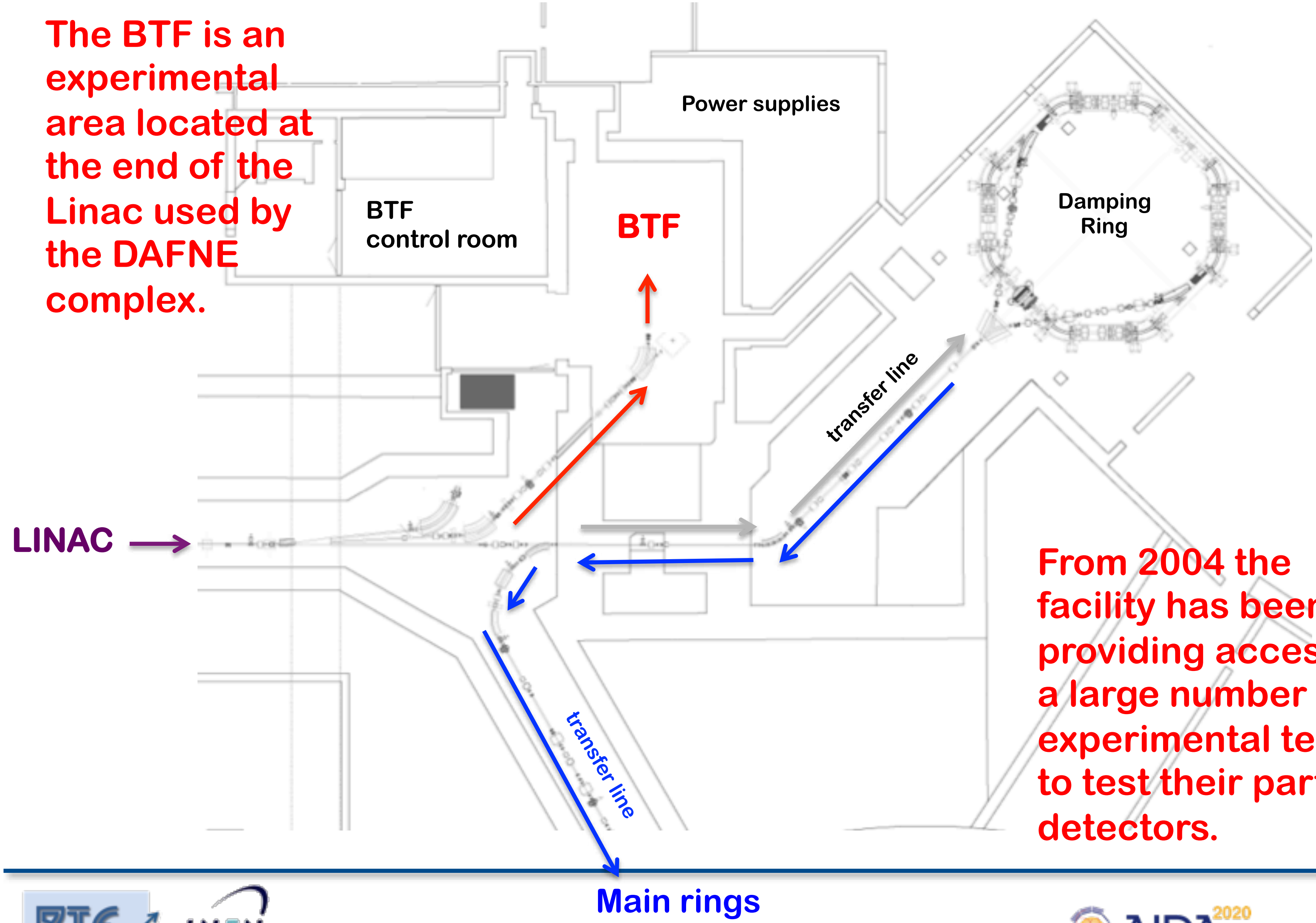
BTF: The Beam Test Facility

Bruno Buonomo, Claudio Di Giulio, Luca Foggetta, Paolo Valente

The DAΦNE complex

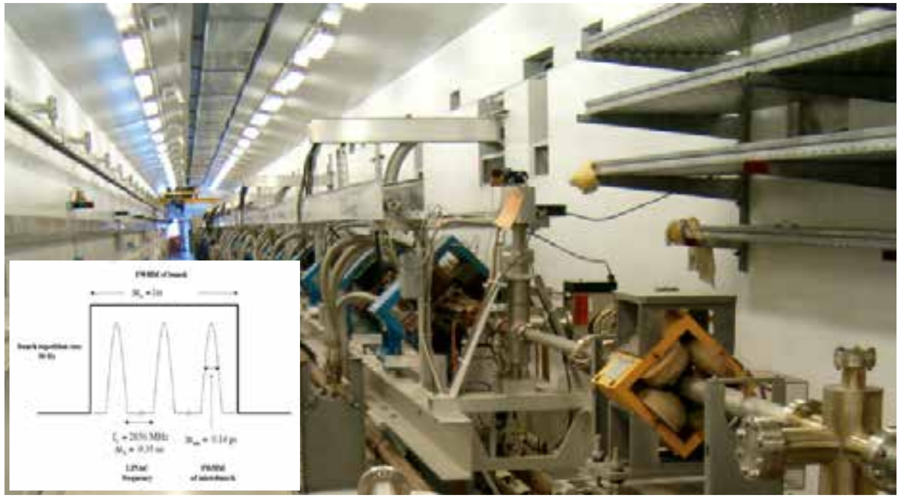
The BTF is an experimental area located at the end of the Linac used by the DAFNE complex.



From 2004 the facility has been providing access to a large number of experimental teams to test their particle detectors.

LINAC DAΦNE

	Design	Operational
e- beam final energy	800 MeV	510 MeV
e+ beam final energy	550 MeV	510 MeV
RF frequency	2856 MHz	
e+ conversion energy	250 MeV	220 MeV
Beam pulse rep. rate	1 to 50 Hz	1 to 50 Hz
Beam pulse length	10 nsec	1.4 to 40 nsec
Gun current	8 A	8 A
Beam spot on positron converter	1 mm	1 mm
Normalized emittance (mm mrad)	1 (e-) 10 (e+)	< 1.5
RMS Energy spread	0.5% (e-) 1.0% (e+)	0.5% (e-) 1.0% (e+)
e- current on e+ converter	5 A	5.2 A
Max output e- current	>150 mA	500 mA
Max output e+ current	36 mA	85 mA
Transport efficiency from capture section to LINAC end	90%	90%
Accelerating structure	SLAC-type, CG, $2\pi/3$	
RF source	4 x 45 MWp SLED-ed klystrons TH2128C	

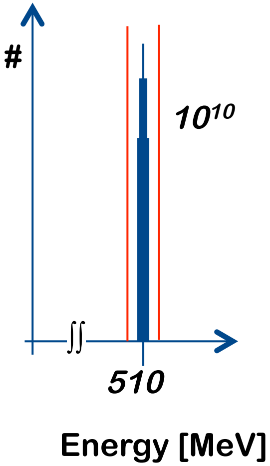


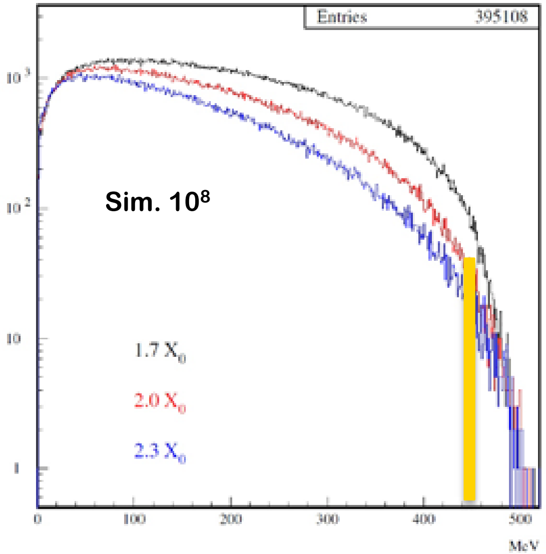
TITAN Beta (Ca,USA) 1995

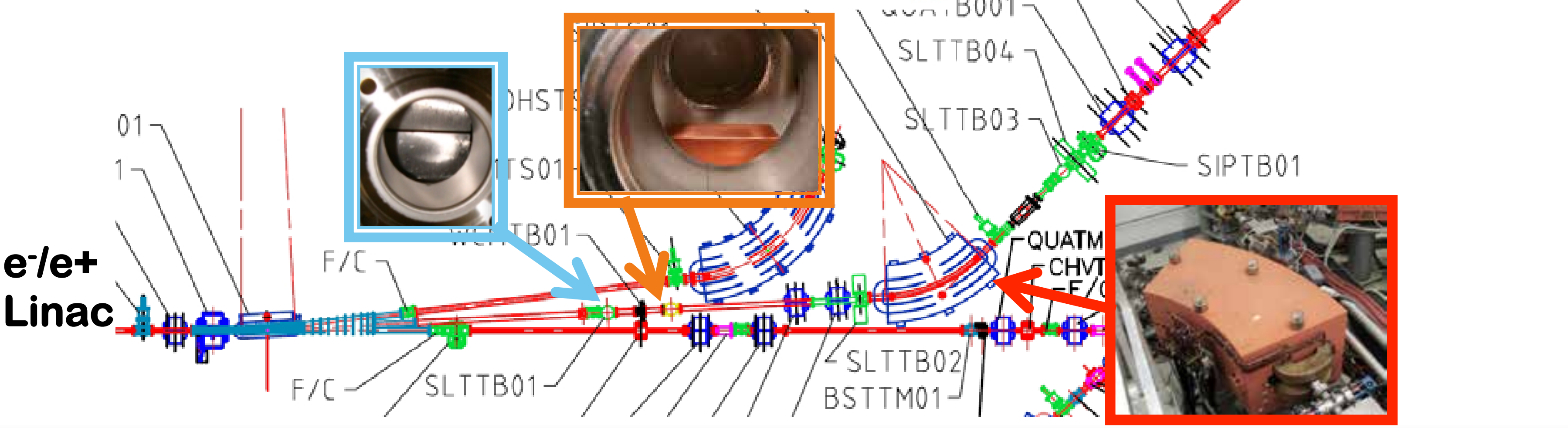
It is a ~60 m long, S-band (2856 MHz) linear accelerator, made up by a thermionic gun, four 45 MW klystrons (Thales TH-2128C) with SLED (SLAC Energy Doubler) compression, and by 15 travelling-wave, $2/3\pi$, SLAC-type, 3 m long accelerating sections.

How the BTF works:

The beam interact with a $\approx 2x_0$, Cu Target ad after is selected in energy and collimated







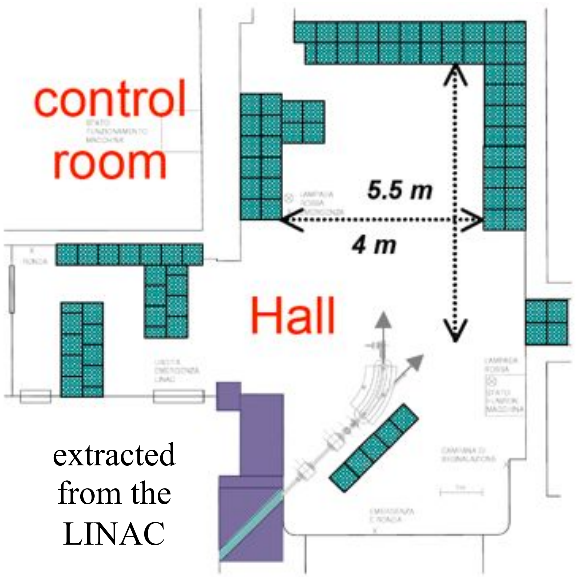
The Beam-Test Facility

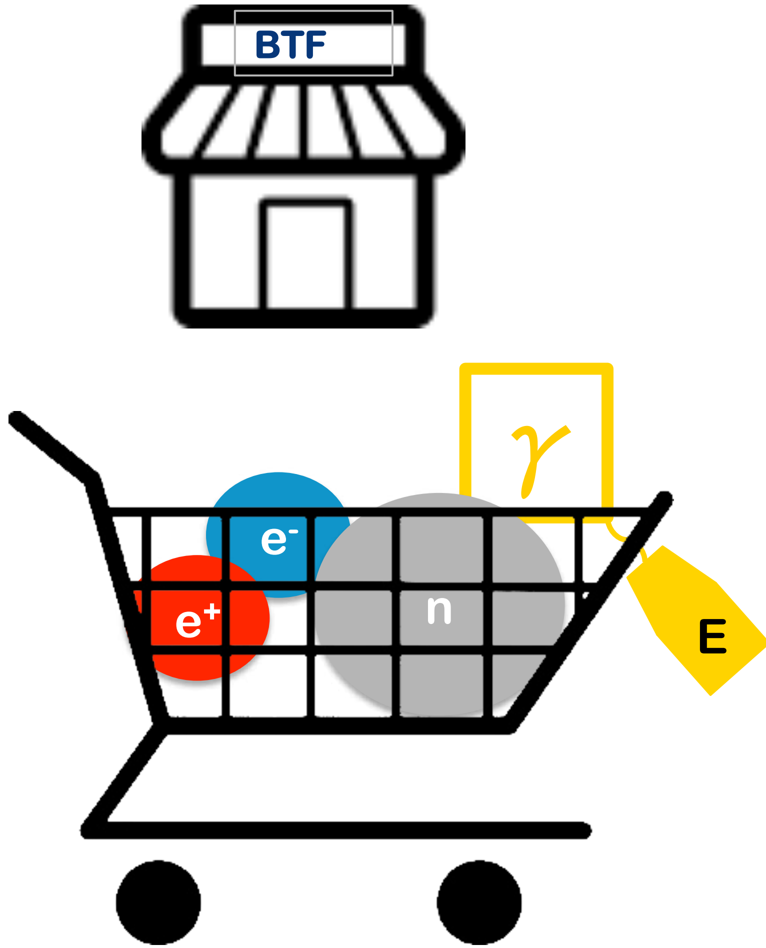
- A **facility** part of the DAΦNE accelerator complex, that allows to:
  - **Extract, attenuate, energy select, focus and collimate electrons and positrons accelerated by the LINAC**
  - **Measure** in real-time and **tune** the beam parameters (particle species, energy, intensity, beam spot size and position)
  - Provide a series of **services**: power supply, networking, gas, DAQ, vacuum and cryogenics, alignment, magnetic fields
- It generally works in "parasitic" mode to the operations of the DAΦNE collider
- Commissioning performed in 2002, users routinely since 2004
- Mainly used by the high-energy physics and astro-particle communities

Parameter	Parasitic mode		Dedicated mode	
	With target	Without target	With target	Without target
Particle species	e^+ or e^- Selectable by user	e^+ or e^- Depending on DAFNE mode	e^+ or e^- Selectable by user	
Energy (MeV)	25–500	510	25–700 (e^-/e^+)	250–730 (e^-) 250–530 (e^+)
Energy spread	1% at 500 MeV	0.5%	0.5%	
Rep. rate (Hz)	Variable between 10 and 49 Depending on DAFNE mode		1–49 Selectable by user	
Pulse duration (ns)	10		1.5–40 Selectable by user	
Intensity (particles/bunch)	$1–10^5$ Depending on the energy	$10^7–1.5\ 10^{10}$	$1–10^5$ Depending on the energy	$10^3–3\ 10^{10}$
Max. average flux	$3.125\ 10^{10}$ particles/s			
Spot size (mm)	0.5–25 (y) × 0.6–55 (x)			
Divergence (mrad)	1–1.5			

BTF products:

- electron or positron:
  - single
  - High intensity
- Photon tagged
- Neutron

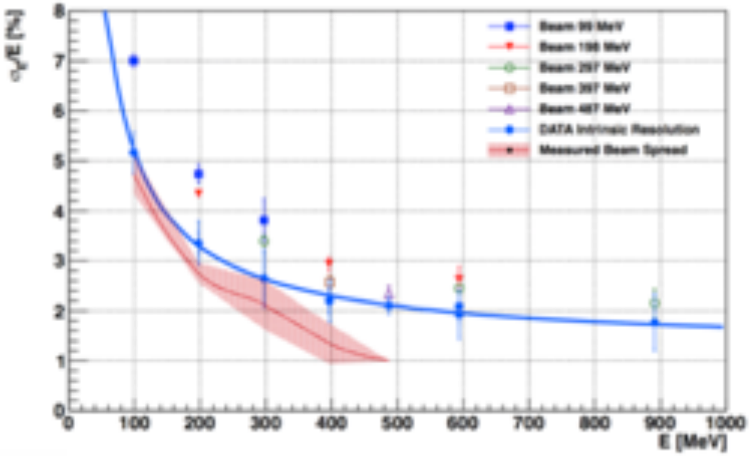


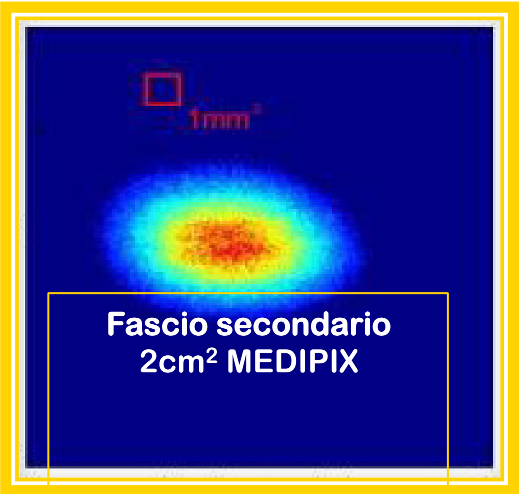


BTF: single particle

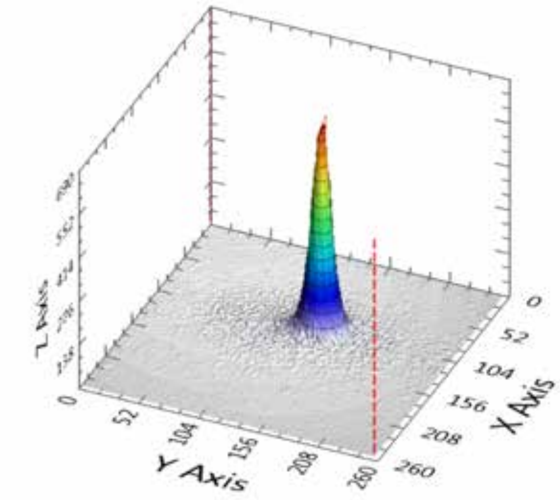
- The primary beam hit the Cu Target
- Energy from 450 to 50 MeV
- The multiplicity follow the Poisson distribution.
- Positron and electron are selectable independently from the LINAC primary.

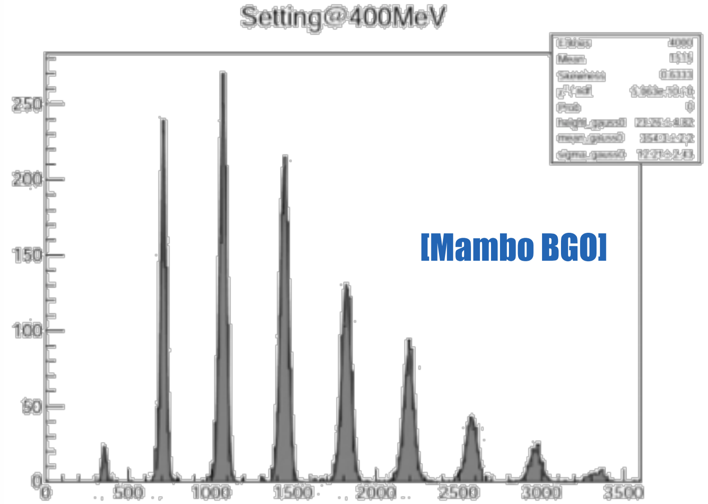
Energy spread measured by LYSO Calorimeter





Best beam (07/03/2016): 440x420 μ m²





BTF High Intensity

- Le LINAC primary beam is transfer in the BTF Hall.

- Thanks to the new shielding (Sept. 2015) the radioprotection limit in the BTF Hall is :

  3.125×10^{10} particles/s

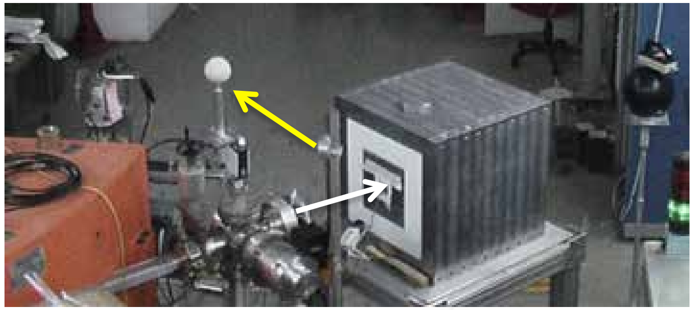
- High intensity beam are requested usually to characterize the air shower process as the AirFLY and AMY.

$$\text{BTF} \qquad 10^{10}\,\frac{e^-}{\text{bunch}} \times 510\ \text{MeV} \approx 5 \times 10^{18}\,\text{eV}$$

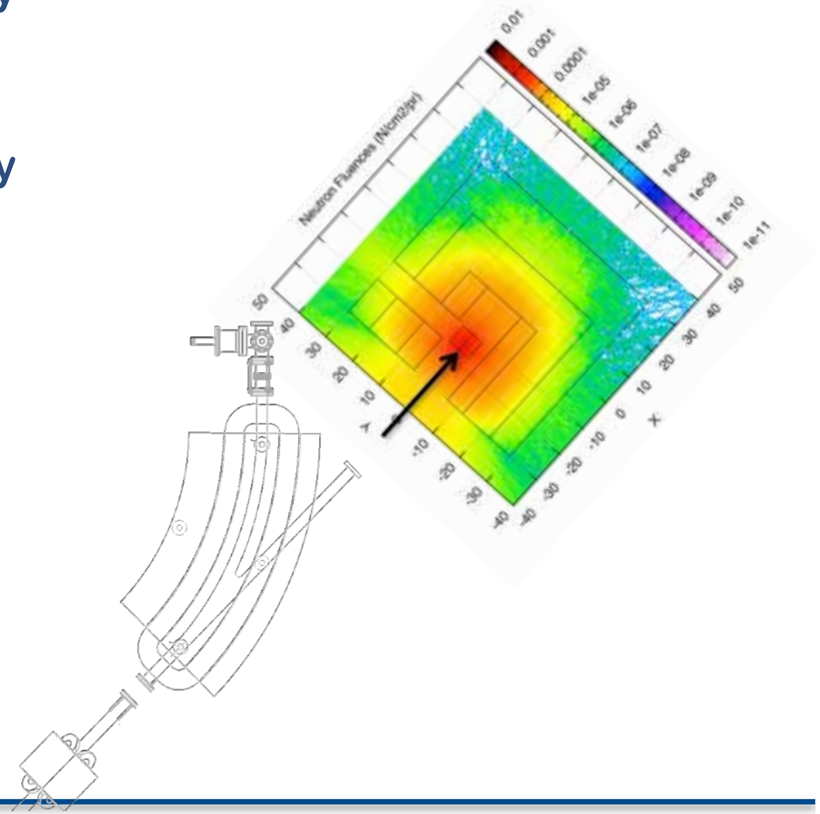
- The High Intensity run are coordinated with the Radioprotection Staff.

- The High intensity primary is used for neutron production too.

n@BTF



- **The LINAC primary hit the Tungsten.**
- **High energy electron produce bremsstrahlung photons with a continuous spectrum. Those photons generate photo-nuclear reaction if the energy is bigger than the neutron binding energy in the target.**



- **The number of neutrons is related to the energy deposited in the target:**

P = rate×energy =[N×f]×E

N = numebr of particle per bunch (1×10^{10})
f = frequency (1-49 Hz)
E = beam energy (510-800 MeV)

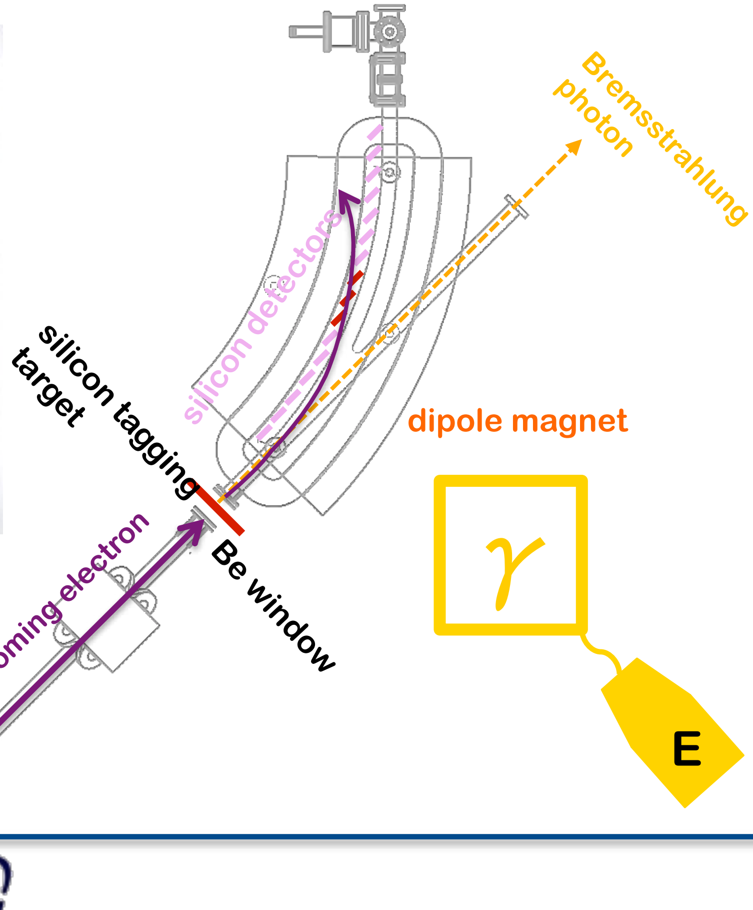
Maximum Power: 40 W at 510 MeV

Swanson-> 10^{11}n for W -> 8.8×10^{8} n/cm^2/s

Photon tagged in BTF

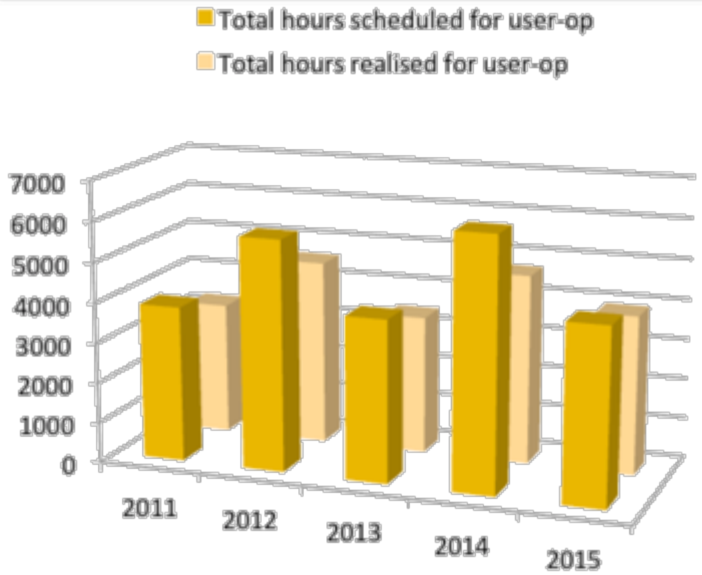
Designed for the AGILE satellite mission.

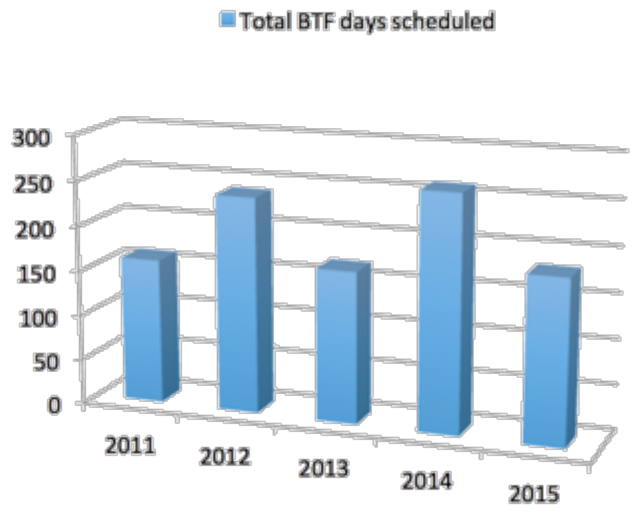
The aim was the calibration of the payload calorimeter and tracker.

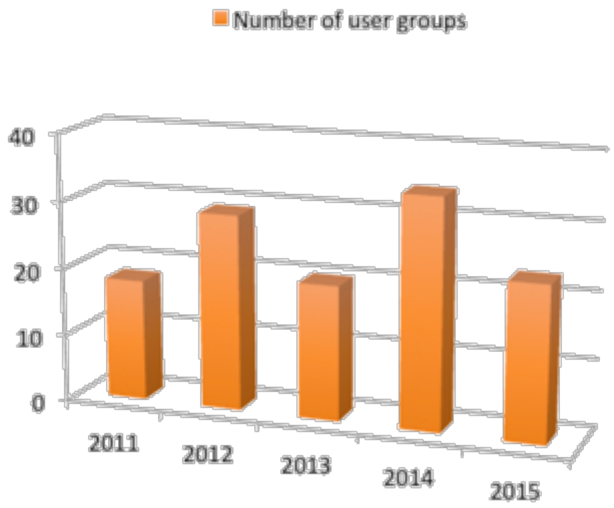


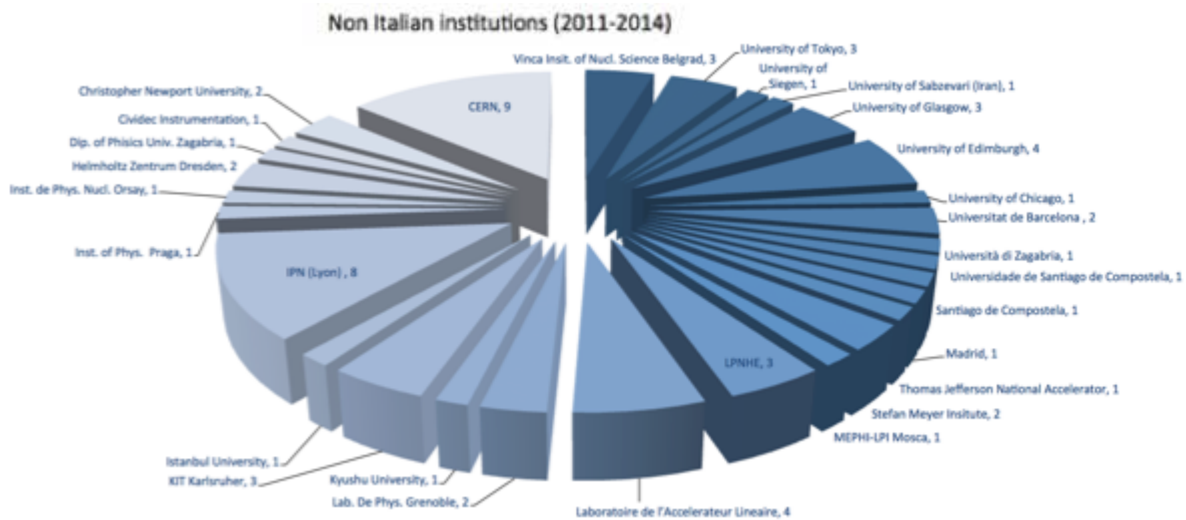
- The photon is “tagged” in energy using the dipole with the internal covered by 10 modules of Si micro-strip.
- The electron hit different strip and it depend from the energy released for the photon production after fixing the dipole current.
- The correlation between the electron position on the Si tracker and the position of the strip in the magnet allow to tagged the photon in energy.

BTF: operation 2011-2015









BTF INFN AIDA 2020

BTF in next years

DAΦNE TECHNICAL NOTE
INFN - LNF, Accelerator Division

1991

Frascati, Oct. 29, 1991
Note: LC-2

DAΦNE-LINAC TEST BEAM

F. Sannibale and G. Vignola

In this note the possibility to include a test beam facility, in the DAΦNE accelerator complex, is discussed.

Between two injections, the DAΦNE-LINAC can deliver the electron beam into an existing hall (see Fig. 1). This area, previously used as "Pion Test Facility", has an extension of about 100 m^2, it is surrounded by concrete walls, it has 20 ton crane capability and an independent entrance.

The $e^+ e^-$ DAΦNE-LINAC main features are:

Max Energy	800 MeV
Conversion Energy 250 MeV	
Repetition rate	50 Hz
Pulse duration	10 ns
Max curr./pulse	150 mA (10^{10} particles)

The main tasks, in order to put the test beam in operation, are :

- Transferline and diagnostic
- Civil Engineering (Hole through the concrete wall)
- Safety system upgrading.

The maximum intensity that can be used, without reinforcing the existing shielding, is under evaluation.

In the following, we describe the transport optics and, in some more details, the "**single electron mode of operation**" which, in our opinion, is the most interesting one for calibration purposes.

2016

ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

INFN-16-04/LNF
11^{th} March 2016

Linear Accelerator Test Facility at LNF
Conceptual Design Report

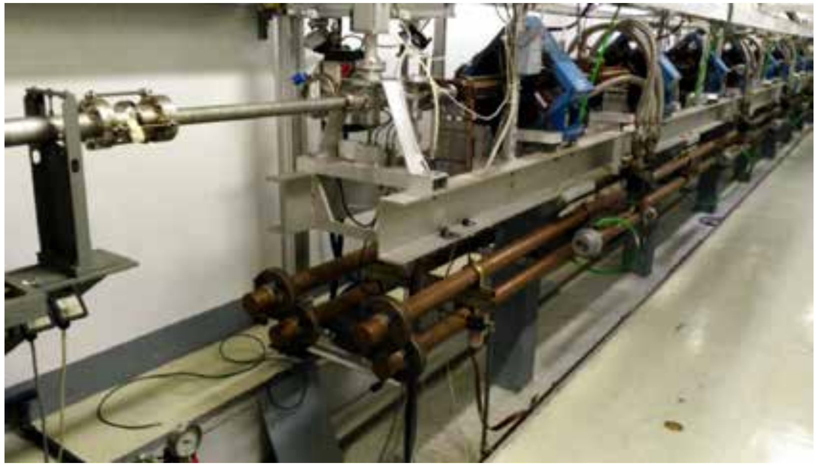
[1]*Istituto Nazionale di Fisica Nucleare, Sezione di Roma*
[2]*INFN Laboratori Nazionali di Frascati Via E. Fermi 40, Frascati, Italy*

Pubblicato da SIDS-Pubblicazioni
Laboratori Nazionali di Frascati

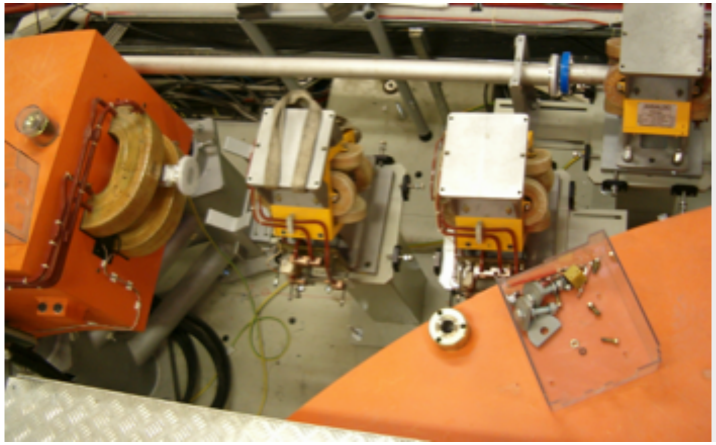
BTF Upgrade project

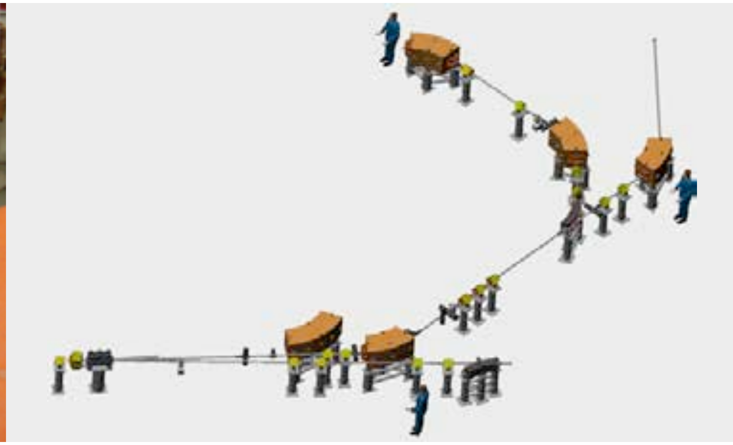
WP1: LINAC consolidation

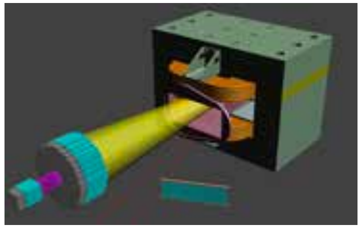
WP2: LINAC up to 1 GeV



WP3: doubling the BTF Line







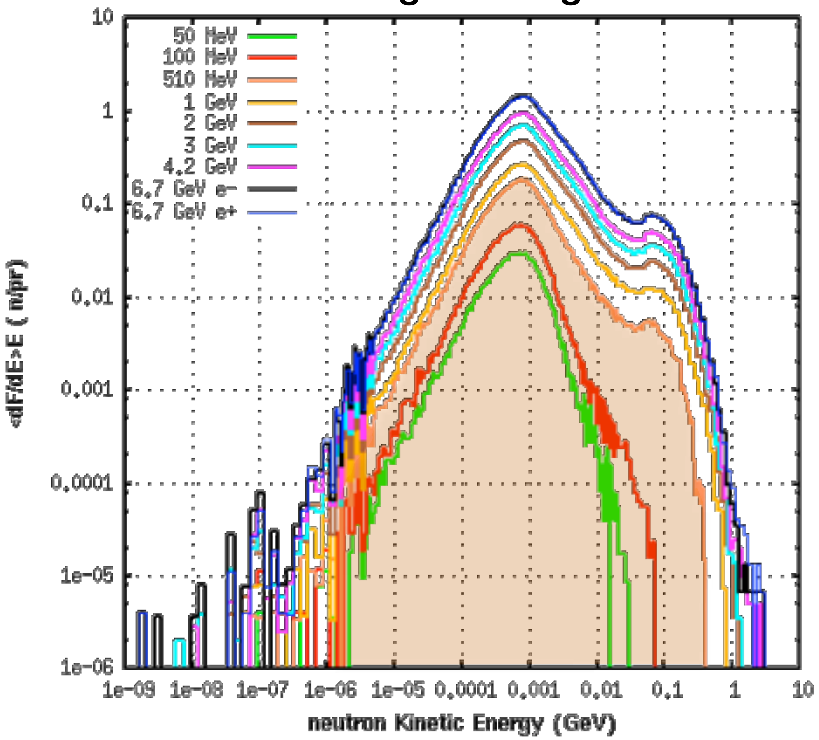
PADME:
Dark Photon

Conclusion

- The BTF with it's characteristics will continue to be an important facility to test and calibrate particle detectors.
- The upgrade project will allow to cover the user requests for the next years.

Neutron electro-production

Tungsten target



Evaporation peak + fast neutrons shoulder

- **At full linac power**: 10^{13} e/s
  - to be compared e.g. with nELBE, N=$6 \cdot 10^{15}$ e/s
- **Swanson estimate**
  - **$9.3 \cdot 10^{10}$ $Z^{(0.73\pm0.05)}$ n/s kW^{-1}**
  - **$2.15 \cdot 10^{12}$ n/s kW^{-1} for Tungsten**
- Optimizing the target configuration can (slightly) improve the yield:
  - n@BTF optimized target: $2.75 \cdot 10^{12}$ n/s kW^{-1}
  - **0.218 n/pr** (over 4π and all spectrum)
- In our case the main limitation will always be the intensity delivered onto the target

n@BTF

With 1.1×10^{11} n in the target:

- 8.8×10^{8} n/cm^2/s exiting from the target
- 1.87×10^{10} γ/cm^2/s exiting from the target

d (m)	$\times10^{-7}$ n/cm^2/pr
0.5	58
1	15
1.5	8

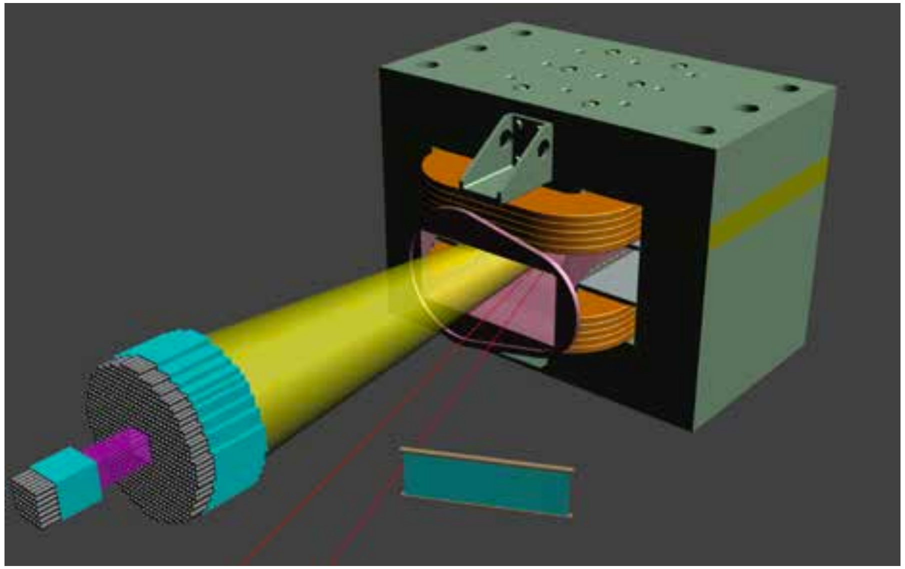
d (m)	$\times10^{-5}$ γ/cm^2/pr
0.5	63
1	5.7
1.5	1

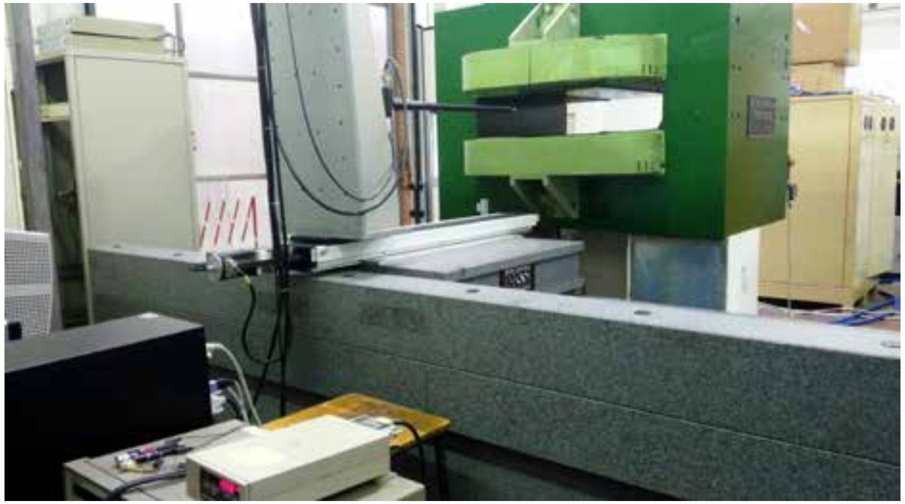
At 1.5 m distance:
Total neutron flux: 8×10^{-7} n/cm^2/pr ±3%

Flux = **4.5×10^{5} n/cm^2/s**
Equivalente dose = 45 mSv/h

At 1.5 m distance
Total photon flux = 1×10^{6} γ/cm^2/s

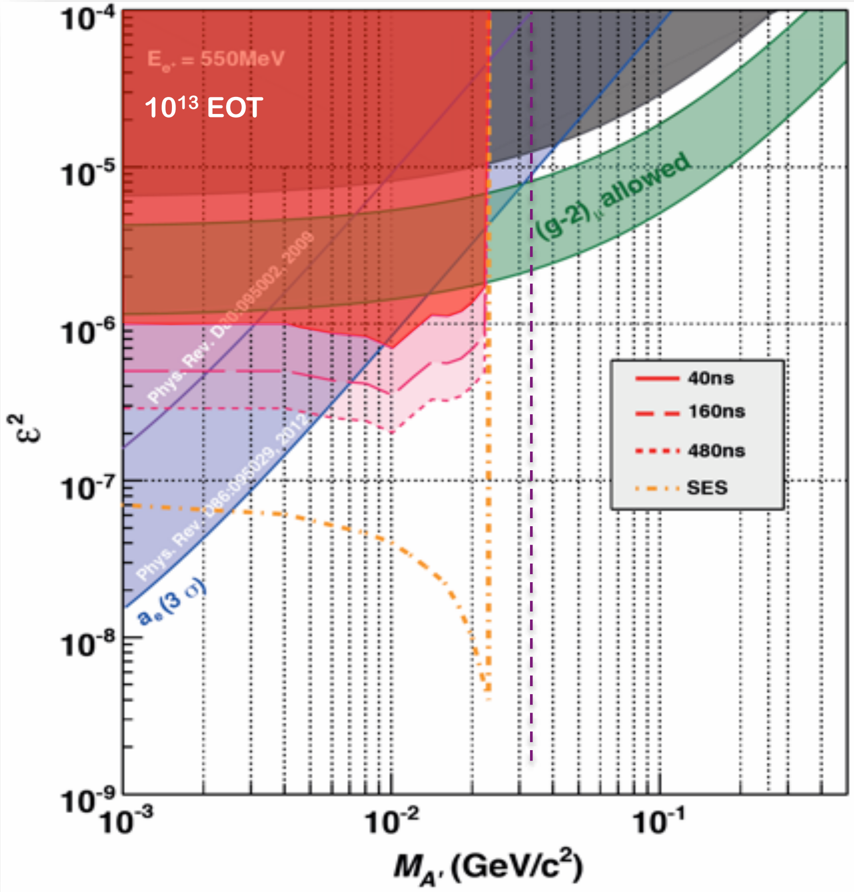
PADME experiment





- CSN I full approval for **1,350 kEuro** for 2016-2018
- Magnet from CERN (OK, being measured now)
- 500 BGO crystals from former L3 experiment
- Calorimeter construction starting in Spring 2016
- Active diamond target being developed in Lecce
- Scintillating bars positron veto being developed in Sofia
- Interest from Hungarian group
- Collaboration with Cornell starting this summer

PADME sensitivity



Based on $2.5\text{x}10^{10}$ fully GEANT4 simulated 550MeV e+ on target events

- Number of BG events is extrapolated to $1\text{x}10^{13}$ electrons on target

PADME 10^{13} EOT

- 2 years of data taking at 60% efficiency
- Bunch length of 40 ns
- 5000 e^+/bunch × $2{\cdot}10^7$s × 49 Hz

E_{e+}=550 MeV: $M_{A'} < 23.7$ MeV/c^2

E_{e+}=1 GeV: $M_{A'} < 32$ MeV/c^2

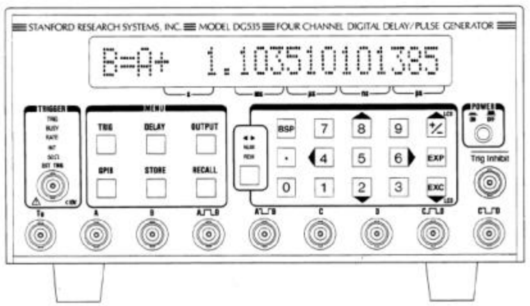
Timing

- DAFNE reference $Ø_4$ for the injection systems
- Conditioned $Ø_4$ -> DELAYED LINAC SYS SIGNAL moves all the LINAC stuff together to match ACCUMULATOR phase)
  - DELAYED GUN SIGNAL -> LINAC SYS REFERENCE (once optimized, not moved for months)
  - BTF REFERENCE -> USER needs DELAYED LINAC SYS

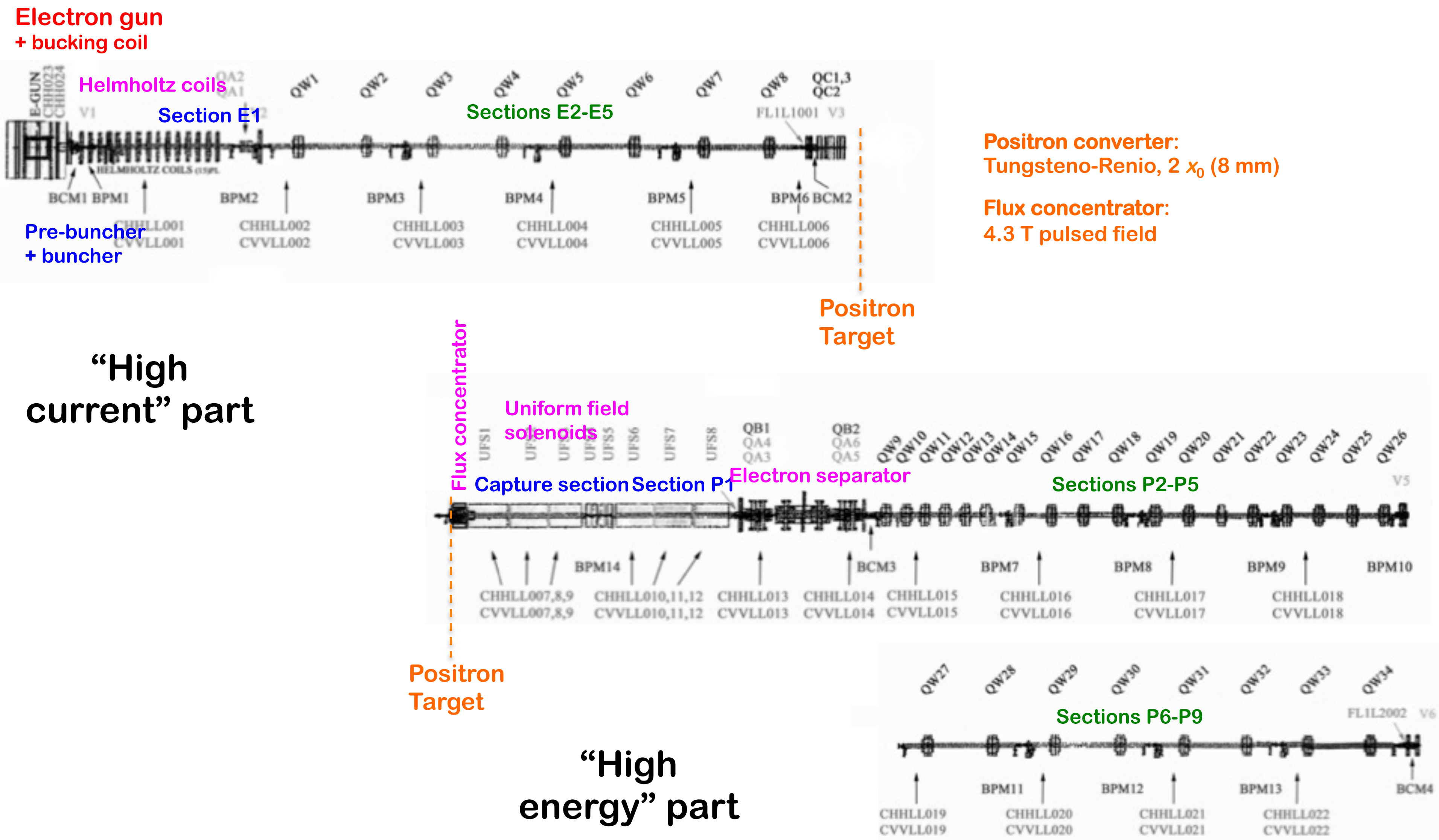
→ WE ARE WORKING in STATIC LINAC+BTF TRIGGERING SCHEME

Some Jitter contribution (see also AMY and UA9 experiences)

- LINAC SYS reference jitter (rms, 10ps, our best measure)
- LINAC GUN jitter (100ps)
- BTF STANFORD DDG535m single channel jitter (rms, 50ps + 0.01ppm of the channel delay) .



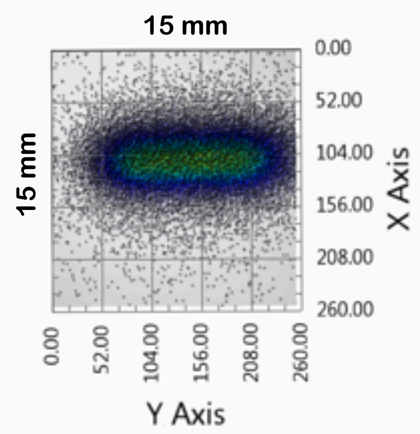
Layout LINAC



PADME

- **Requirements**
  - Highest possible repetition rate
  - Intermediate intensity in order to have a low pile-up probability
  - Positrons of highest possible energy
  - Longest possible bunch, to reduce the pile-up probability
  - Momentum spread <1%
  - Divergence <1 mrad
  - Spot< 1 mm (σ)
  - 10^{13} eot

- **Choices**
  - Dedicated use of the LINAC at 49 Hz
  - Use a dedicated optimized target instead of positron converter
  - Run at 40 ns in present configuration; upgrade of the LINAC gun pulser



Additional collimation after the last bending, in order to reduce dispersion