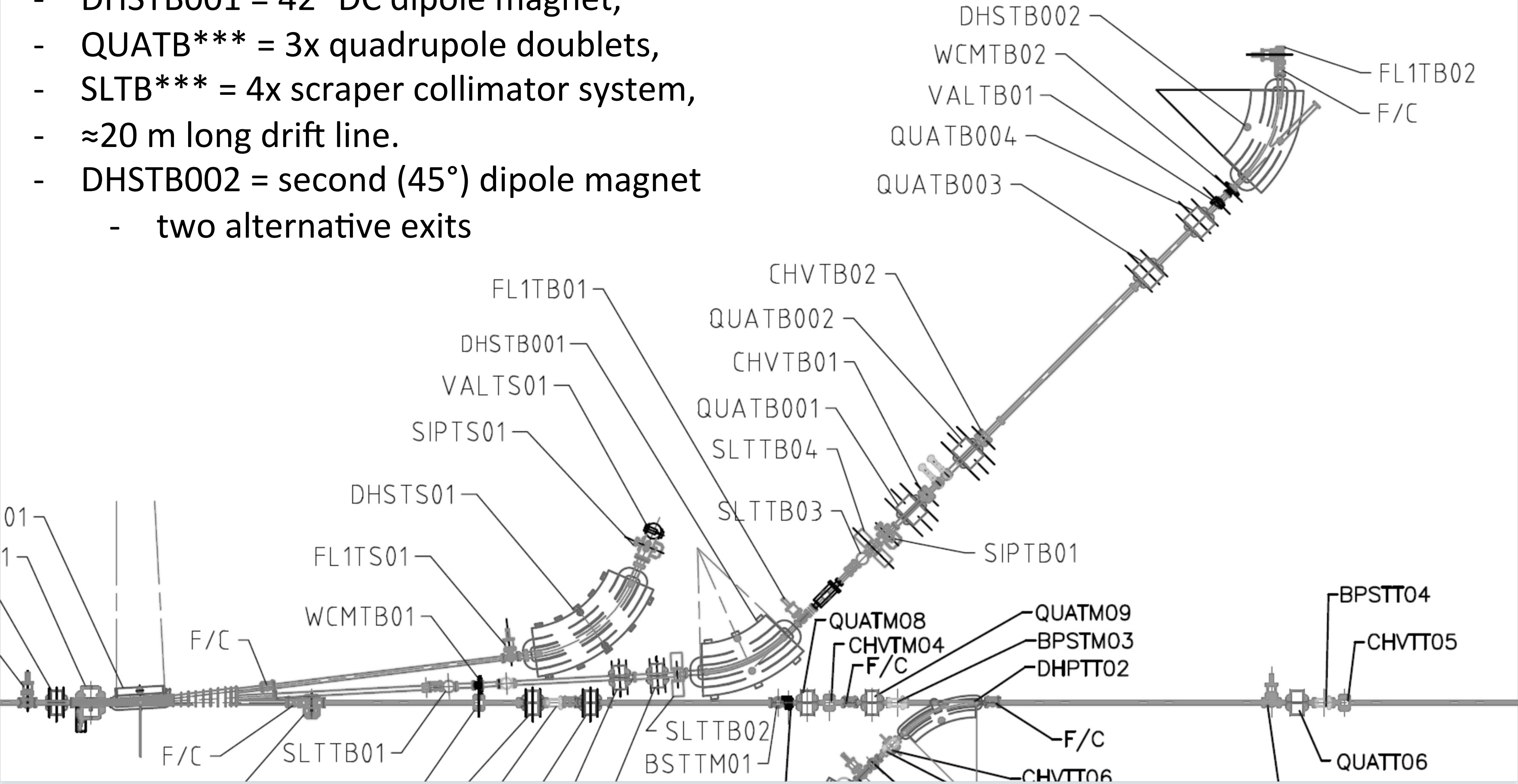
Parameter	Value
Maximum rep. rate	1-25 Hz [50 Hz]
Pulse duration	1.4 ⟶ 40 ns
Linac frequency	2,856 GHz
Microbunching period	~350 ps
Nominal energy	510 MeV

Electron phase par	Value
Tunable Energy	300->750 MeV
Nominal charge	3×10^{10} e^-/bunch
Nominal current	500mA

Positron phase par	Value
Tunable Energy	300->550 MeV
Nominal charge	5.5×10^{9} e^+/bunch
Nominal current	85mA

BTF line: trasporto

- DHPTB101 = 3° pulsed dipole
- DHSTB001 = 42° DC dipole magnet,
- QUATB*** = 3x quadrupole doublets,
- SLTB*** = 4x scraper collimator system,
- ≈20 m long drift line.
- DHSTB002 = second (45°) dipole magnet
  - two alternative exits

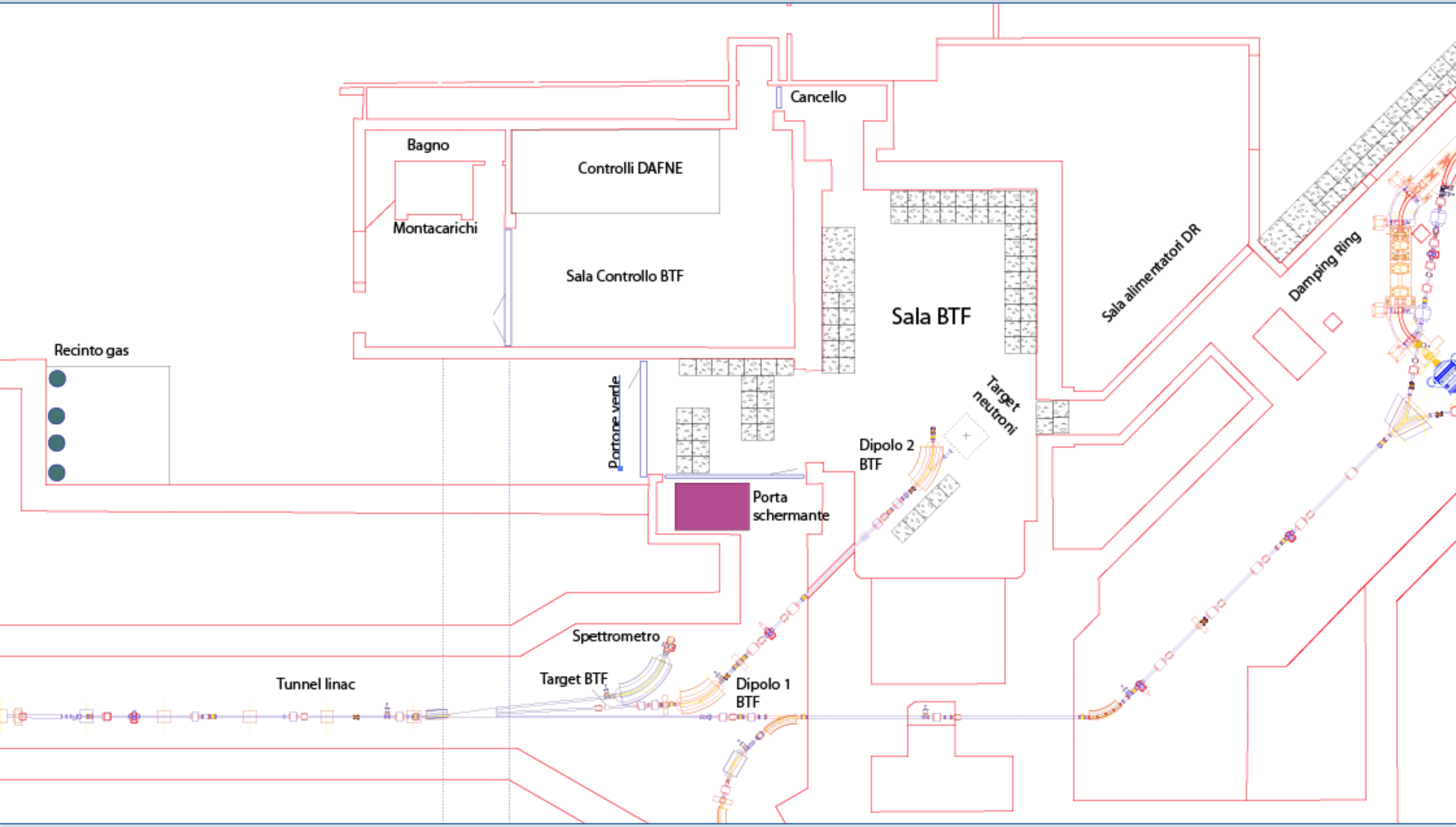


BTF line

45° line
- Equipped with detector testing gadgets:
  - Remote-control table
  - Beam spot and intensity diagnostic for medium and low intensity bean

Straight line
- Slightly more background
- Used for neutron photoproduction or high-intensity tests
- Equipped with fluorescence flag

BTF complex

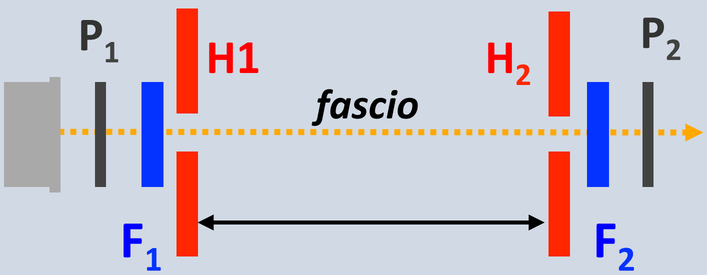


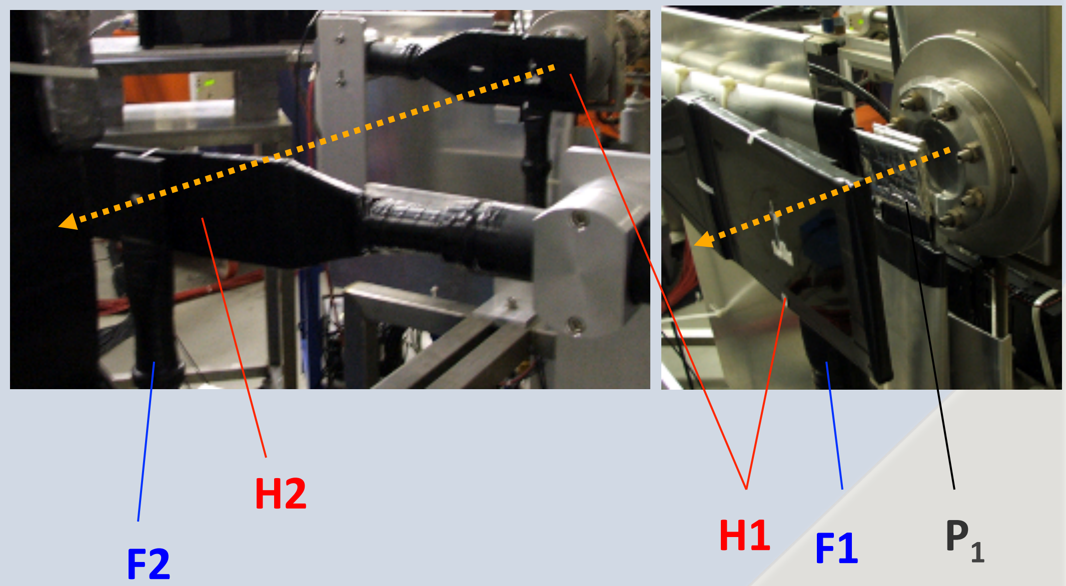
Cancello
Bagno
Controlli DAFNE
Montacarichi
Sala Controllo BTF
Sala BTF
Sala alimentatori DR
Damping Ring
Recinto gas
Portone verde
Target neutroni
Dipolo 2 BTF
Porta schermante
Spettrometro
Tunnel linac
Target BTF
Dipolo 1 BTF

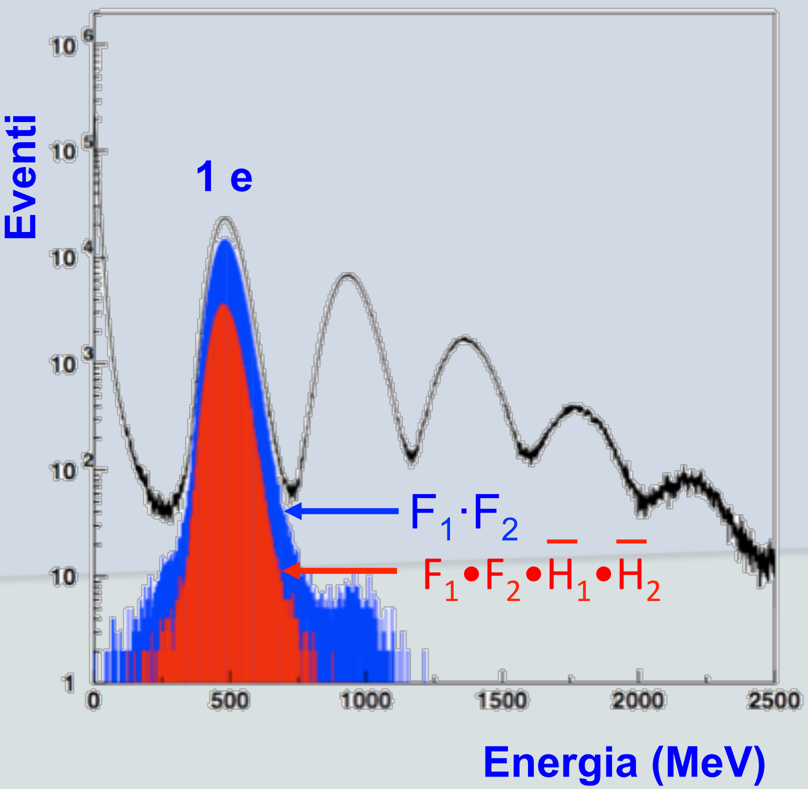
Test di rivelatori

Esempio di applicazione a bassa intensità

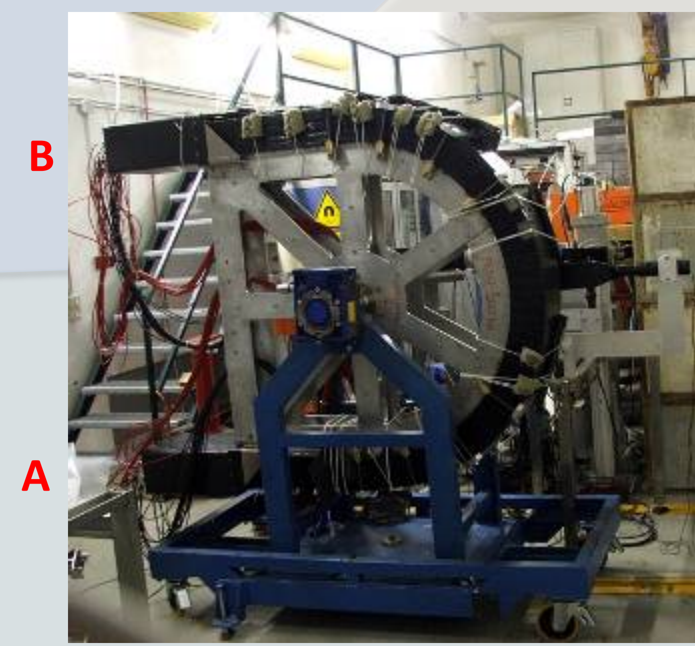
(Misura di inefficienza γ veto di NA62 a bassa energia)





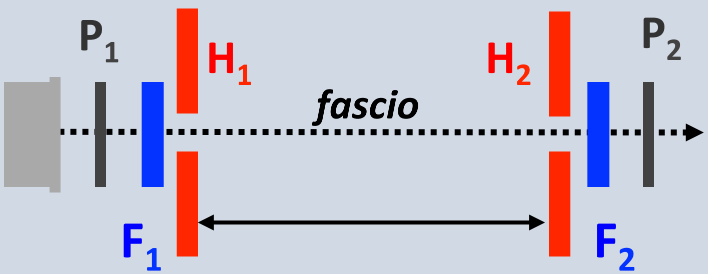


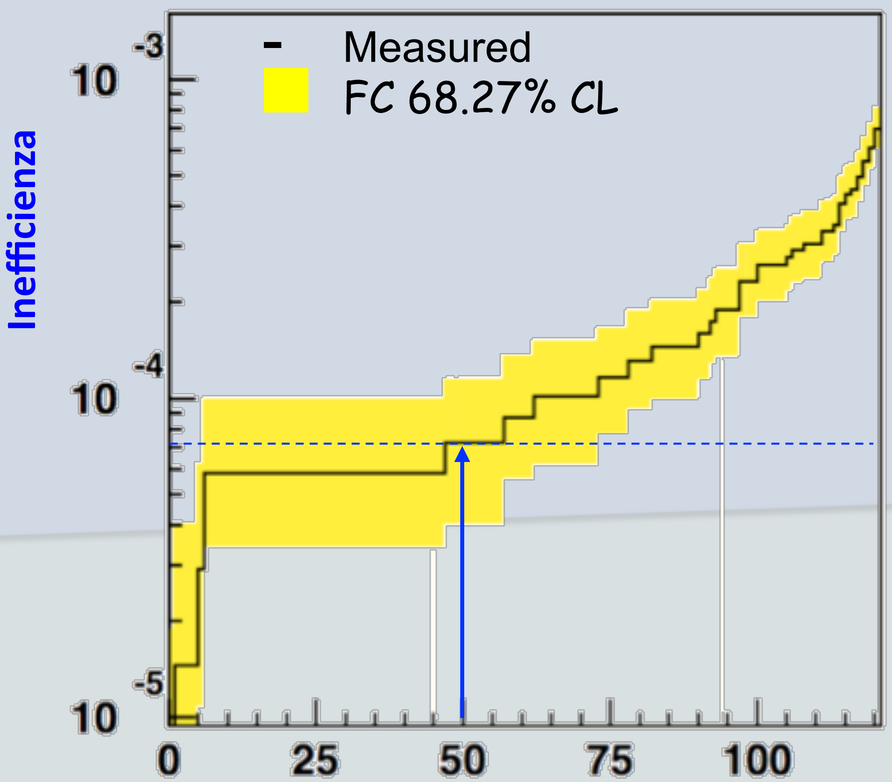
Calorimetro
Pb/fibre



Esempio di applicazione a bassa intensità

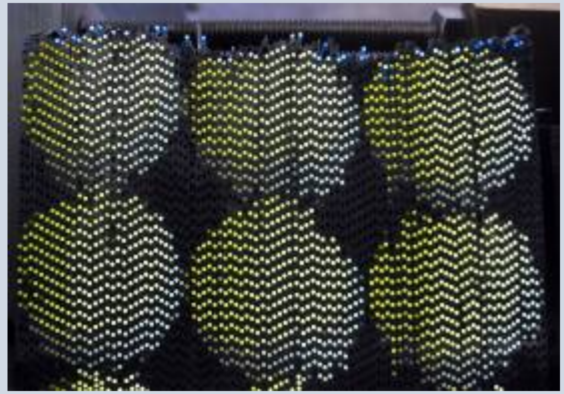
(Misura di inefficienza γ veto di NA62 a bassa energia)

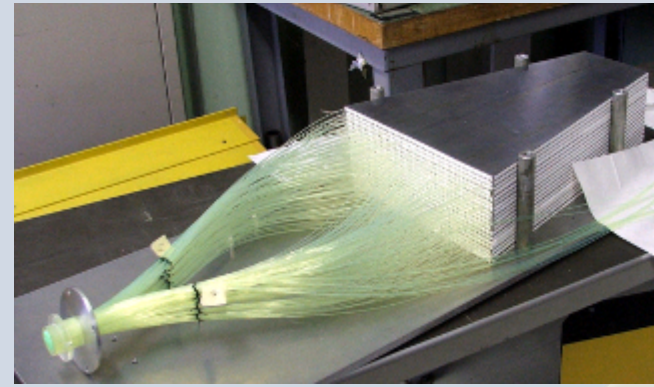


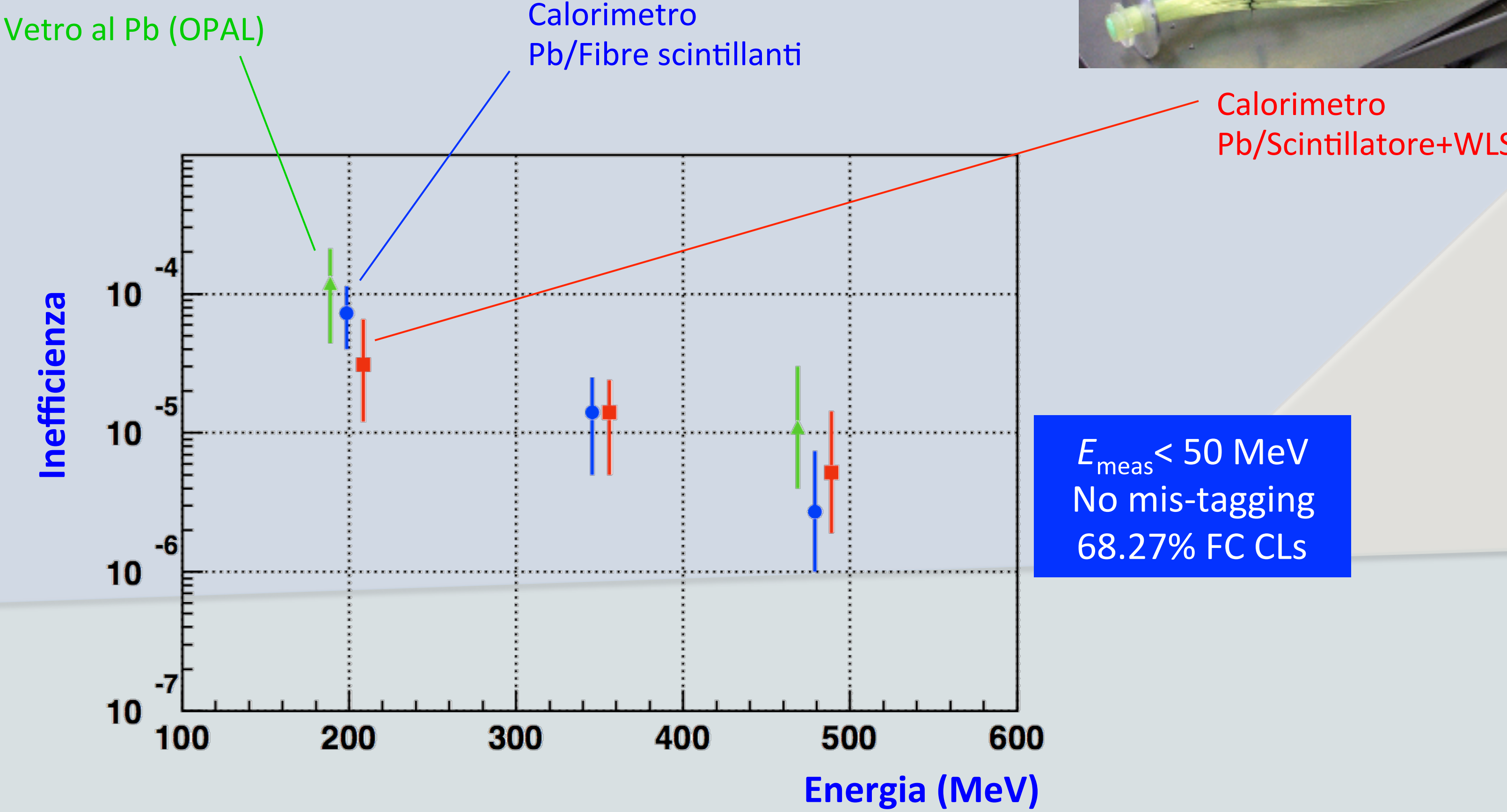


$1-\varepsilon = (7.3^{+4.1}_{-3.3}) \times 10^{-5}$

$E_{A+B} < 50$ MeV



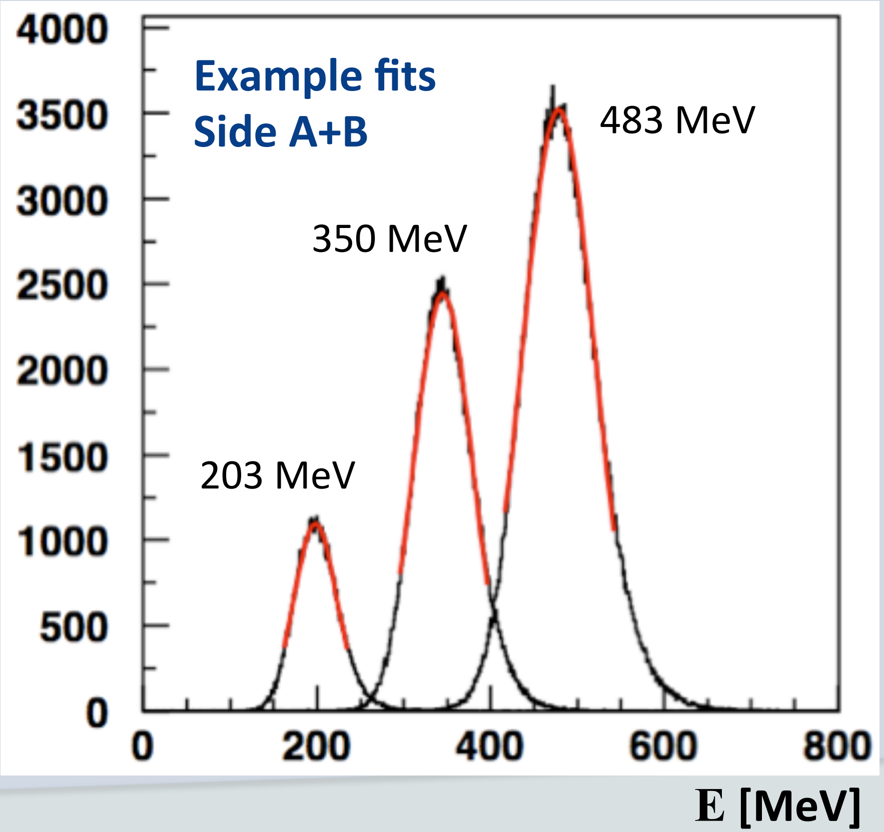


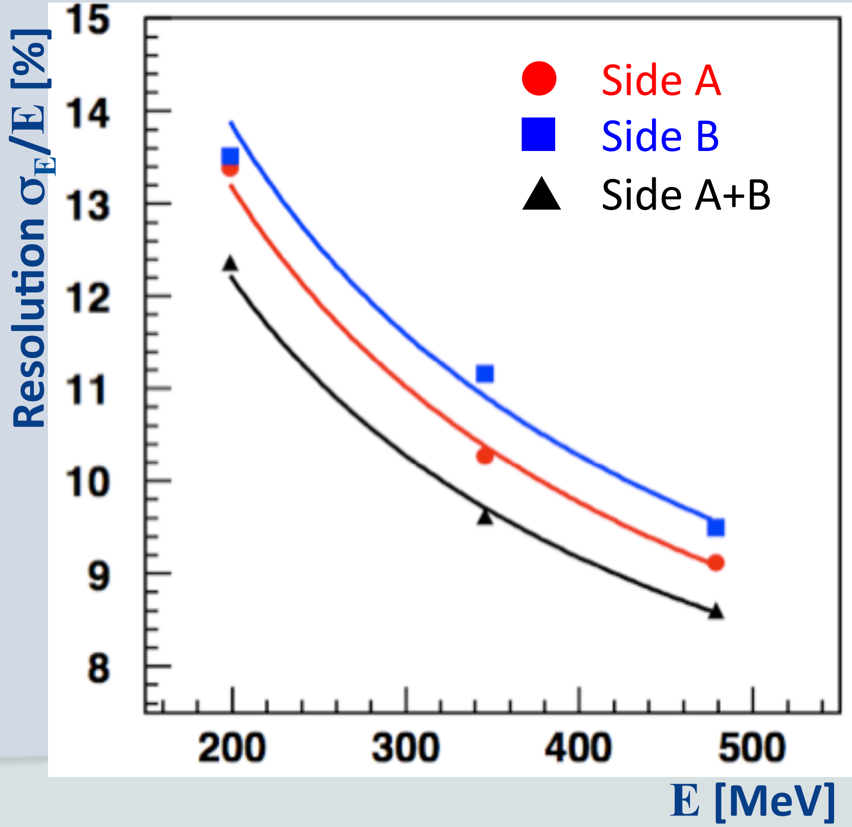


E_{meas}< 50 MeV
No mis-tagging
68.27% FC CLs

Fiber prototype energy resolution

Perform Gaussian fits to 1e⁻ peak (±1.5s) after run-by-run calibration

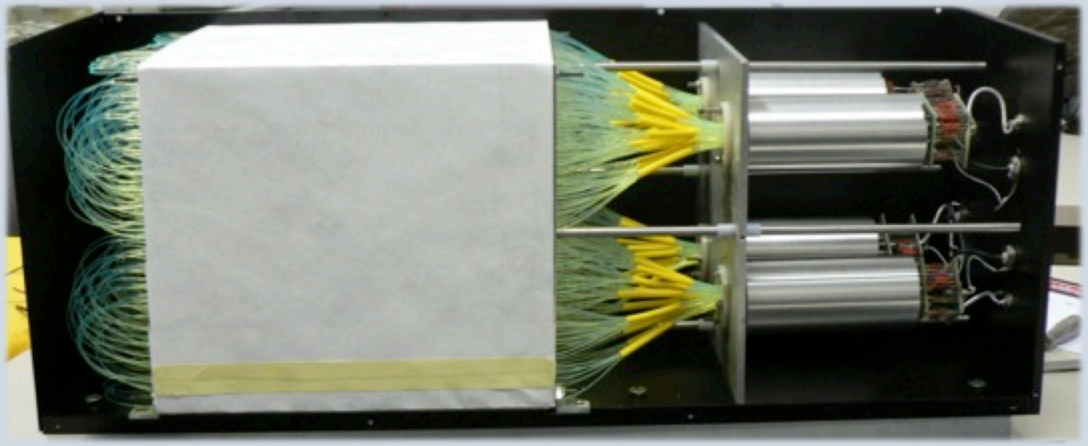




Using information from both sides:

$$\frac{\sigma_E}{E} = \frac{5.1\%}{\sqrt{E\,[\mathrm{GeV}]}} \oplus 4.4\%$$

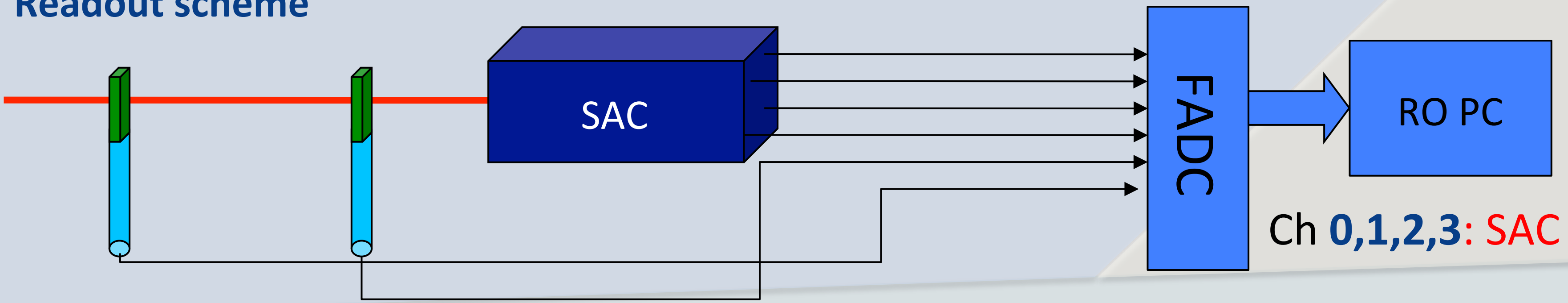
Small angle calorimeter test 2013



SAC main characteristics

70 lead scintillator sandwiches
1.5mm lead
1.5mm scintillator
Kuraray Y-11(250) 1mm fibers
20.5x20.5 cm^2 front face
4 Hamamatsu R6427 PMT

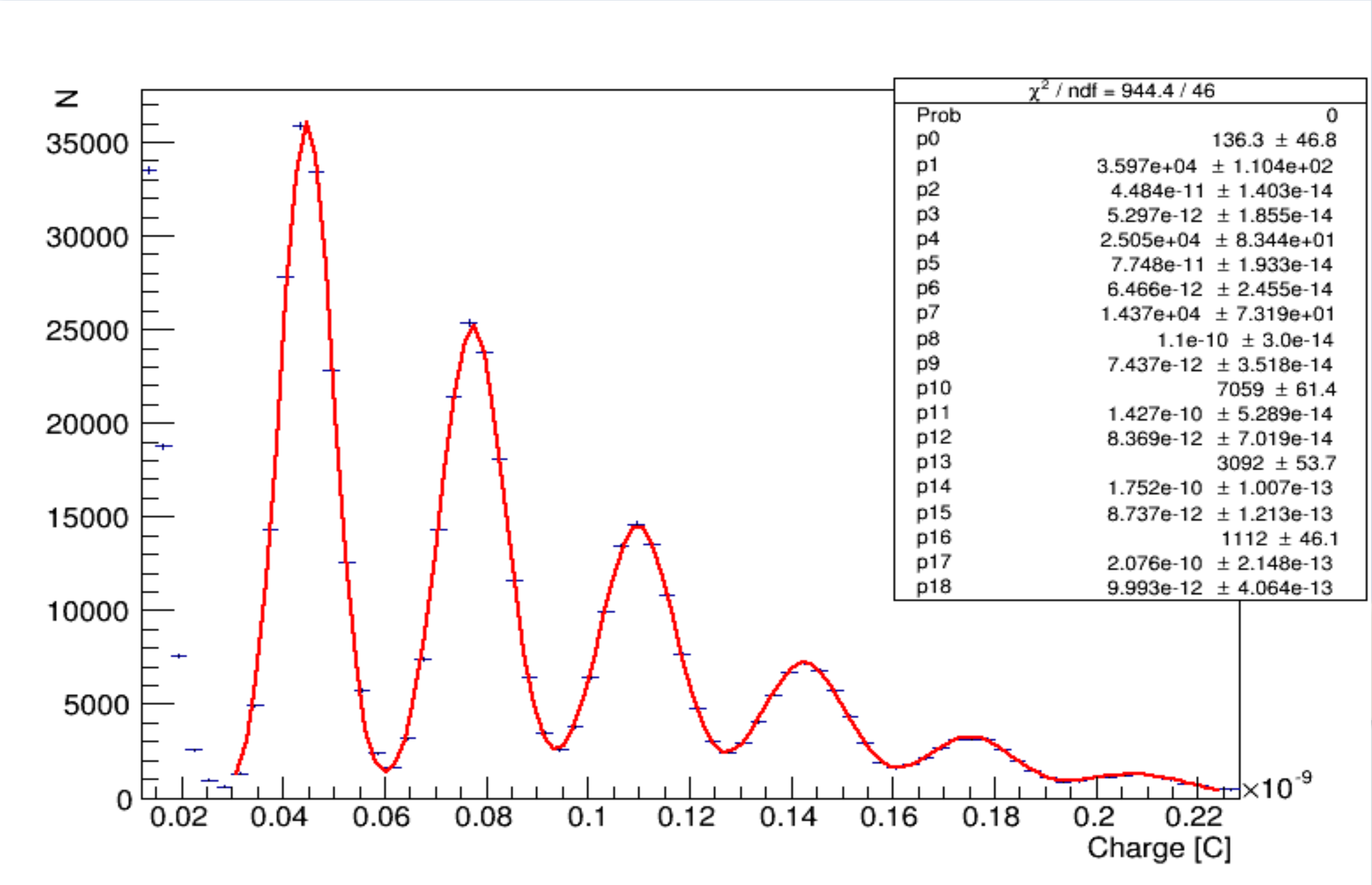
Readout scheme



Electron energy: 570MeV to 606 MeV 24 spills per second 10ns spill
Everything readout by a 1 GHz FADC (including the trigger scintillators)
External triggering from the BTF
No trigger bias and possibility for offline study

Collected spectrum of the BTF beam

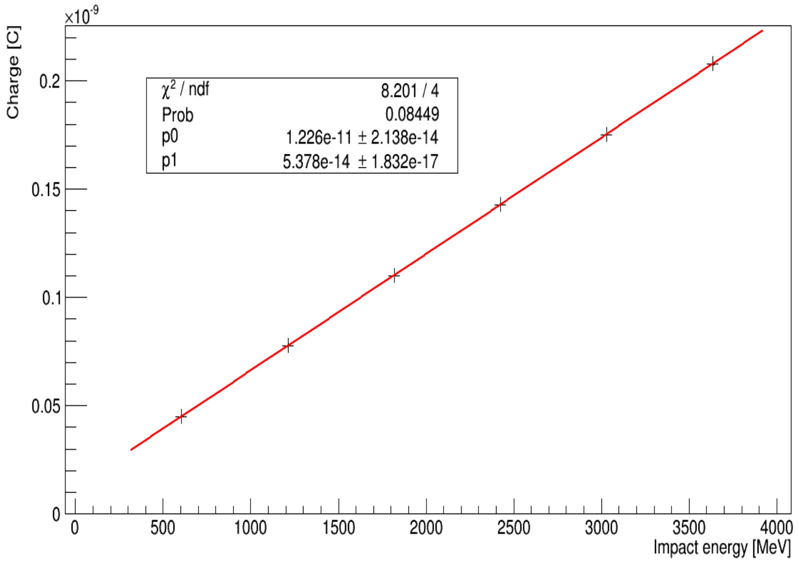
Charge collected on the 4 PMTs



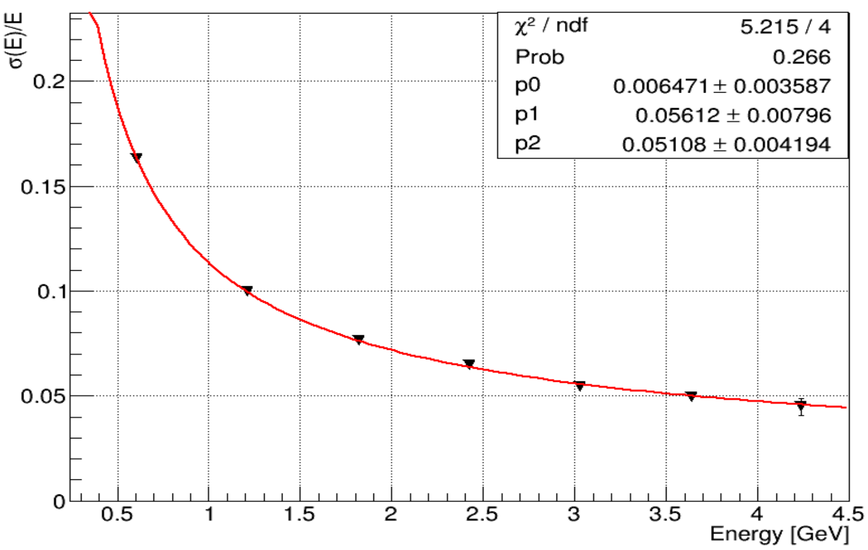
Fit performed with 6 gaussian distribution with no constraints

Linearity and energy resolution

Linearity results



Energy resolution

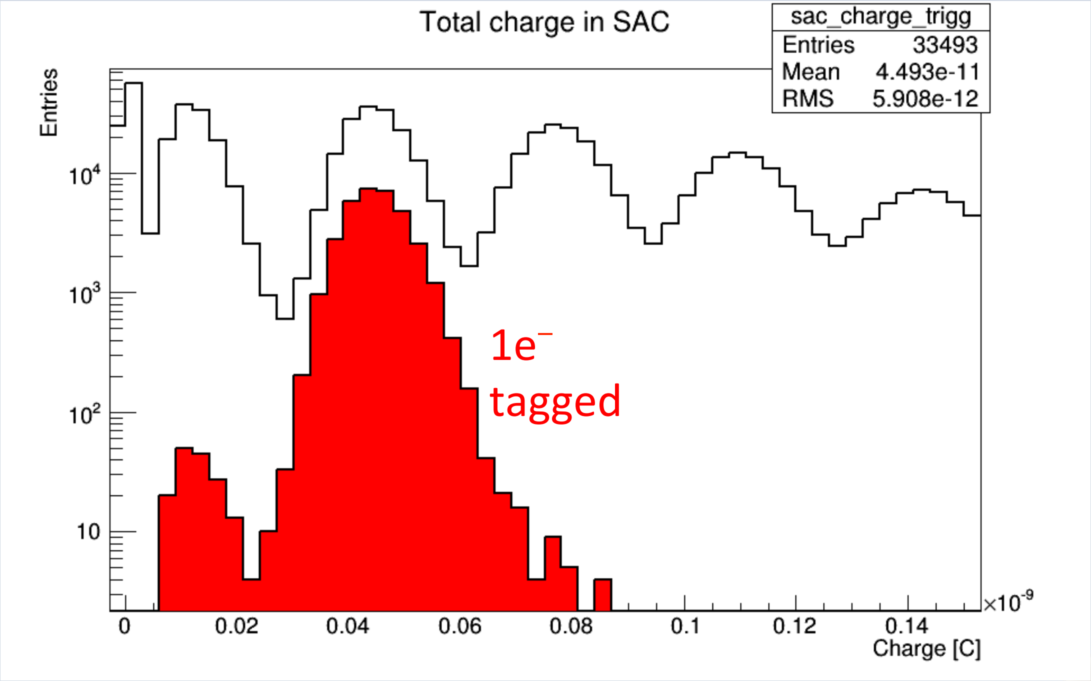


Linearity of the response seem to be quite good single impact point!

No scanning of the front surface

$$\frac{\sigma(E)}{E} = \frac{6\%}{\sqrt{E(GeV)}} \oplus \frac{5\%}{E} \oplus 0.6\%$$

SAC inefficiency for electrons



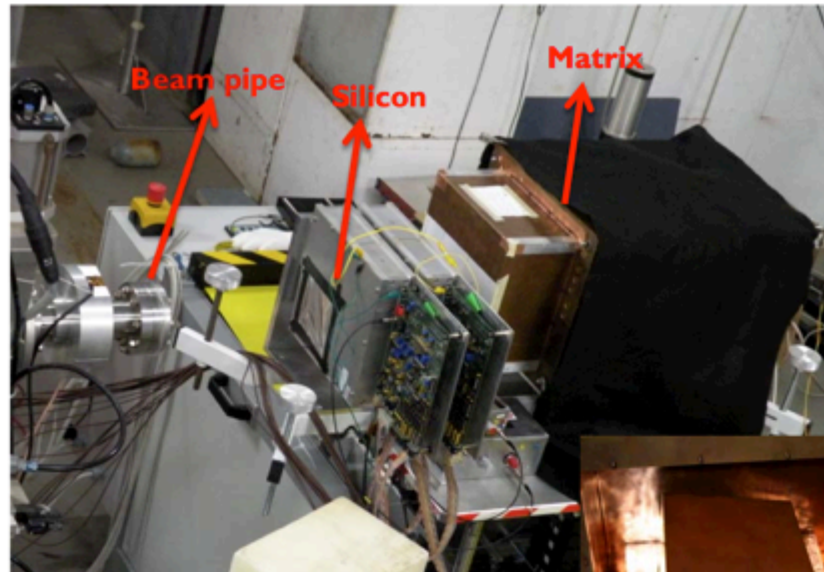
The events below 1e peak doesn't look exactly as inefficient events

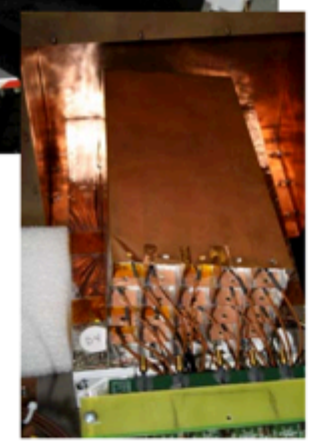
- They are above the no-activity in SAC – 5 pC
- That kind of activity seem to present also under the 1-2-3-x electrons peaks
- No inefficient events below 5pc leads to an inefficiency estimate:

5 pC cut: inefficiency < $6x10^{-5}$

Test of LYSO calorimeter

- LYSO Matrix
- Silicon beam telescope:
  - Single-side 228μm strip pitch
  - 2 planes x-y
  - Active area 8.75x8.75 cm^2

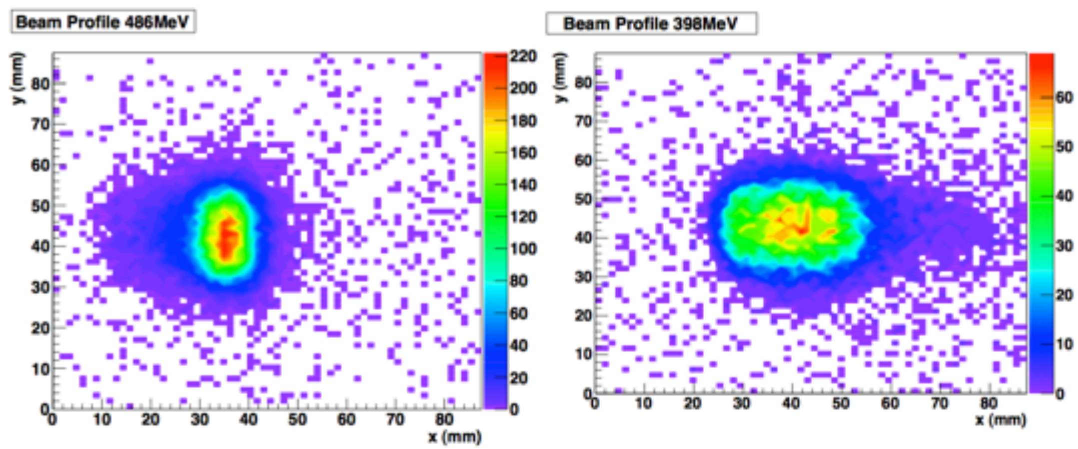




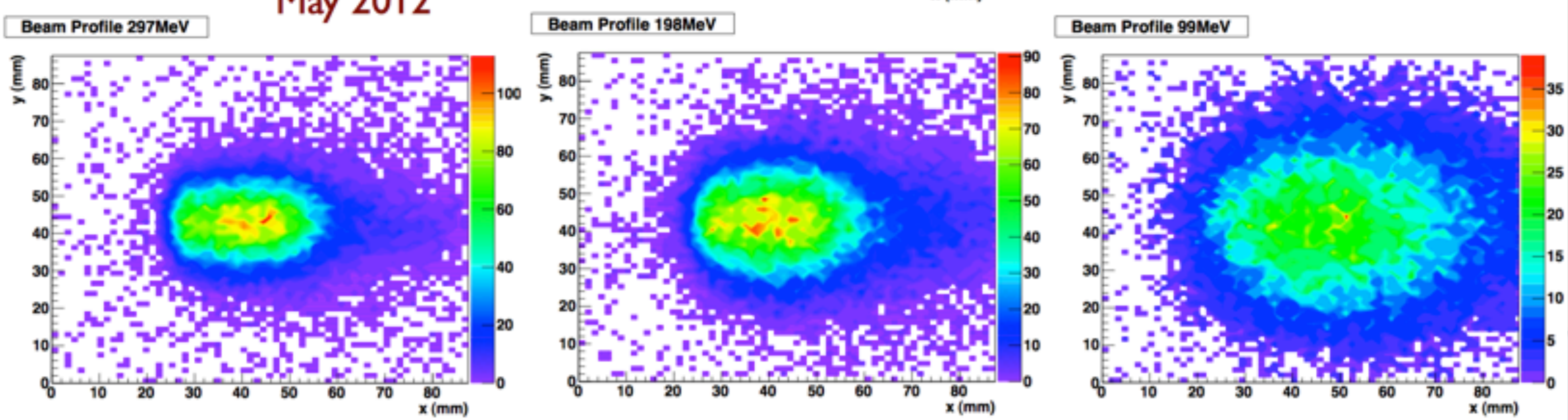
- Data:
  - 5 energies: from 99MeV to 487 MeV
  - 3 different positions

Beam size vs. energy

- Strong correlation between energy and beam profile
  - Larger size at low energy
- Selection on position to perform energy resolution measurement

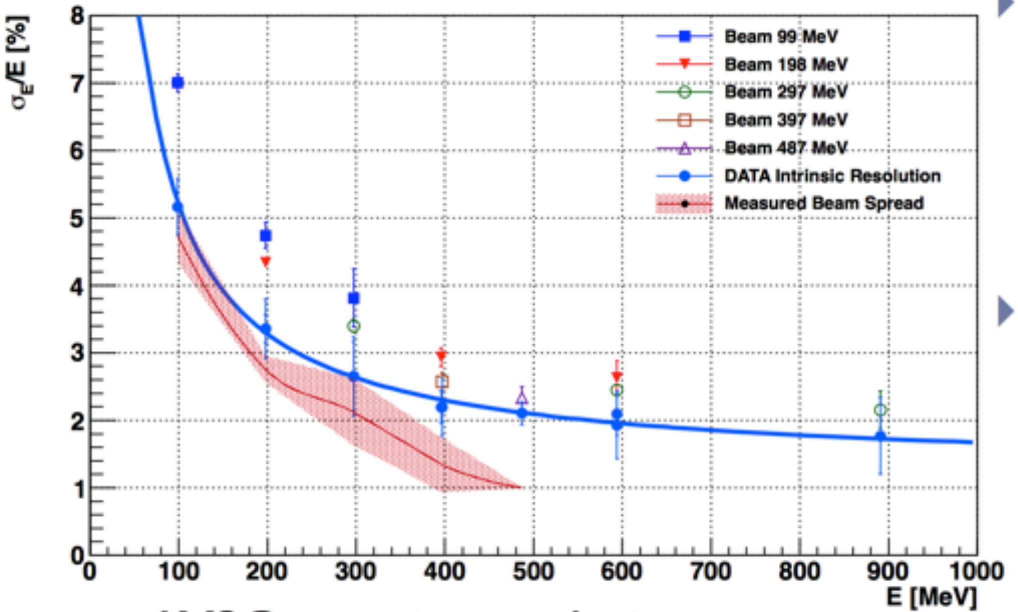


May 2012



6 A. Rossi - 1st BTF User workshop 06/05/2014

Beam energy spread



- Beam spread at 500MeV fixed at 1%
  - Only one point at this energy, BS can't be extracted
- Measured beam spread: May 2012
  - 4.8% at 100MeV
  - 2.7% at 200MeV
  - 2.1% at 300MeV
  - 1.4% at 400MeV

- LYSO matrix resolution

$$\frac{\sigma_E}{E} = \frac{1.1\%}{\sqrt{\mathrm{E(GeV)}}} \oplus \frac{0.4\%}{\mathrm{E(GeV)}} \oplus 1.2\%$$

Rossi et. al., "A LYSO calorimeter for the SuperB factory", Nucl. Instr. and Meth. in Phys. Res. A 718 (2013)
S. Germani et al., "The SuperB factory electromagnetic calorimeter", J. Phys. Conf. Ser. 404, 012065 (2012)

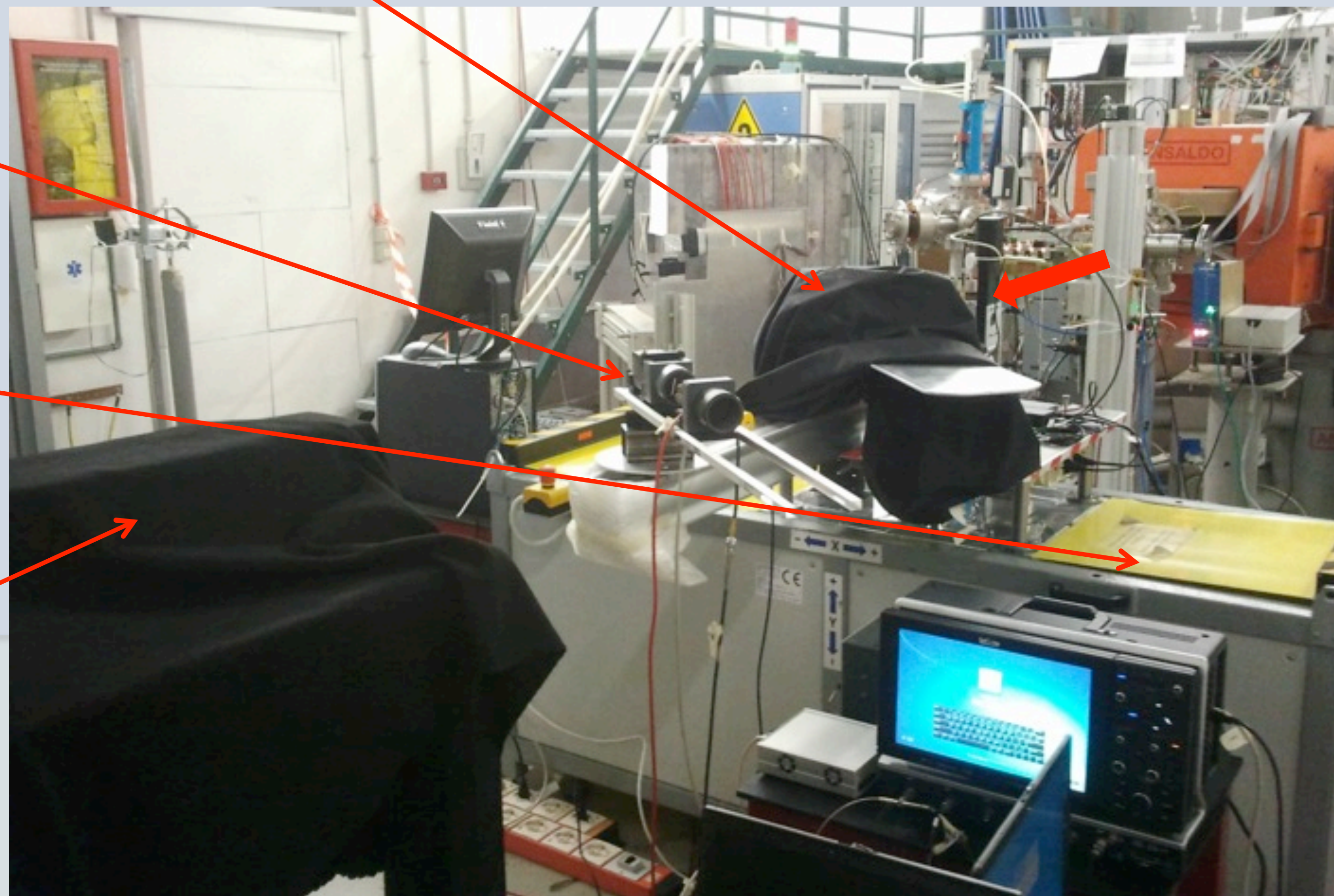
Cerenkov detector test

LAL Cerenkov

INFN Cerenkov

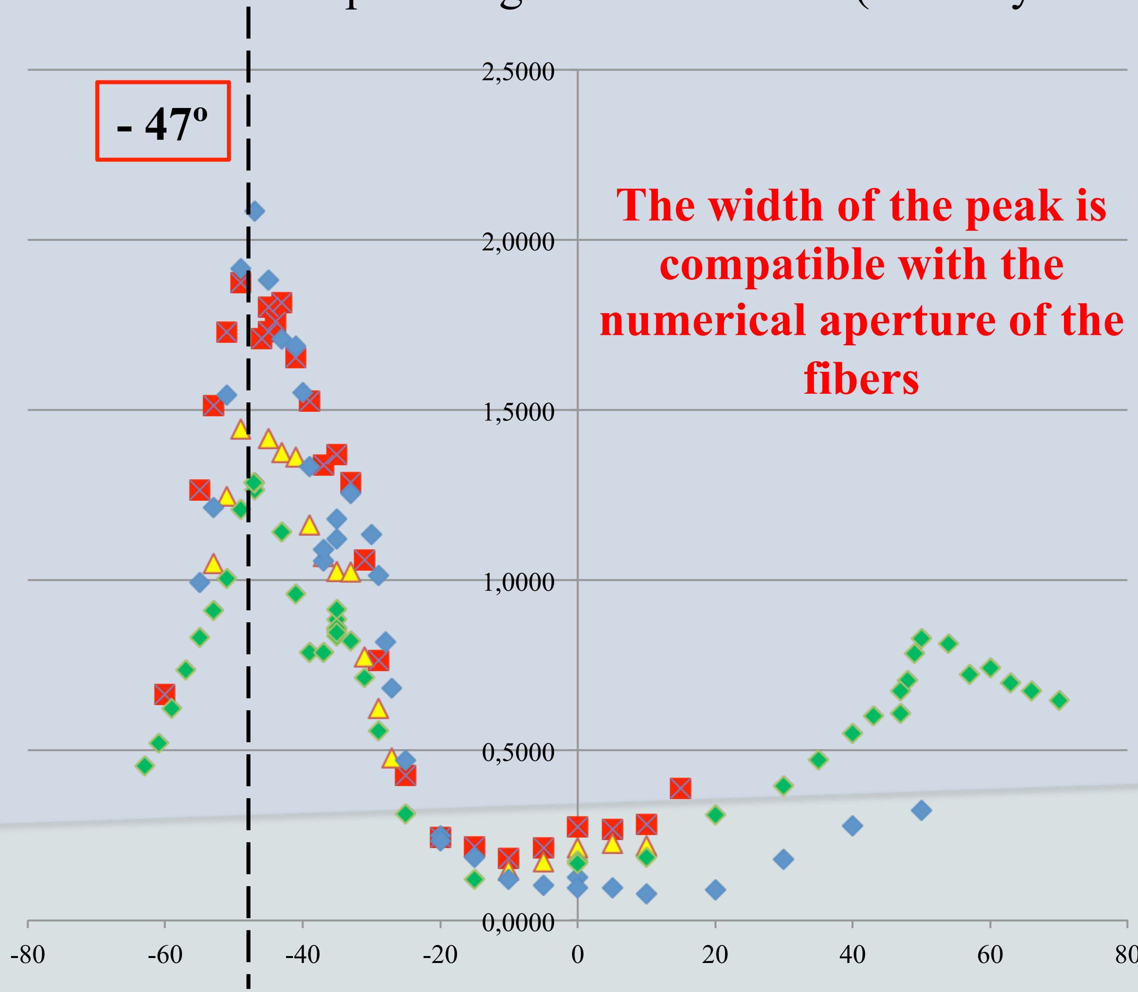
BTF Remote
Control Table

BTF Calorimeter

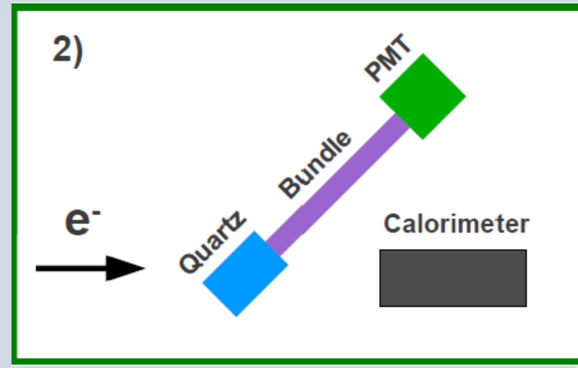


Cerenkov detector test

Charge signal normalized to number of incident electron and electron path length in the radiator (arbitrary units)

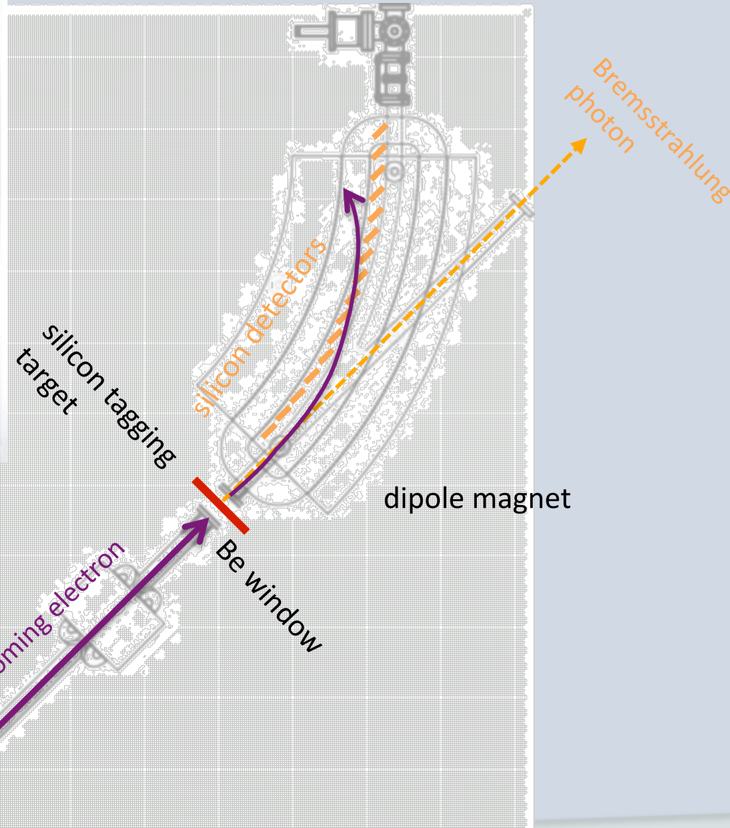


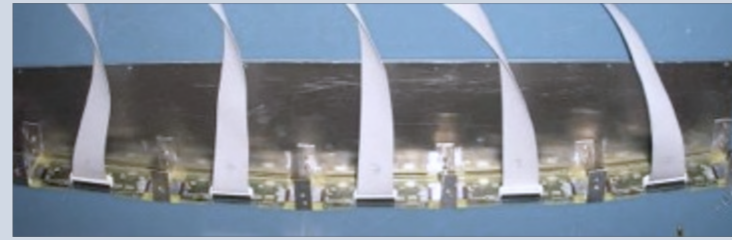
Radiator rotation angle

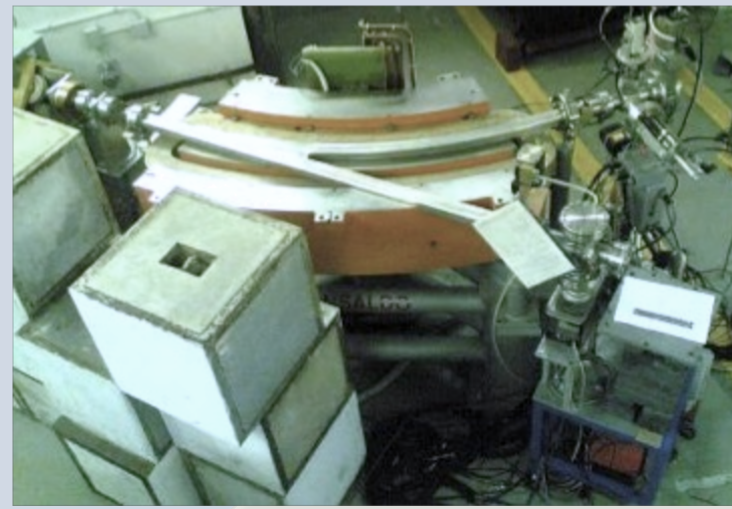


Optical grease at interfaces between fibers, PMT and radiator

Photon tagging/1





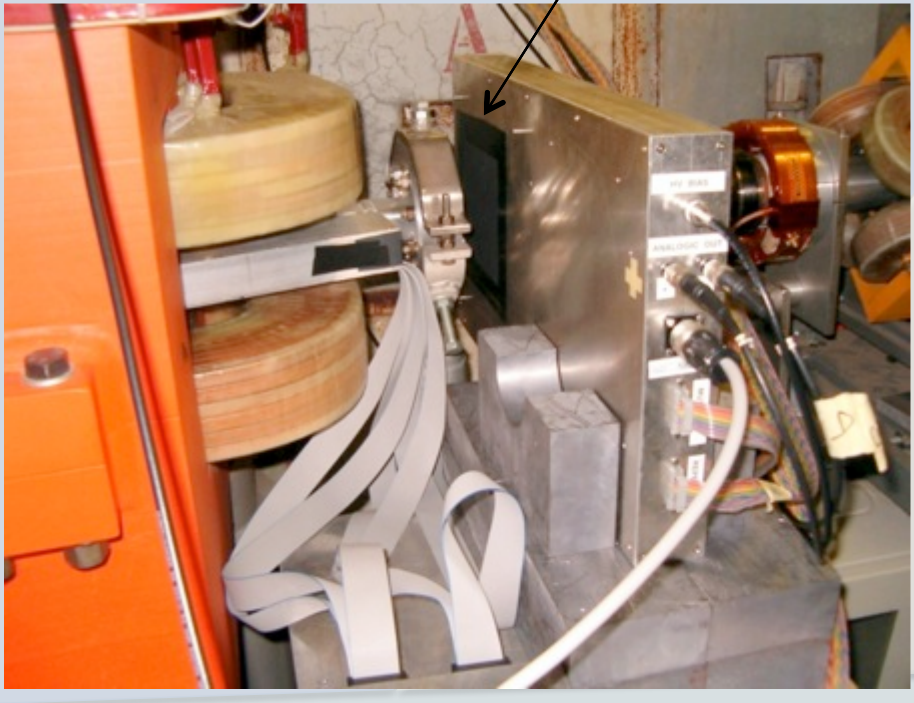


- Designed and built in close collaboration with the **AGILE collaboration** with the main purpose ot the AGILE scientific payload calibration:
  - Silicon trackers + calorimeter

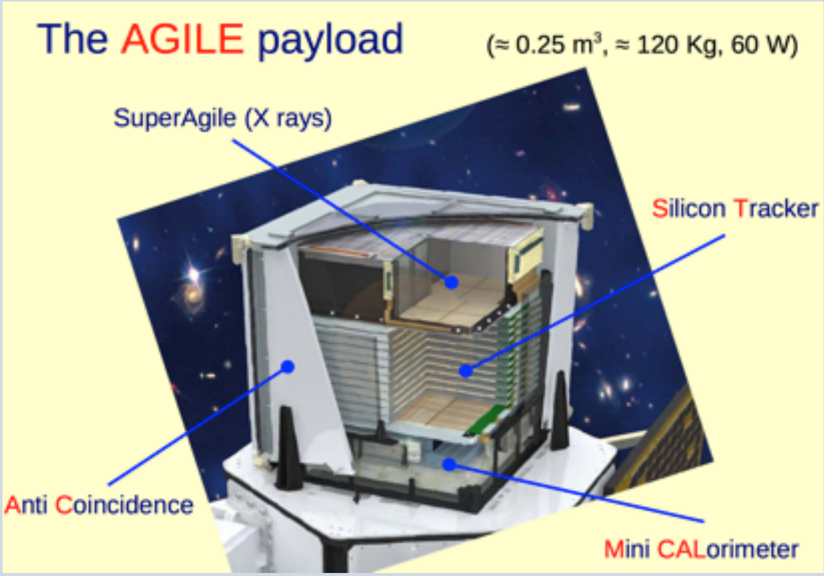
2005: photon tagging

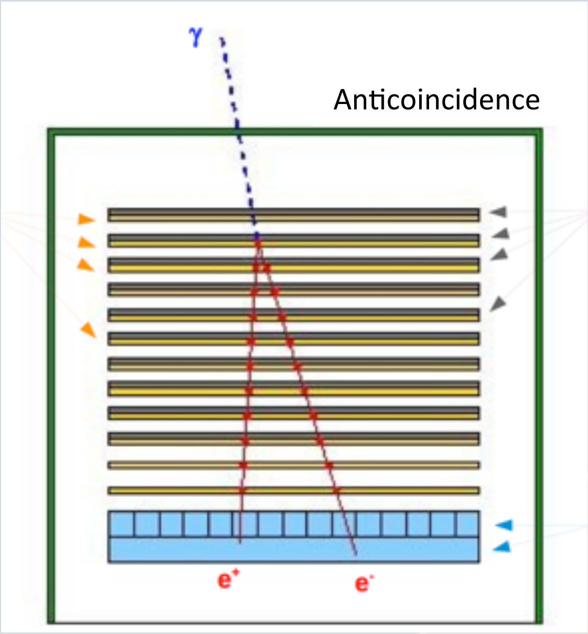
Silicon tagging detectors

Silicon tagging target



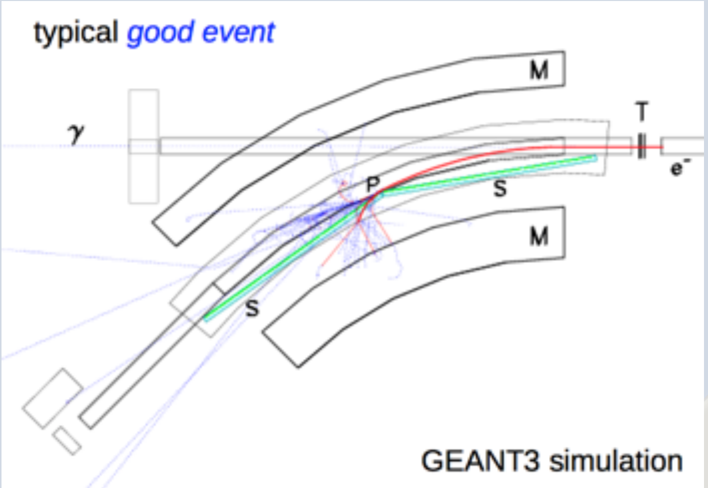
Test del payload di AGILE



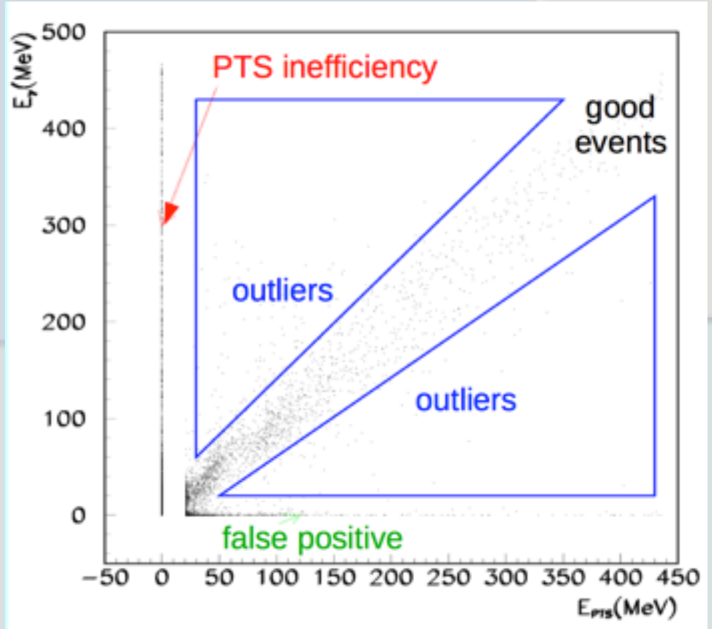


Tagging performance

In the ideal good event the e-interacts with the target T emitting a single γ-ray and then is deflected by the magnet M, going to hit the PTS detector S in the point P
The position of P depends on the residual kinetic energy of the e-, that is correlated to the energy Eγ of the emitted γ-ray



Inefficiency
The e- after emitting the γ-ray, don't reach the tagging detector S in P (due to the beam divergence, pipe interaction or geometric reasons)
False positive
An e- not emitting the γ-ray produces secondary particles hitting the tagging detector S somewhere, giving false γ-ray reconstruction
Outliers
Some combination of the previous cases, giving wrong γ-ray energy

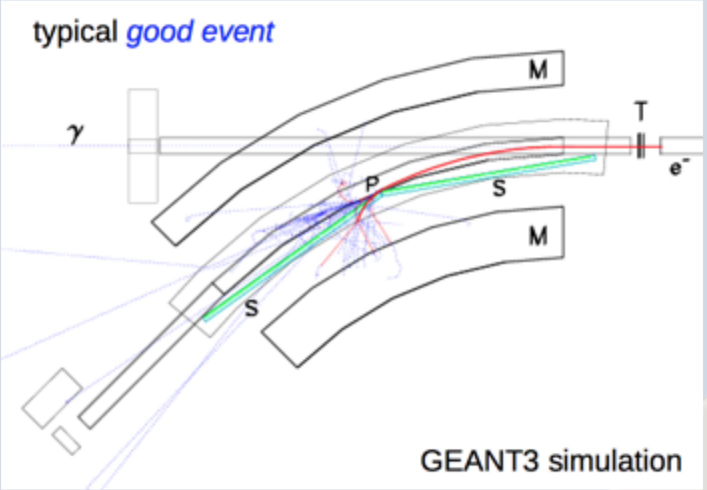


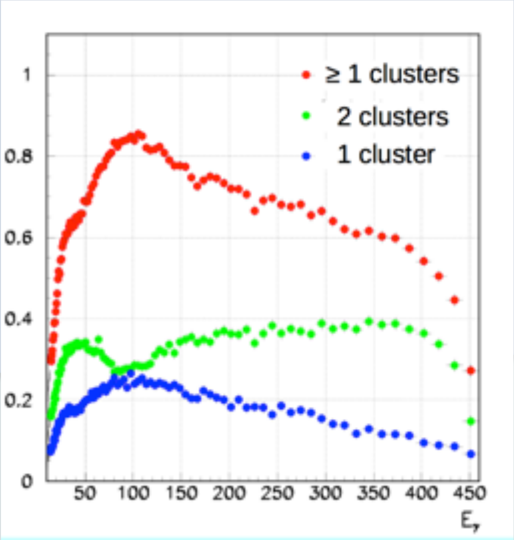
Tagging performance

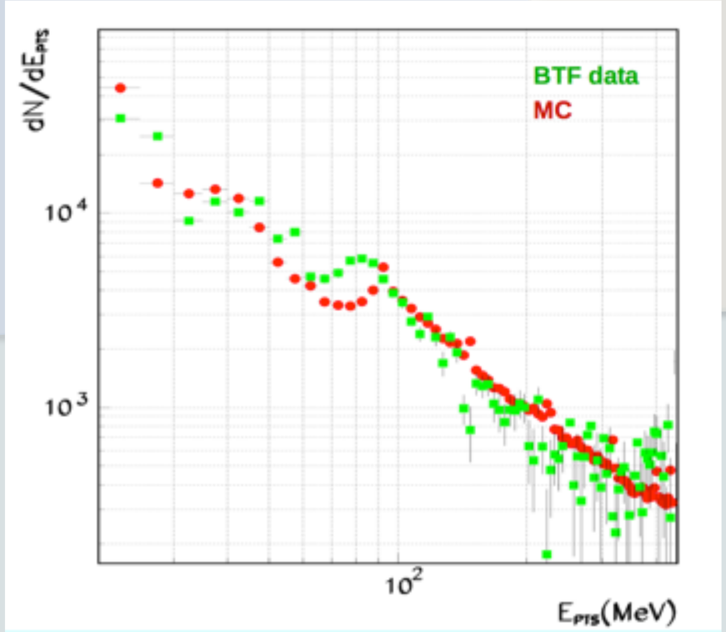
The tagging detector can be hit in more than one point P, due to background and/or multiple interactions

Efficiency depends on the number of clusters (Ncl) required

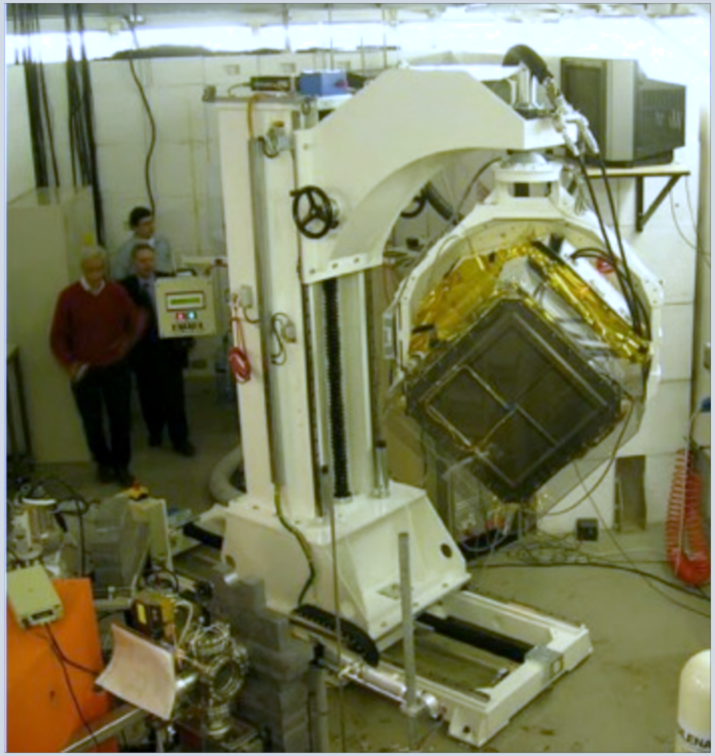
Best energy resolution is expected with the Ncl = 1 requirement, that implies a lower efficiency

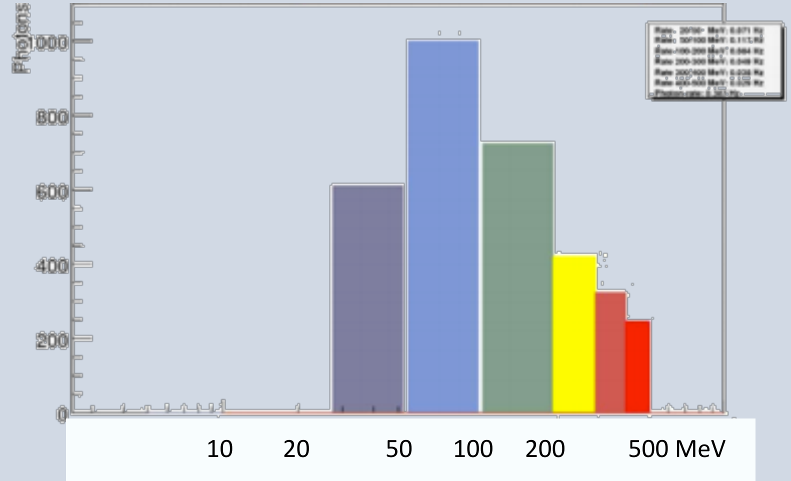


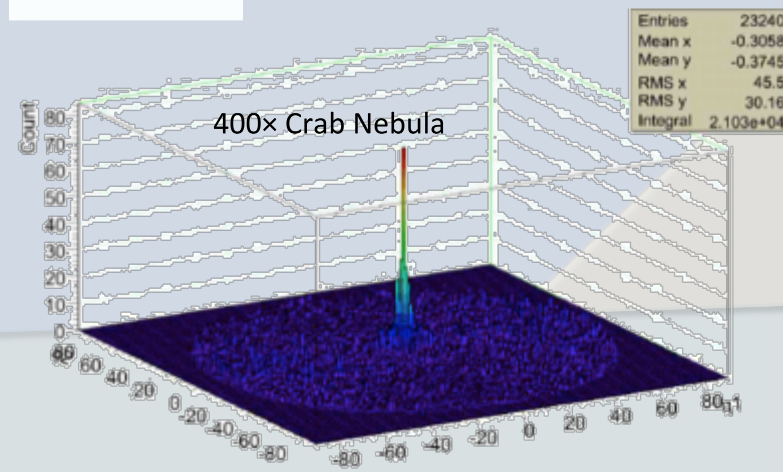




Photon tagging/2



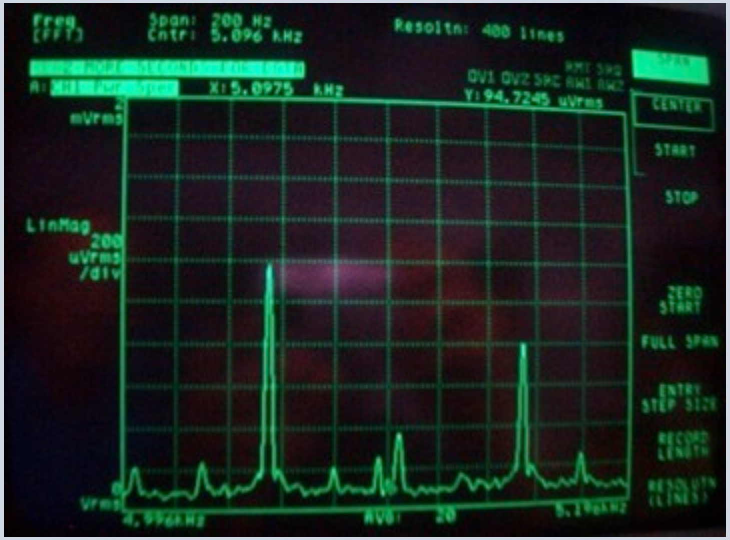


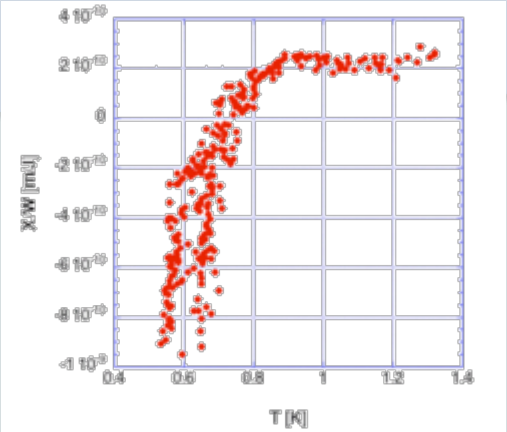


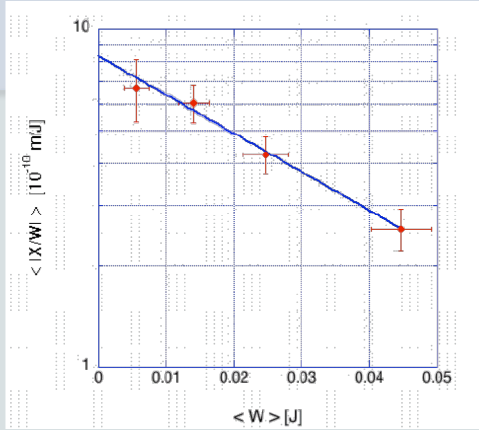
Test ad alta intensità

RAP

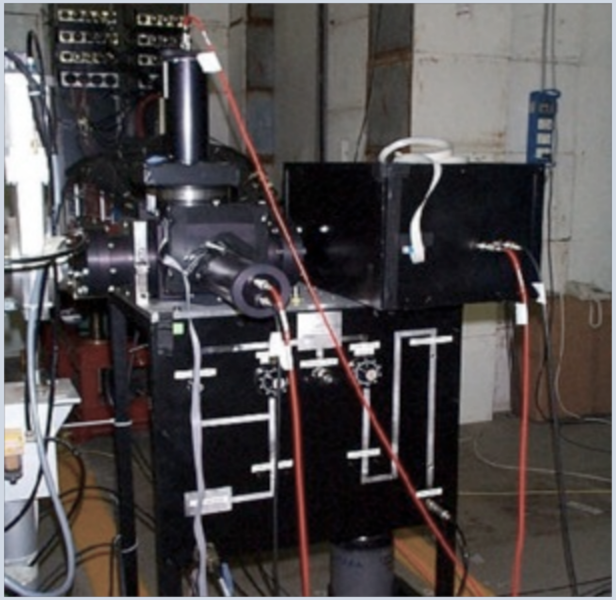
- Study of thermo-acustic effect on cryogenic resonant antenna due to charged particles (background to GW detectors like Nautilus)
- Runs in 2003, 2005 and 2009

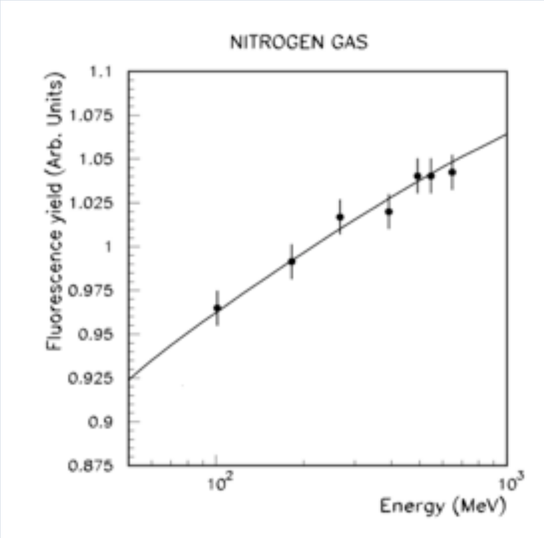




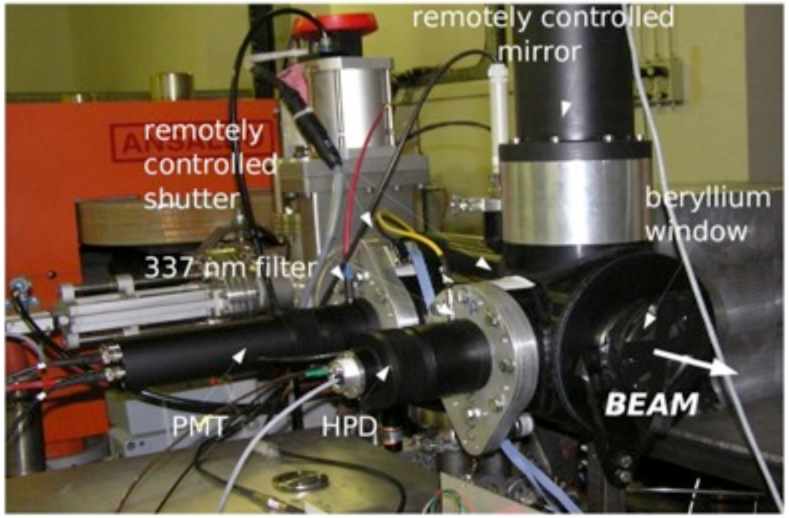


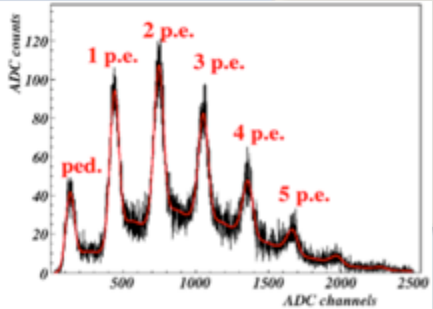
AIRFLY





2003: first run
Fluorescence yield
relative to Cerenkov





2008:
Absolute fluorescence yield measurement

AMY

Observations of microwave continuum emission from air shower plasma (SLAC)

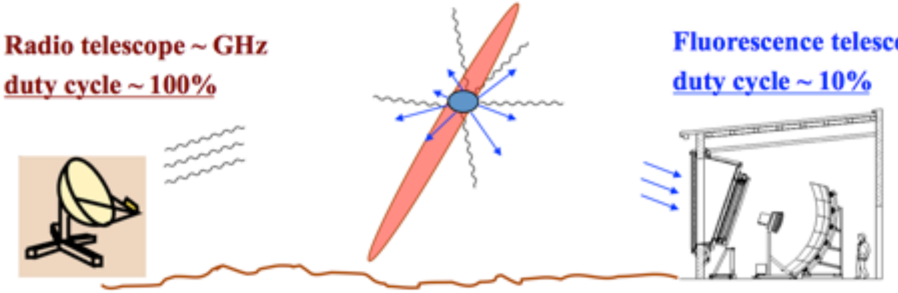
P.W. Gorham et al.
Physical Review D 78, 032007 (2008)

Microwave Bremsstrahlung Radiation (MBR)

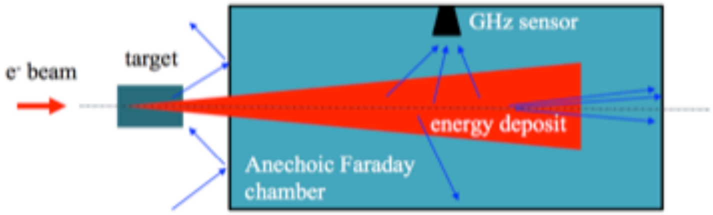
isotropic and not polarized (like fluorescence radiation)

Radio telescope ~ GHz
duty cycle ~ 100%

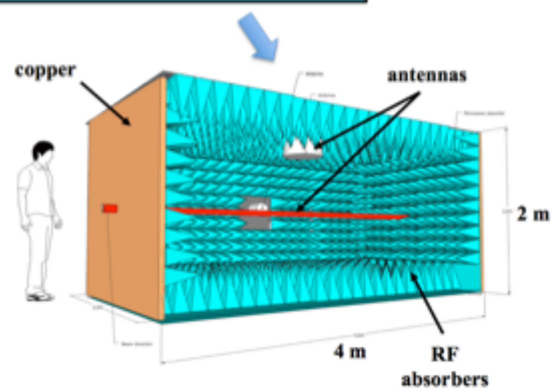
Fluorescence telescope
duty cycle ~ 10%



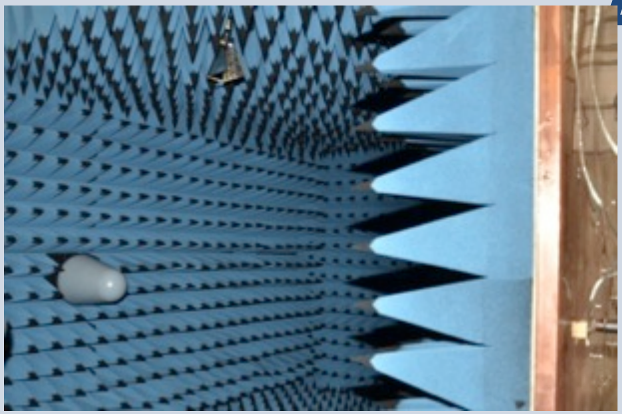
Energy deposit →	**plasma** $T_e \sim 10^5$ K →	**Secondary electrons excite N_2 ⇒ fluorescence radiation**
		Secondary electrons produce bremsstrahlung radiation in the field of the neutral molecules

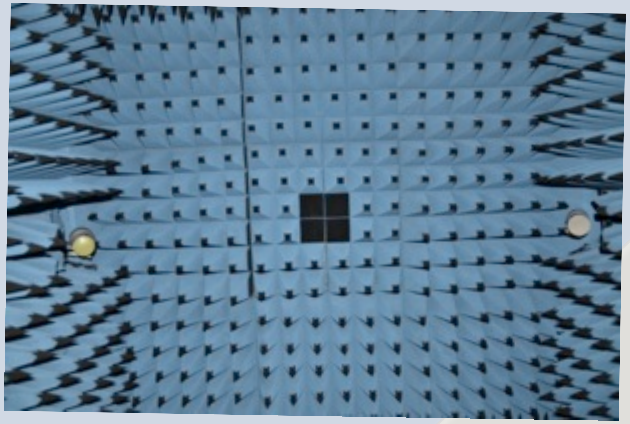


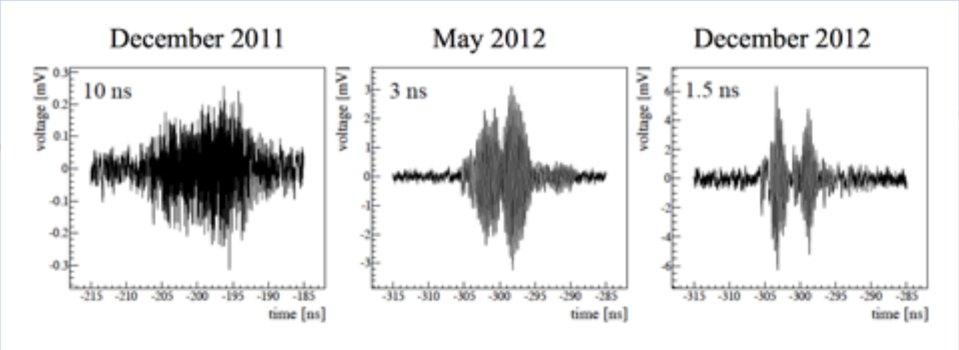
- MBR ~ energy deposit
- shield from outside radiation
- avoid reflections within the chamber

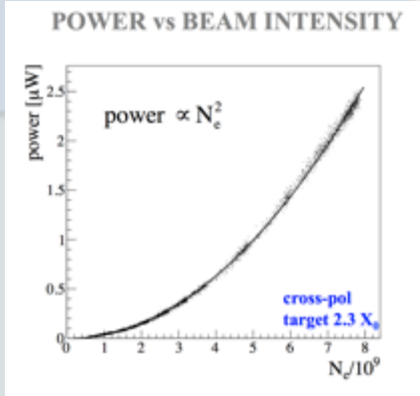


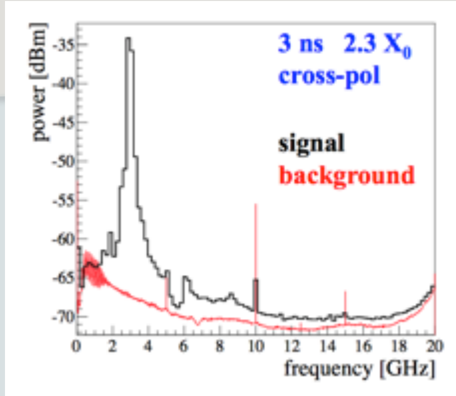
AMY



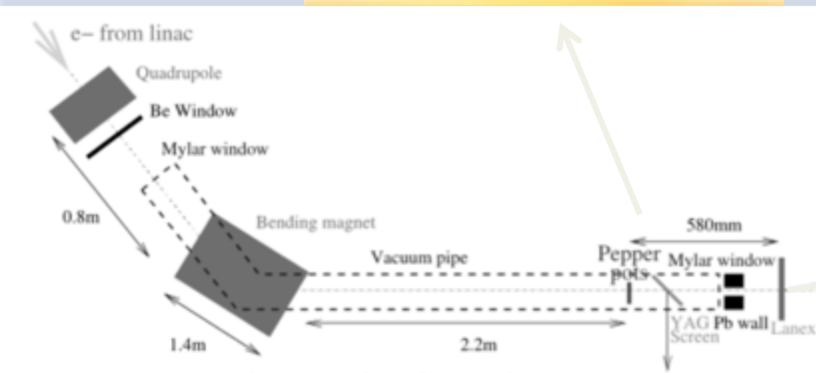


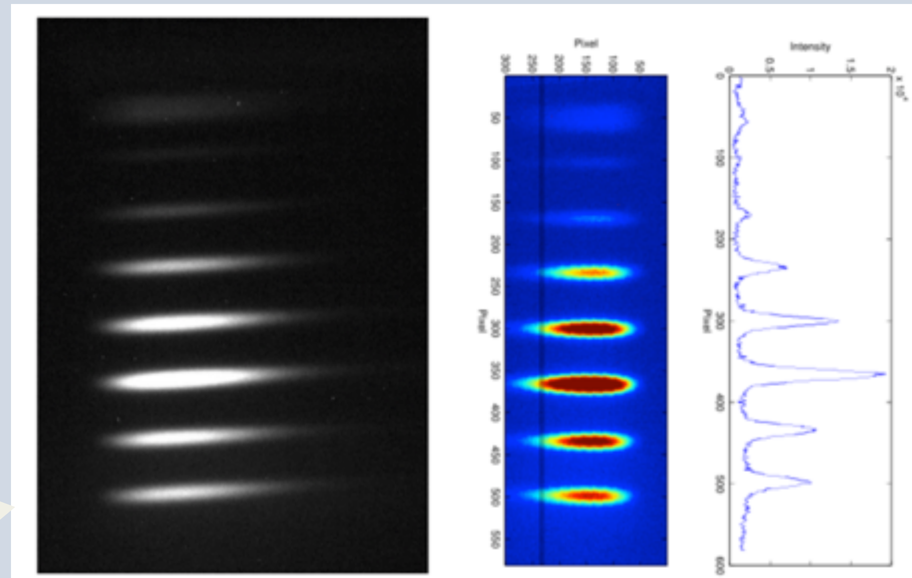

December 2011
May 2012
December 2012
10 ns
3 ns
1.5 ns
voltage [mV]
time [ns]


POWER vs BEAM INTENSITY
power ∝ N_e^2
power [μW]
cross-pol
target 2.3 X_0
$N_e/10^9$


3 ns 2.3 X_0
cross-pol
signal
background
power [dBm]
frequency [GHz]

Emittance measurement





Measured emittance @ 508 MeV:

$\sqrt{\langle x^2 \rangle}=4$ mm

$\sqrt{\langle x'^2 \rangle}=1.7$ mrad

$\sqrt{\langle x \rangle^2 \langle x' \rangle^2 - \langle xx' \rangle^2}=4$ mm·mrad

Schermature e radio-protezione

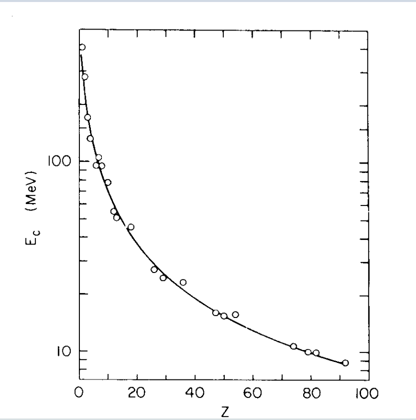
Obiettivo

- Dosi nelle aree **esterne** delle schermature frequentate dal personale siano mantenute al di sotto di 1-2 mSv/anno, nelle normali condizioni di lavoro.
  - Eventuali scostamenti potrebbero al più provocare la classificazione di alcune aree come zone sorvegliate o controllate.
- Nelle normali condizioni di lavoro il rateo di equivalente di dose non dovrebbe superare qualche μSv/h
- In condizioni non abituali si potrebbero accettare, per breve durata di tempo, valori fino a qualche decina di μSv/h.

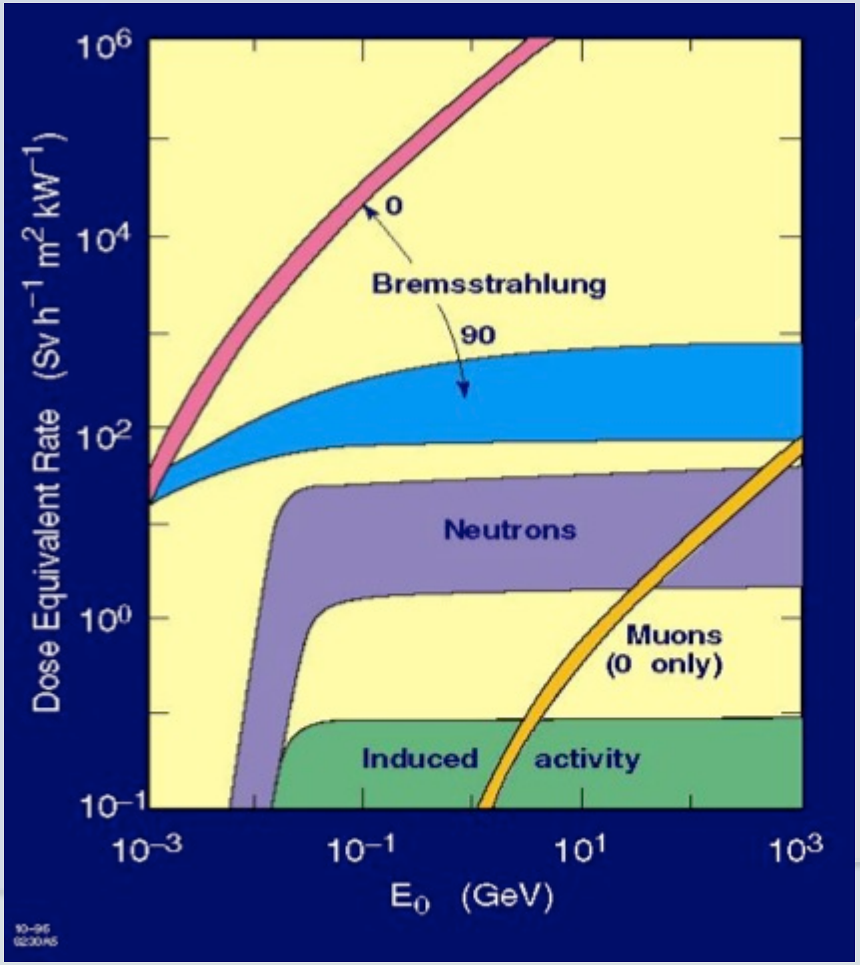
Campi di radiazione istantanea generati da:

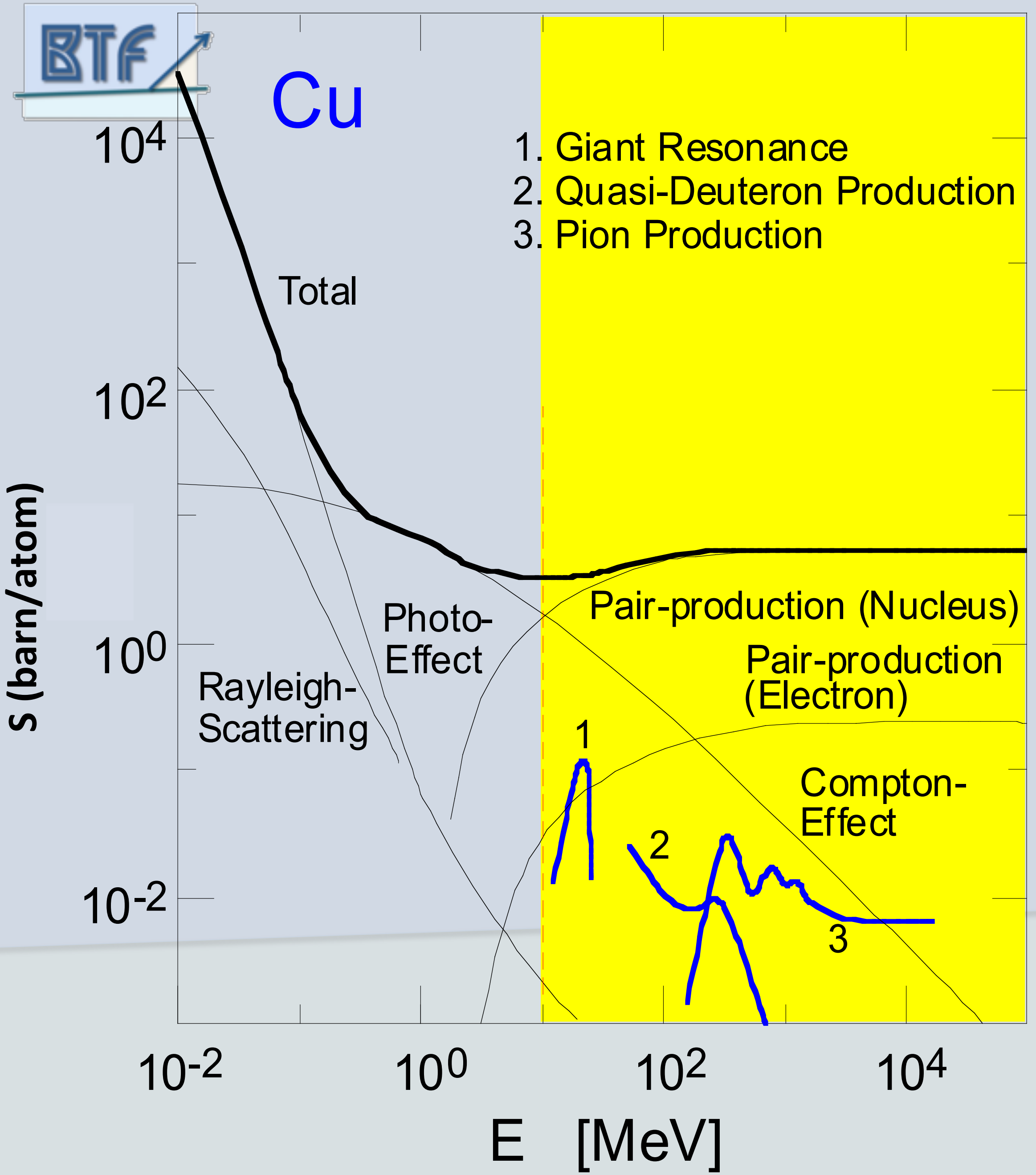
- Perdita di fascio lungo le linee da vuoto degli acceleratori
- Possono essere attese o inattese
  - In particolare perdite parziali o totali sono attese intorno a componenti quali:
    - Setti di iniezione
    - Collimatori
    - Beam stoppers
    - Pozzi di spegnimento
    - Fenditure
- Perdite non attese sono quelle dovute a malfunzionamenti o a errori di impostazione

- Quando un fascio di elettroni di alta energia colpisce un materiale bersaglio, nel mezzo colpito si propaga una cascata elettromagnetica.
- Le particelle secondarie prodotte altro non sono che la radiazione istantanea di cui all'altra trasparenza.
- I campi di radiazioni al di la' degli schermi sono essenzialmente fotoni e neutroni



L'energia critica E_c per un dato materiale definisce il confine fra le perdite di energia per collisione o per irraggiamento. Ne consegue che negli acceleratori di alta energia gli elettroni sono ad energie ben al di sopra dell'energia critica





Sezioni d'urto delle principali interazioni
dei fotoni in rame.

1 barn=10^{-28} m^2

Sono prodotti via fotoproduzione neutroni di varie energie. Alcuni di questi neutroni costituiscono la componente piu' penetrante della radiazione determinando i livelli di dose al di la'degli schermi spessi.

Termini sorgente

Ai fini della valutazione delle schermature vengono considerate le seguenti componenti:

- Bremmsstrahlung
- Neutroni della risonanza gigante
- Neutroni di alta energia

Attenuazione

Bremsstrahlung

Coefficienti di attenuazione

Materiale	Densità (g/cm^3)	Angolo (gradi)	λ (cm)
Calcestruzzo ordinario	2.3	0	204
Calcestruzzo ordinario	2.3	90	18.7
Calcestruzzo caricato	3.4	0	13.8
Calcestruzzo caricato	3.4	90	12.6
Piombo	11.35		2.2

Risonanza Gigante

Coefficienti di attenuazione

Materiale	Densità (g/cm^2)	λ (cm)
Calcestruzzo ordinario	2.3	17.4
Calcestruzzo caricato	3.4	48.9

Neutroni di alta energia

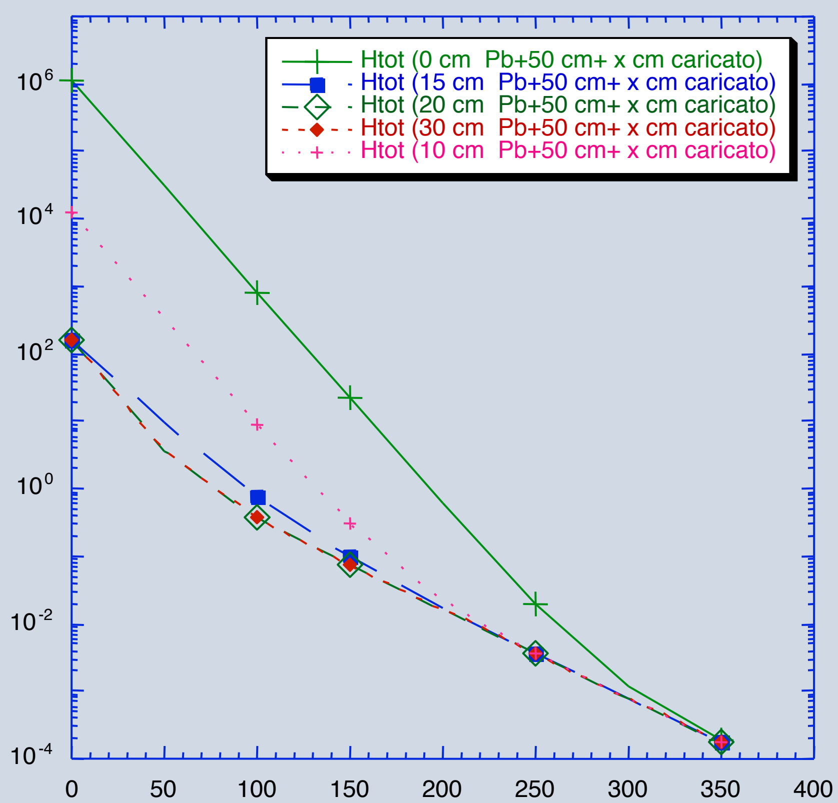
Coefficienti di attenuazione

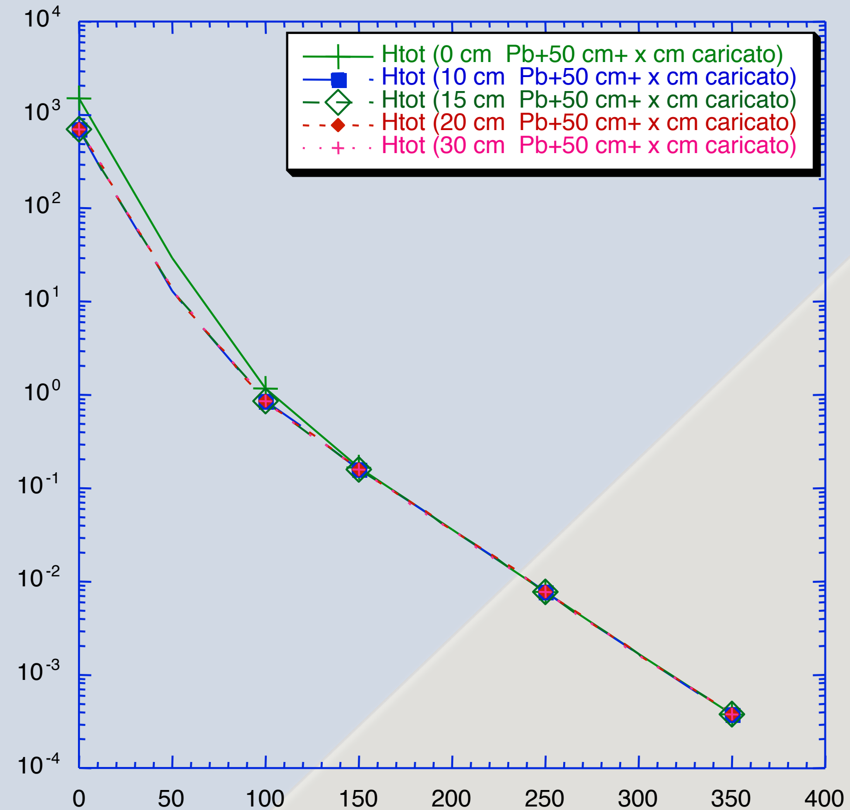
Materiale	Densità (g/cm^2)	λ (cm)
Calcestruzzo ordinario	2.3	8.9
Calcestruzzo caricato	3.4	33

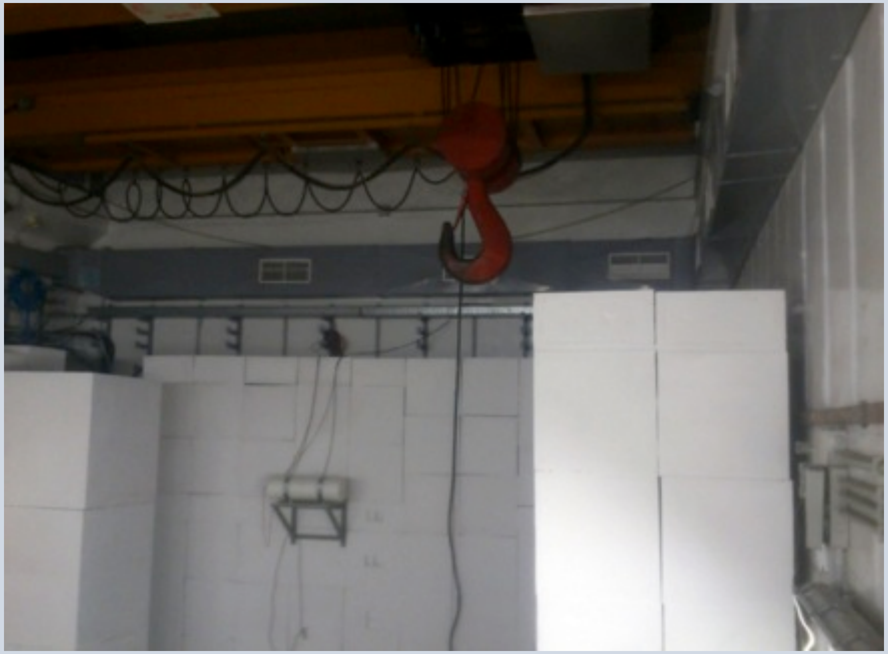
In riferimento ai neutroni di alta energia si e' fatto uso dei seguenti fattori di trasmissione in piombo

per n < 25 MeV 0.7 per n > 25 MeV 0.68

Attenuazione Totale 0 gradi







+ 1 m di calcestruzzo
+ 15 cm di Pb attorno al "target"

Produzione di neutroni

- Number of neutrons proportional to the electron beam power:

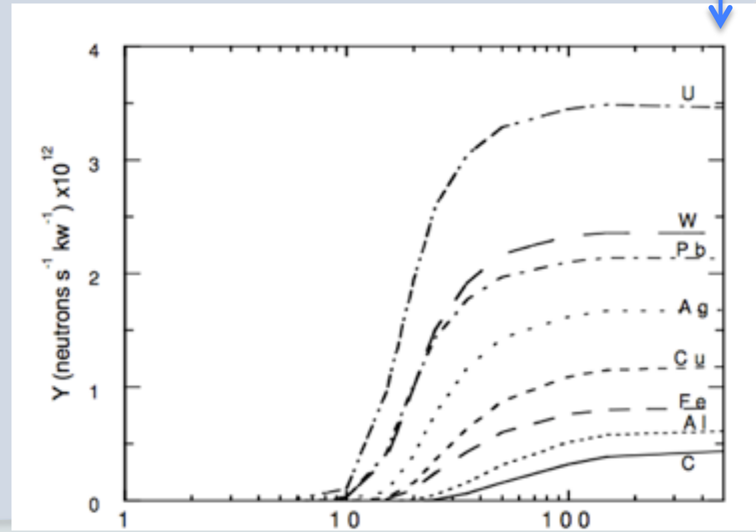
  P = rate×energy =[N×f]×E

  - N = number of particles per bunch (let's consider 1×10^{10})
  - f = frequency (up to 49 Hz)
  - E = beam energy (usually 510, up to 800)

  Maximum power: 40 W at 510 MeV

- From Swanson's empirical formula
  - 10^{11} n/s for Tungsten
  - -20% on Lead, +50% on Uranium

500 MeV

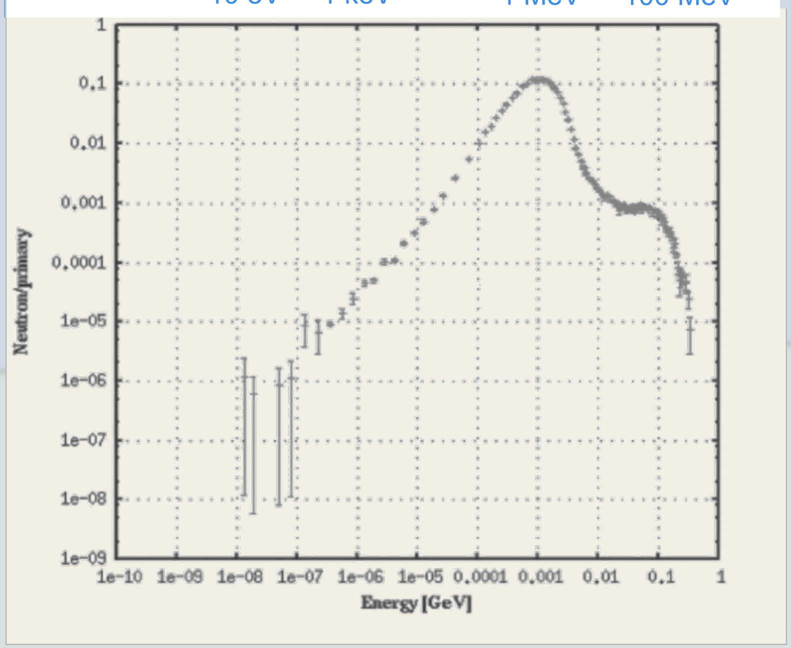


n@BTF

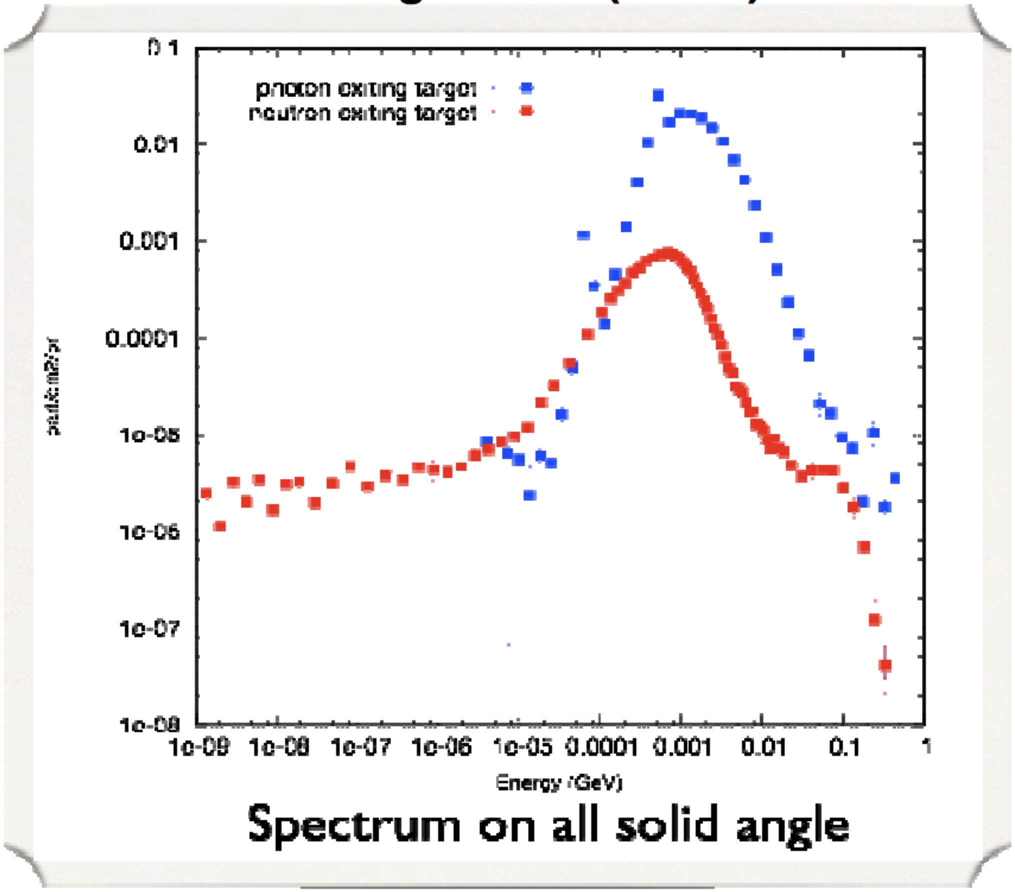
- Simulated and designed an optimized target (W cylinder d=70 mm, l=60 mm) and shielding system (lead and polyethylene)
- Measurements of the neutron field (Bonner spheres) and of the photon background in good agreement with simulations

Isolethargic fluence

10 eV 1 keV 1 MeV 100 MeV



Isolethargic Plot =(dF/dE)dE



Spectrum on all solid angle

Fluxes are integrated on all solid angle and energy spectrum @ target exit

n yield	1.1E11 n/s
n exiting	8.8E8 n/cm2/s
photons	1.9E10 ph/cm2/s

n@BTF

With 1.1×10^{11} n in the target:

- 8.8×10^{8} n/cm²/s exiting from the target
- 1.87×10^{10} γ/cm²/s exiting from the target

d (m)	$\times10^{-7}$ n/cm²/pr
0.5	58
1	15
1.5	8

At 1.5 m distance:
Total neutron flux: 8×10^{-7} n/cm²/pr ±3%

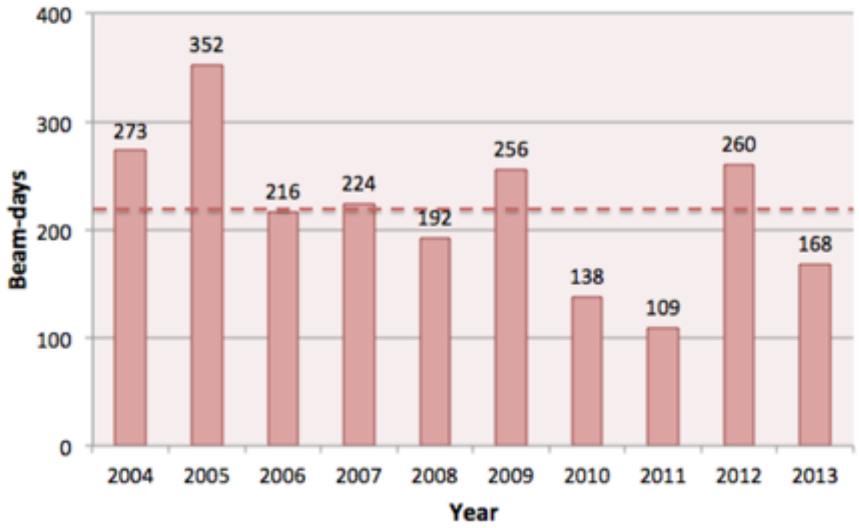
Flux = **4.5×10^{5} n/cm²/s**
Equivalente dose = 45 mSv/h

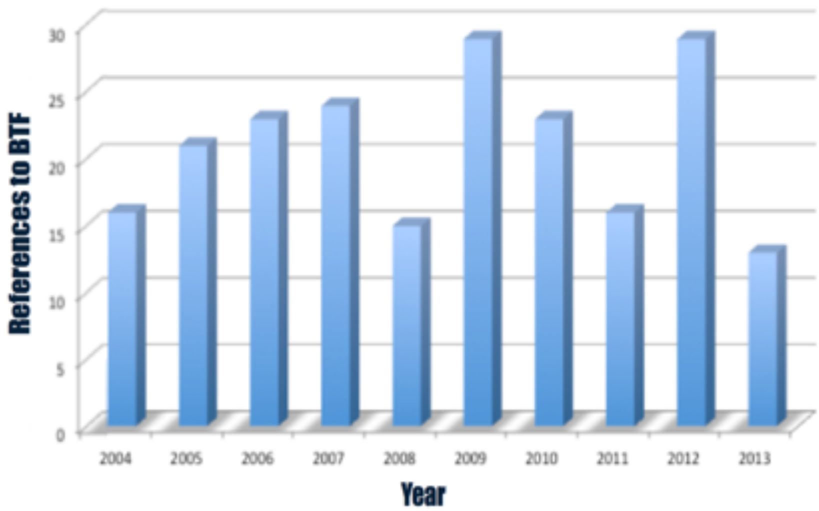
d (m)	$\times10^{-5}$ γ/cm²/pr
0.5	63
1	5.7
1.5	1

At 1.5 m distance
Total photon flux = 1×10^{6} γ/cm²/s

More measurements planned in 2014: **charged particles**?
(pions, protons, alpha, …)

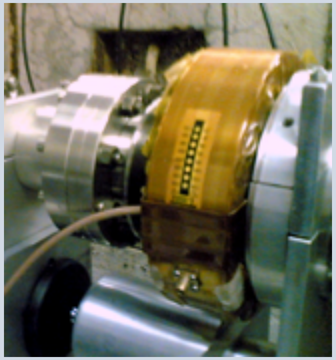
Utenti





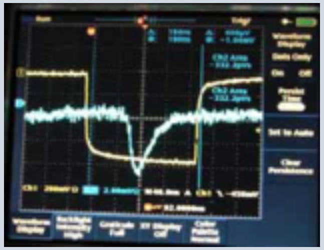
- At least 20 teams/year
- Average of 8 days/team
- Average of 220 beam-days/year
- Typically, two calls/year (November and May)
- 40% of rejection in 2013

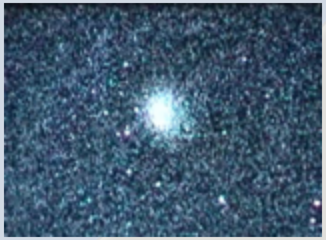
Diagnostics



High intensity

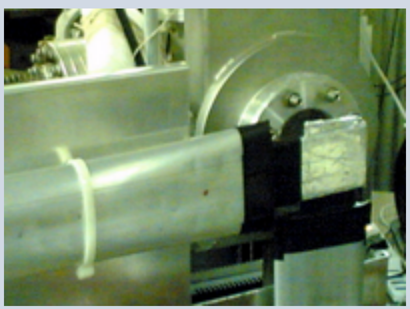
- Integrating current toroid
- Fluorescence flag

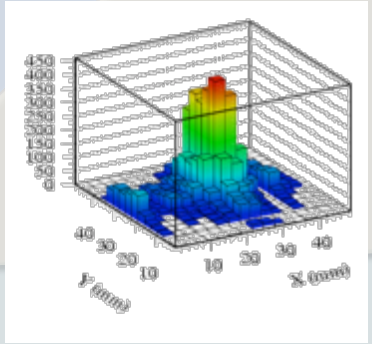


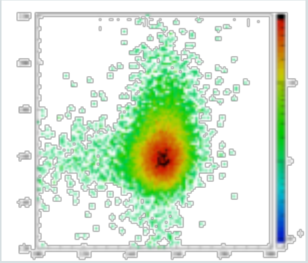


Medium-low intensity

- Scintillating fibers hodoscope
- Silicon micro-strip detectors (currently under maintenance)
- GEM Time-projection chambers

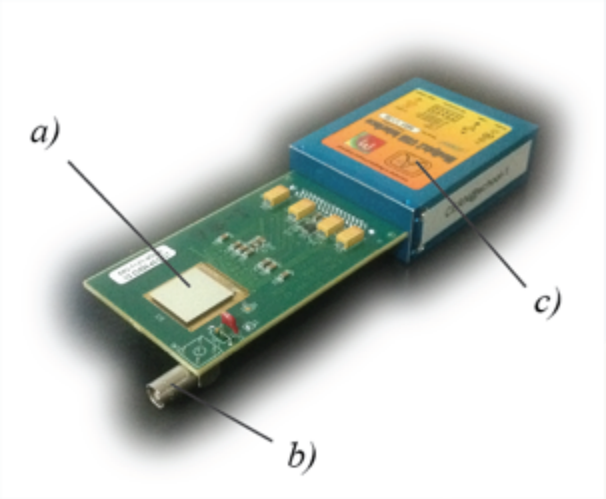


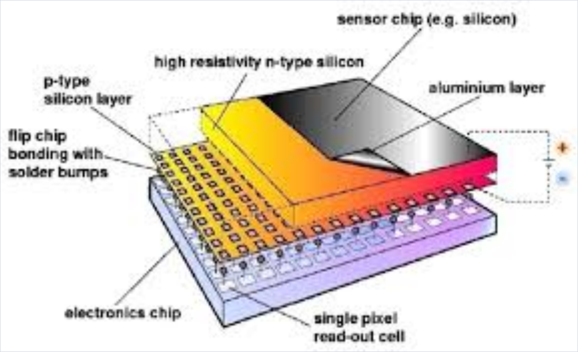


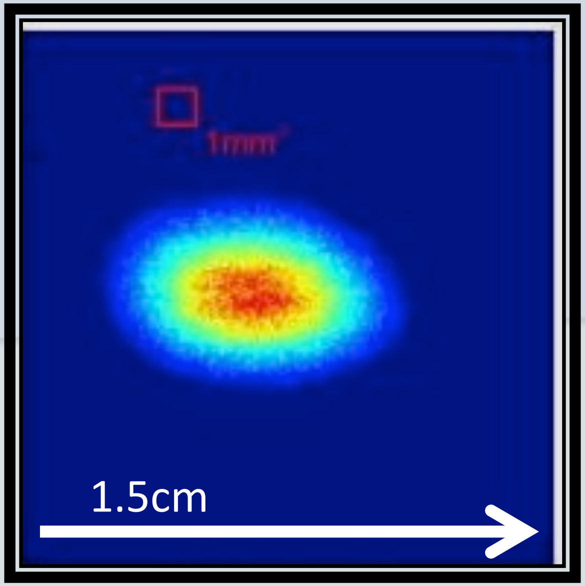


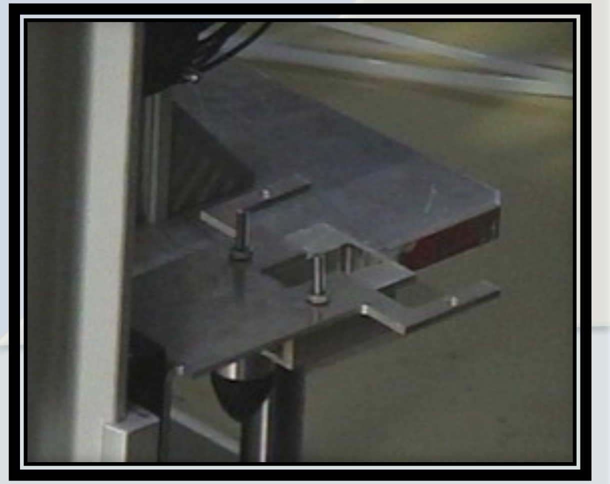
Medipix

- Timepix and Blue Box
- BTF timing
- Windows VM USB 2.0



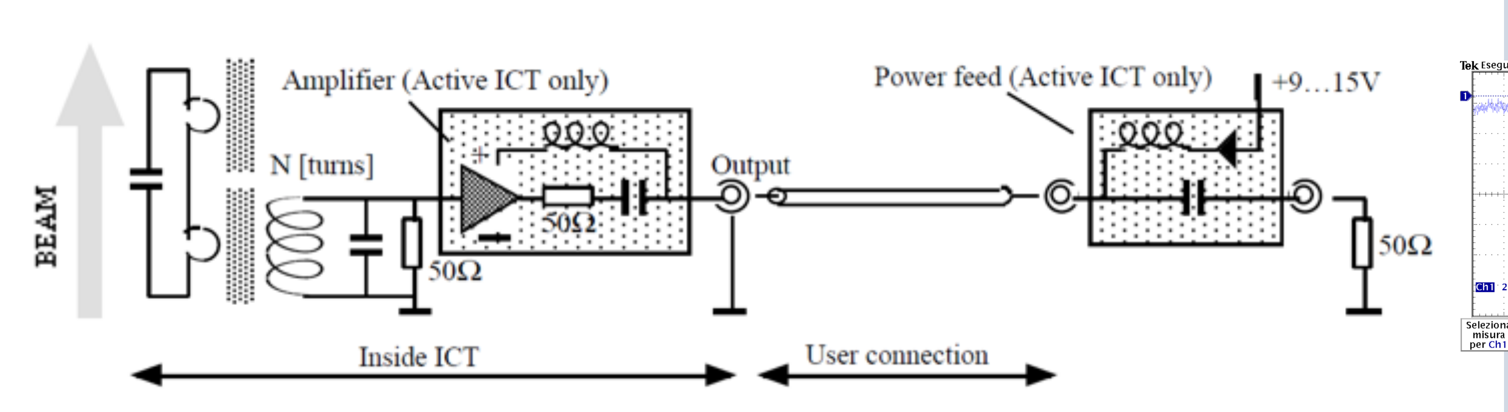


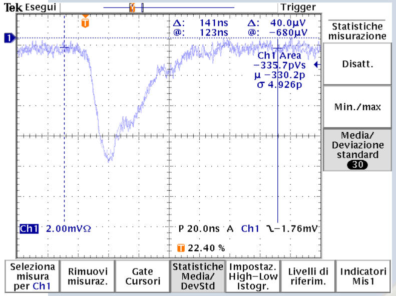


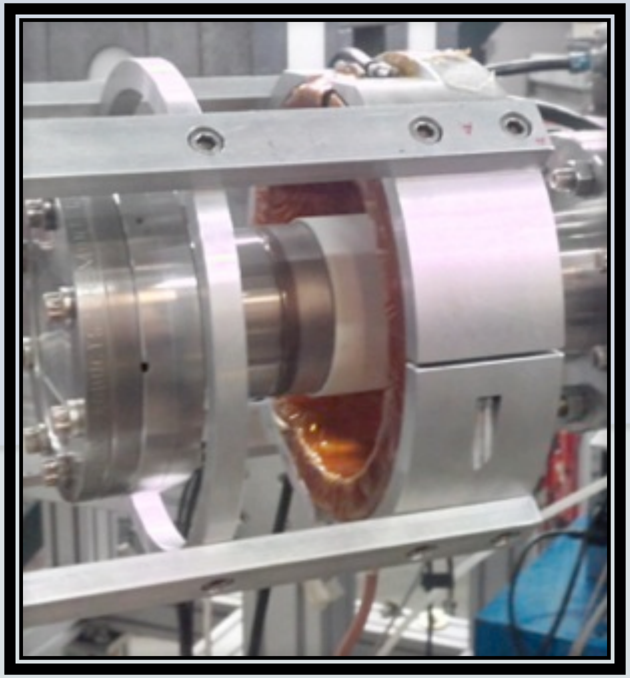


- 256x256 pixel detector
- 55µm pixel - σ=15 µm
- 50 Hz gated OK
- 1.5 cm square -> ~2cm^2 area
- Wide range multiplicity
- Easy to use

Diagnostics - ICT







Waveform generator: Agilent Arbitrary waveform Generator 33250A
Oscilloscope: Tektronix TDS 3054C
WCM: Bergoz Integrating Current Transformer (ICT-122-070-05:1)

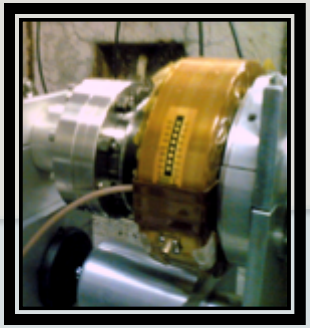
<u>WCM reply:</u>

∫Vds :   μ= 167 pVs   **σ= 5 pVs**

I_{ped}= -59 pVs

$\mathbf{I_{wcm}}$= ∫Vds- I_{ped}= **226 pVs**

$\mathbf{Q_{out}}$= I_{wcm}/R= **4.52 pC**



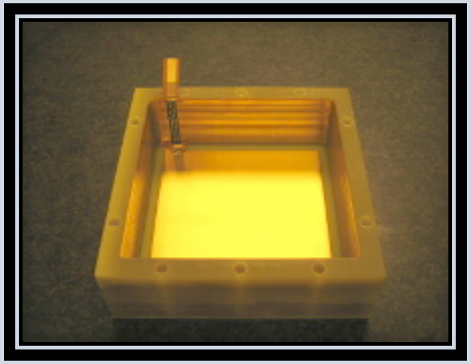
<u>RATIO:</u>

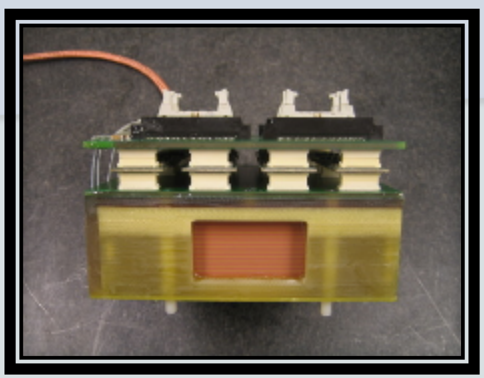
Theoretical ICT ratio = 0.1

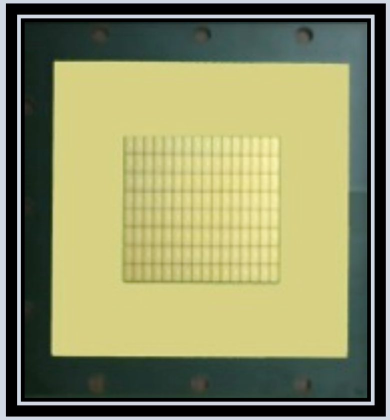
<u>**R (ratio)**</u>= $Q_{out}/Q_{in} = I_{wcm}/I_{imp}$= <u>**0.098**</u>

<u>**ΔR**</u>**=** $\sqrt{((\sigma_{wcm}/I_{imp})^2+((I_{wcm}*\sigma_{imp})/I_{imp}^2)^2)}$= <u>**0.002**</u>

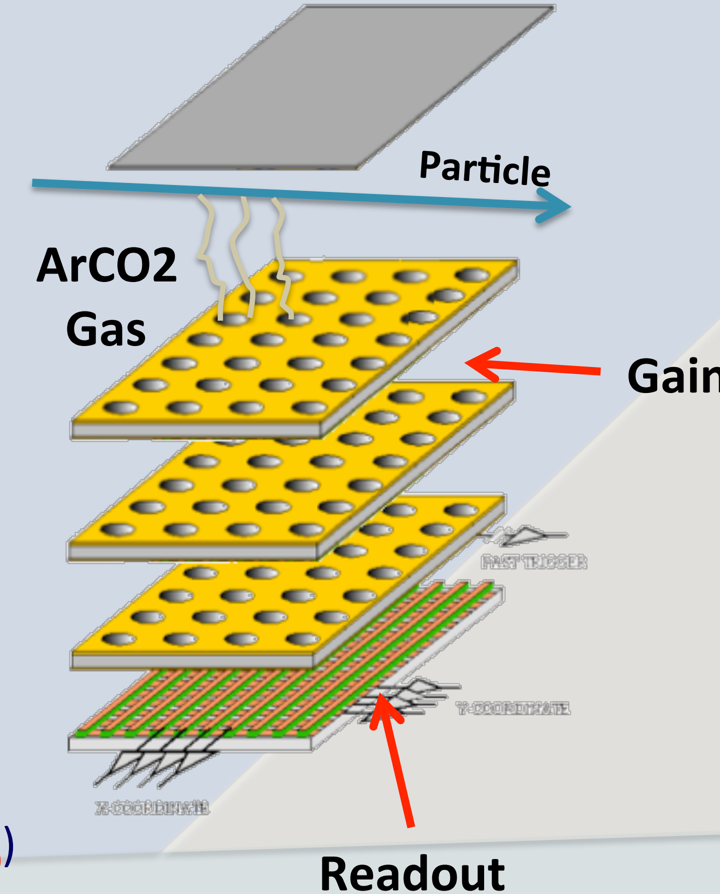
Diagnostics – GEM TPC

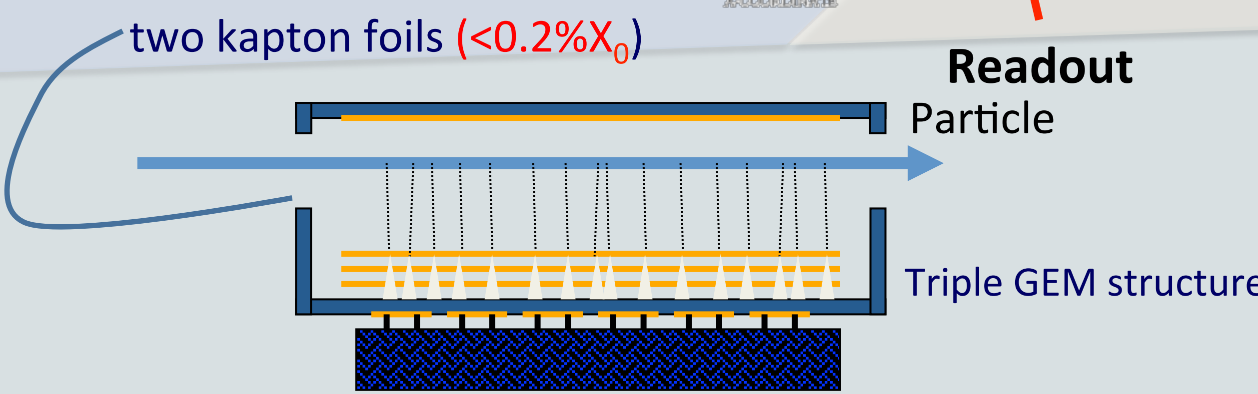




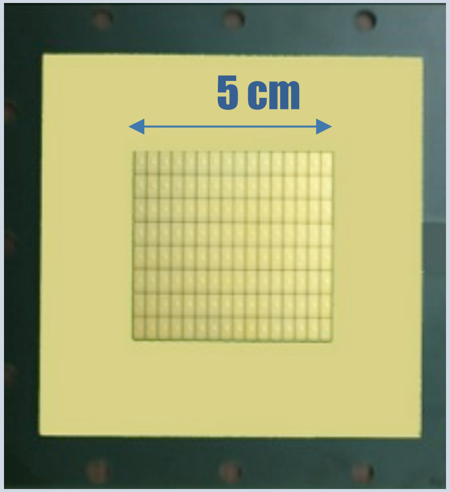


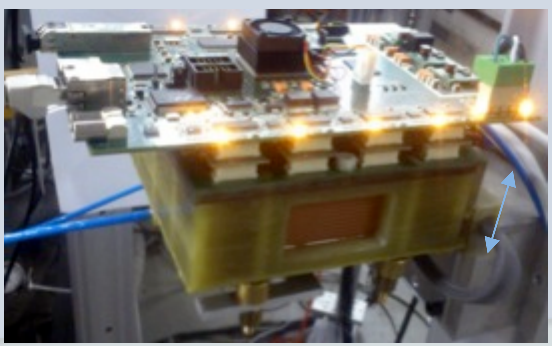
3x6mm^2 pads
8x16 pads grid





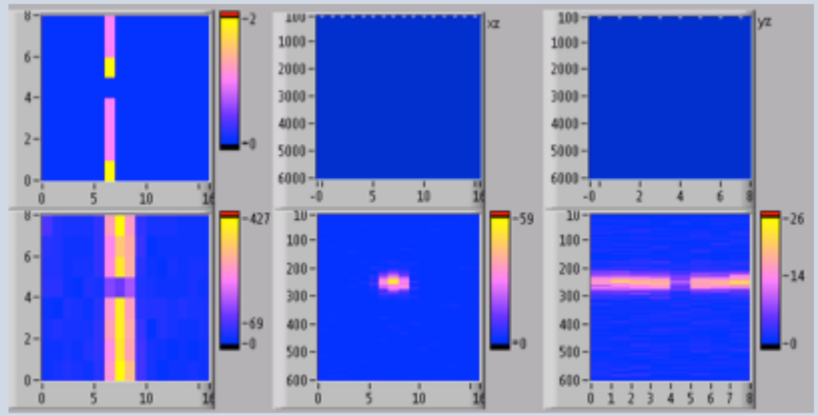
GEM TPC

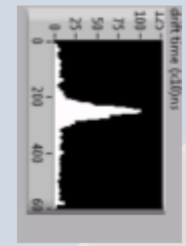




4 cm

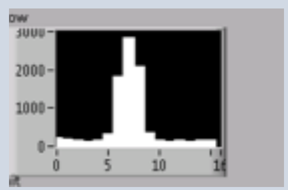
Top Front Side





4 cm

Vertical



5 cm

Horizontal

XY configuration (hit)

- 16x8 (XY) pads configuration
- 3x6 mm^2 - submm resolution

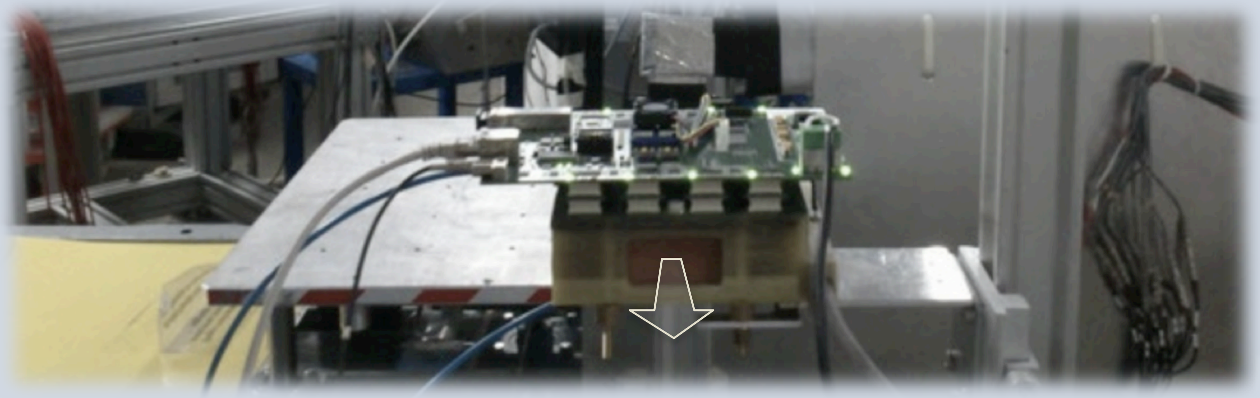
Z configuration (time)

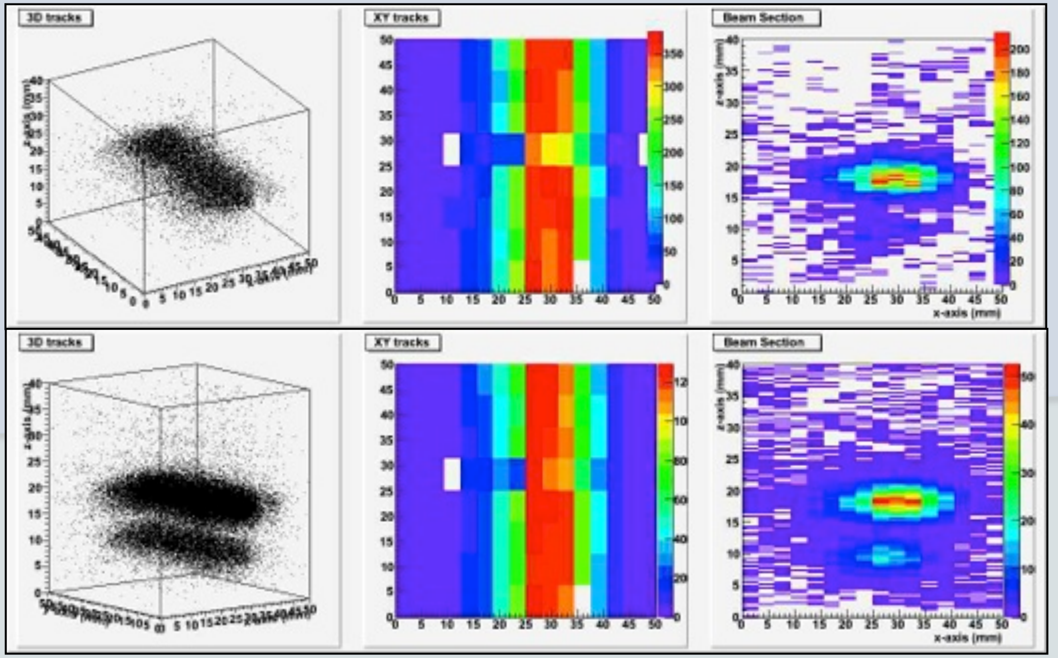
- 6μs max drift -> 80 μm resolution

Clocking

- 15 Hz gated OK

GEM TPC example: channeling



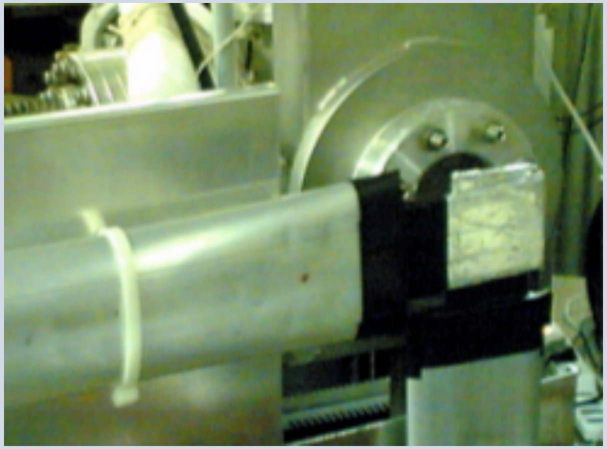


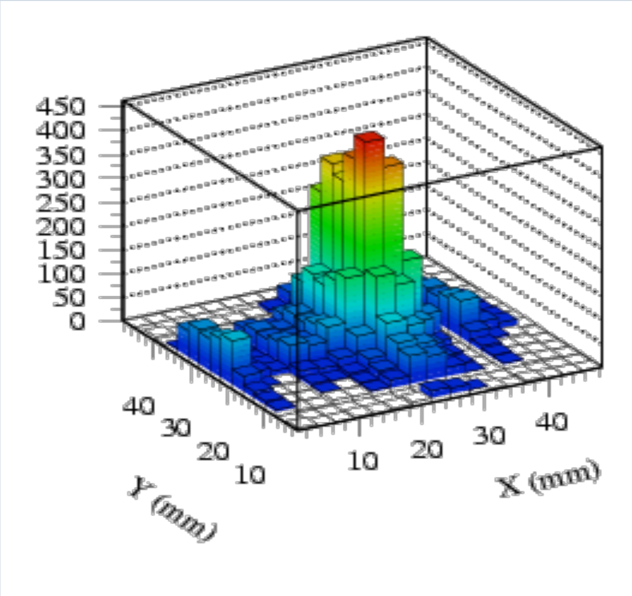
Positron beam, 477 MeV

- No channeling

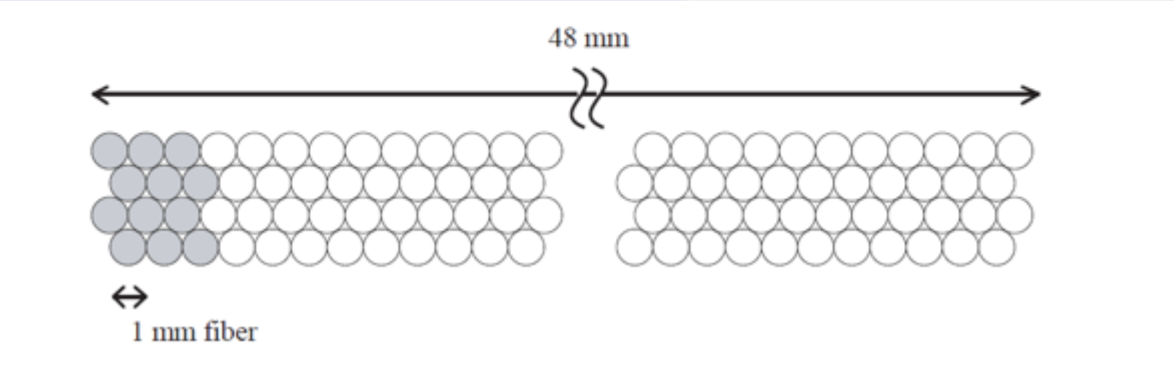
- Channeling

Diagnostics - fiber hodoscope

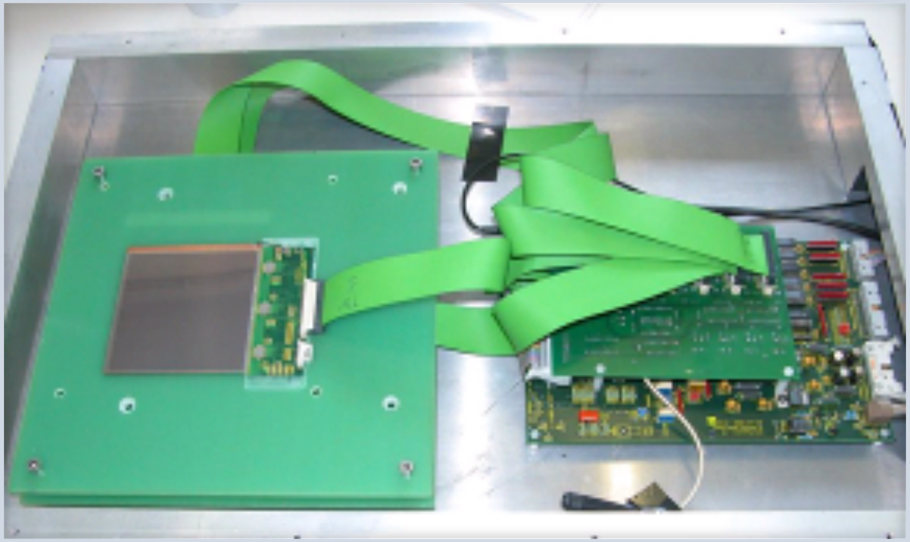


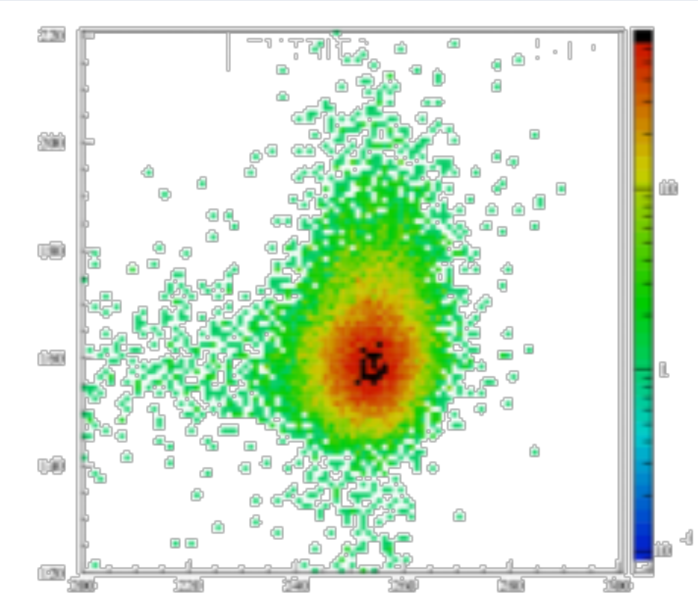


- 16X16 scintillating fibers
- Φ=1mm/12 staggered
- 3 mm pitch readout
- 50 Hz gated OK – DAQ BTF
- 48x48 mm^2-> ~23cm^2 area
- Medium-Low intensity



Diagnostics - strip tracker



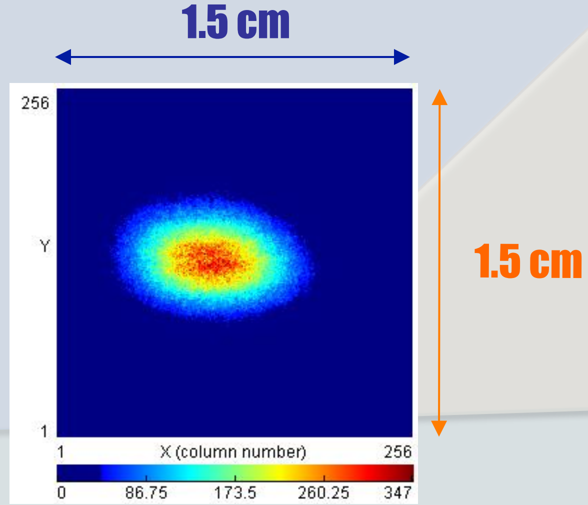


- 400μm Silicon micro-strip detectors
  - 2 couple 10X10 cm^2 XY plane
  - 368 (one read-one float) strips per plane
  - 100 μm resolution
  - TAA1 readout
  - Developed AGILE Satellite
  - 25 Hz gated OK
  - BTF-DAQ
  - Hi and Low multiplicity

(currently under maintenance)

Medipix

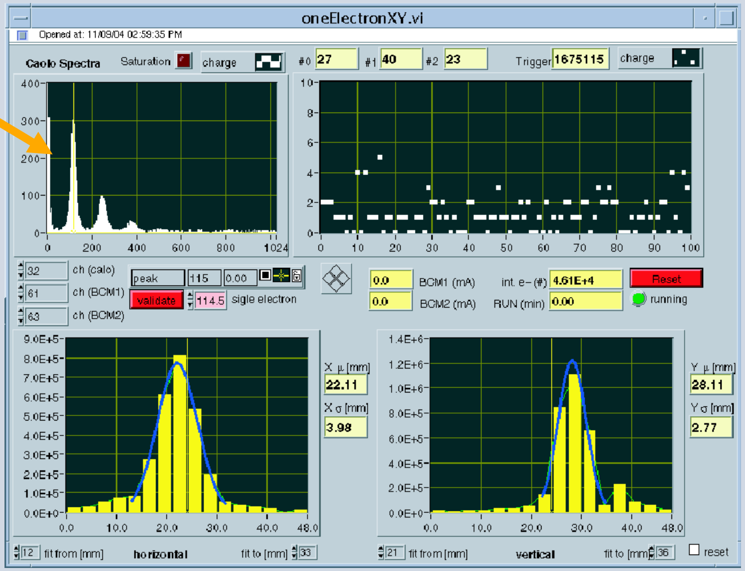
Medipix detector for precision spot measurement



Control system

- ‘old’ online monitor of BTF diagnostics integrated in the DAFNE general control system

calorimeter



XY beam profile detector

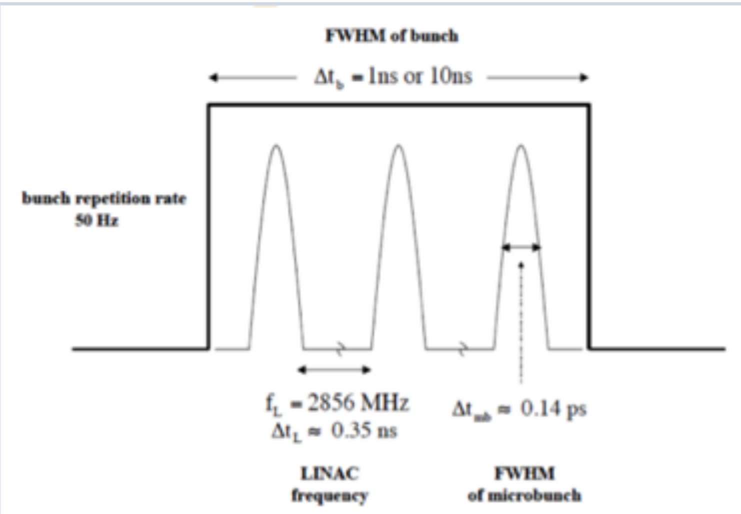
- Many additional bits and pieces added during the last years and have to be integrated:
  - New remotely controlled motorized table
  - GEM TPC acquisition system
  - Slits/collimators/target motors and encoders
  - WCM’s oscilloscope readout

- Significant work already done and still under way on controls, in close collaboration [or by] the !CHAOS project
- The BTF line (magnets, controls, diagnostics, tools) will be the first real application of !CHAOS
- First commissioning going on this week
- No nice picture to show, but we expect a brand new [working] system soon

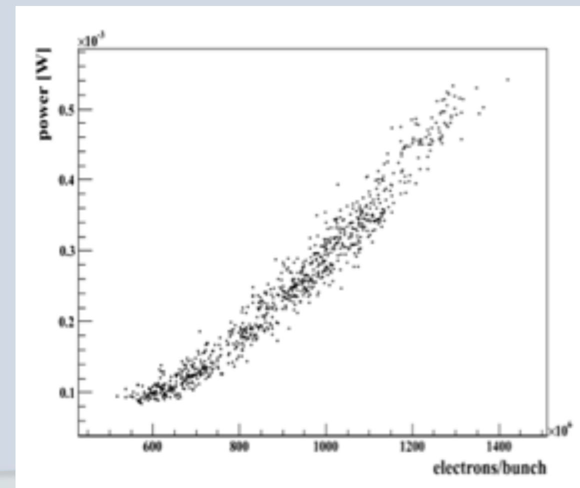
Beam parameters

Parameter	Value
Maximum rep. rate	**1-24 Hz** **[49 Hz]**
Pulse duration	**1 / 10 ns**
Linac frequency	**2,856 GHz**

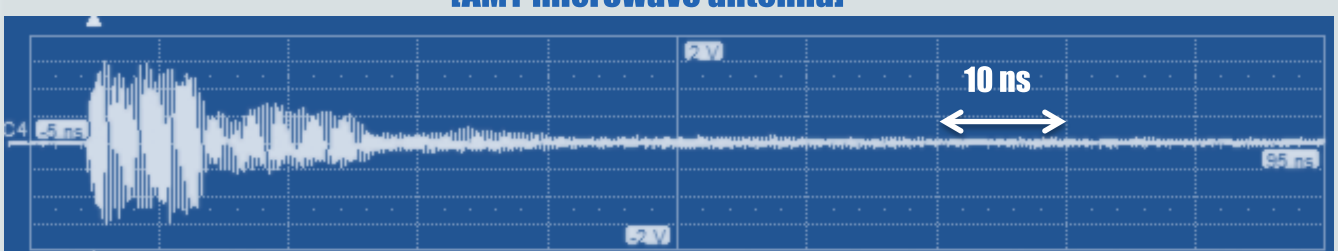
Parameter	Value
Maximum allowed intensity	**3×10^{10} e^-/s**
Maximum energy	**510 MeV** **[650 /550 MeV e^-/e^+]**



[AMY microwave antenna]

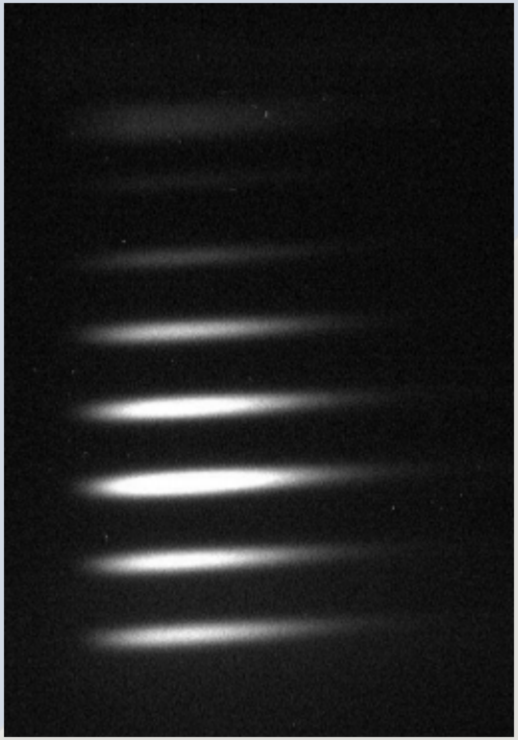


[AMY microwave antenna]



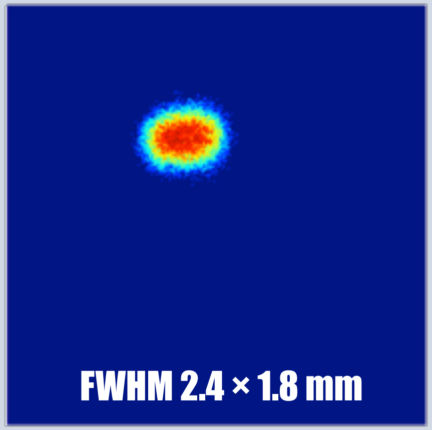
Beam parameters

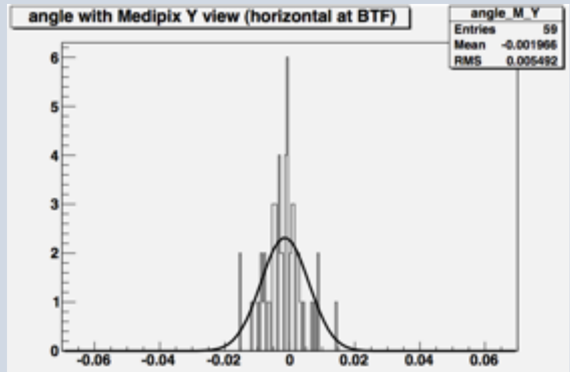
- Measured emittance:
  - $\sqrt{\langle x^2 \rangle} = 4$ mm
  - $\sqrt{\langle x'^2 \rangle} = 1.7$ mrad
  - $\sqrt{(\langle x \rangle^2 \langle x' \rangle^2 - \langle xx' \rangle^2)} = 4$ mm·mrad



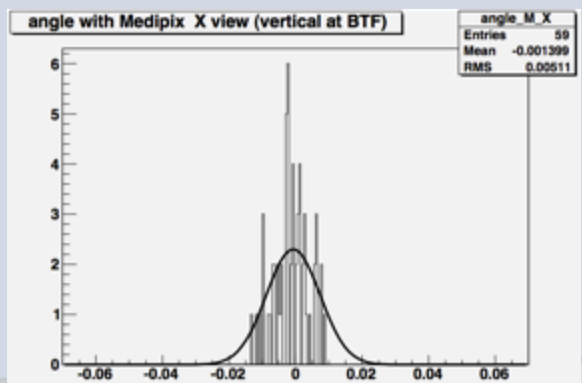
[508 MeV, Pepper pot]

Beam parameters





2 mrad RMS



1.4 mrad RMS

[UA9 Medipix detector]

Maggiori informazioni

- http://www.lnf.infn.it/acceleratori/btf
- http://wiki.infn.it/strutture/lnf/da/btf/beam_characteristics
- http://www.lnf.infn.it/acceleratori/btf/docs/NIM515_3.pdf
- https://agenda.infn.it/event/btf2014