Performance and Upgrade of the DAFNE Beam Test Facility

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Outline

- Introduction: properties of the BTF beam
- Detectors for beam intensity diagnostics
- Detectors for beam size & position diagnostics
- Upgrade of the facility
- Summary and perspectives
The BTF is a $e^-/e^+$ test-beam facility in the Frascati DAΦNE collider complex. It makes use of the high current Linac:
- $1 \div 4000$ mA $e^+/e^-$
- 1 ns pulses, at least $10^7$ particles

Primary beam attenuation in order to:
- reach single particle regime, for detector testing purposes
- tune the beam intensity
- tune the beam energy
**BTF layout**

- **6° pulsed dipole**
- **45° dipole + strip detector**
- **Collimator, W slits**

**from Linac**
\[ \sigma_E = 0.5\% \]

**to spectrometer**
**Selectable Cu target**

**to BTF hall**
**E selector**
**to main rings**

**Increase energy and angular spread:**
1.7, 2.0 or 2.3 \( X_0 \) depth
**BTF beam**

- Beam intensity can be adjusted by means of the **energy dispersion** and **collimators**, down to **single particle** pulses
- Both $e^-$ and $e^+$ can be produced

<table>
<thead>
<tr>
<th>Number</th>
<th>$1\pm10^{10}$ e$^-$/pulse ($10^3$ s$^{-1}$ allowed in 2003)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>50–750 MeV</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>50 Hz [1 pulse to spectrometer]</td>
</tr>
<tr>
<td>Pulse Duration</td>
<td>1 or 10 ns</td>
</tr>
<tr>
<td>$p$ resolution</td>
<td>1%</td>
</tr>
<tr>
<td>Spot size $\sigma_{x,y}$</td>
<td>$\approx 2$ mm</td>
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</tbody>
</table>

**Beam diagnostics in a wide energy and intensity range is needed**

- Employing particle detector is mandatory for the **single particle** regime, where no beam diagnostics detector is sensitive…
- …but **saturation** effects are likely to arise above many hundreds particles in a **single bunch** of 1 [or 10] ns duration
Calorimetric counting

Number of produced electrons counted by total energy deposited in lead/scintillating fiber calorimeter (KLOE type):

- Limited to few tens of MeV, due to energy resolution

- Limited to few tens of particles, due to saturation effects

Calorimetric is **OK at low intensity**, not for high multiplicity beams: e.g. the AIRFLY experiment, designed to measure absolute fluorescence yield in air and its energy dependence, needs:

- full energy range
- maximum beam intensity
Cerenkov beam monitor

- A new detector, designed and built, in collaboration with the AIRFLY group, based on Cerenkov light emission

- Cross-calibrated with calorimetric measurement at low particle multiplicity

- Used to monitor beam intensity at higher intensity up $10^4 \div 10^5$ particles, in the full energy range

- Dynamical range can be further extended:
  - put a calibrated optical filter in front of the PMT
  - Use air as Cerenkov radiator
Cerenkov beam monitor

No optical filter

:10 optical filter
(measured attenuation = 0.096)
2 layers (x,y) × 384 strips, analog readout

410 μm thick, single-side, AC coupled strips, 121 μm pitch, 242 μm readout pitch

**Optimal focusing** at 493 MeV, measured spot size: \( \sigma \approx 2 \times 2 \text{ mm}^2 \)

**Defocused**

Beam spot measured with transfer line quadrupoles off, limited by vacuum pipe section

**OK for low intensity beam**
Sci-fi profile detector

- A permanent beam position and size monitor needed, both for beam **steering** and **optimization** purposes, and for providing useful information for detector testing, complementing the beam intensity monitors

- Such a position sensitive detector should have:
  - **negligible mass**, not to spoil beam characteristics (energy, divergence, spot size)
  - **good resolution**, as compared to beam typical size (1 mm required)
  - **sensitivity** both for **single particle** (even at low energy) and at **high beam intensity**

- **cladded scintillating fibers**, Pol.Hi.Tech type 0046, 1 mm diameter

- 4 layers of fibers glued together

- staggered by ½ fiber to minimize dead zones
Sci-fi profile detector

- Fibers are **bundled** together, light readout with **multi-anode PMT**
- With 16 pixel MA-PMT, 48 × 1 mm can be instrumented by bundling together **12 fibers** (3 adjacent fibers × 4 layers).
- Bundles are coupled to the photocathode through **grooved PVC mask**
- **Spatial resolution** should still be at mm level

- **Two detectors at 90°, for measuring x and y profiles, 4.8 × 4.8 cm² active area**
Sci-fi profile detector

- Charge weighted profiles for x and y fiber bundles

- Consistent with beam image from AGILE Si tracker
**horizontal scan:**
exit angle changed by changing current of the final bending magnet

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**Sci-fi profile detector**

Measured **x** and **y profiles** are available in real-time in the control system of the facility, together with the calorimetric measurement of the beam intensity.
Sci-fi profile detector

Calorimeter E=493 MeV

E in fibers, 1 e⁻

H size

Calorimeter E=101 MeV

E in fibers, 1 e⁻

H size

Spot size dominated by multiple Coulomb scattering:

E scan

E (MeV)

H size (mm)
Sci-fi profile detector

Intensity scan

\[ <n> \approx 2 \]

\[ \chi^2/\text{ndf} = 27.67 / 10 \]

\[ P1 = 117.2 \]

\[ P2 = 32.83 \]

\[ P3 = 2.795 \]

\[ P4 = -1.539 \]

\[ P5 = 0.6410 \]

\[ P6 = 0.09224 \times 10^{-2} \]

horizontal size (mm)

\[ <n> \approx 150 \]

\[ \chi^2/\text{ndf} = 2619 / 7 \]

\[ P1 = 261.9 \]

\[ P2 = 7.7 \]

\[ P3 = 2.955 \]

\[ P4 = 1.75 \]

\[ P5 = 13.85 \]

\[ P6 = 0.5685 \]

horizontal size (mm)

\[ <n> \approx 600 \]

\[ \chi^2/\text{ndf} = 2007 / 9 \]

\[ P1 = 7210.7 \]

\[ P2 = 2007 \]

\[ P3 = 3.489 \]

\[ P4 = 11.10 \]

\[ P5 = 0.1035 \]

horizontal size (mm)

- Same performance at intermediate intensity
‘Parasitic’ operation

- **During the DEAR 2002** and the **FINUDA 2003** runs, a duty cycle of ~50% was reached, corresponding to $5 \times 10^5$ particles/day.

- **Switch to BTF, 1.5 min**, is **dominated by transport dipole ramping up**.

- **Practically no BTF operation is possible during the KLOE run**, due to the topping-up mode (continuous injections, without stopping the data taking).
BTF history

Feb. 2002
First beam delivered; commissioning of the line

KLOE data taking

Beam characterization; Operation during DEAR run (Parasitic mode)

Operation during DAΦNE shutdown (Dedicated mode)

Operation during FINUDA run (Parasitic mode)

Apr. 2004 – …
At least 1 year of KLOE data taking
- To operate the BTF almost independently from the collider, we designed a completely separate line at the Linac exit.

- Room in tunnel made by moving down the spectrometer dipole and detector.

- The transport magnet, the large and slow dipole, is replaced by a pulsed magnet;

- In the first phase, beam will be deflected by a dedicated, fast DC dipole.

- Attenuating target and slits moved to BTF line, no need to remove them for injection.

- The selector system, dipole magnet+slits, is moved to the dedicated line, no need to change settings for injection.
- The Linac final part was completely dismantled

- The lines have been rebuilt:
  - new thin chamber,
  - new vacuum line,
  - all magnet repositioned, new elements added

- Services reconnected (power, controls, cooling); vacuum restored
BTF upgrade

- Modified Linac re-commissioned:
  - spectrometer line OK
  - main rings transfer-line OK, KLOE run started
  - new BTF line also OK (without attenuator and without collimators)
- We will restart beam delivery to experimental groups from May 27
Summary

✓ A wide range of beam intensity and energy is accessible at the BTF
✓ A large number of experimental groups with different requirements successfully run at the BTF, thanks to
  ▪ easy tunable beam parameters
  ▪ efficient and effective diagnostics tools
  ▪ high level of reproducibility in different running configurations

✓ The operation of the BTF in ‘parasitic mode’ to the collider experiments was successfully implemented with good efficiency (40%-50%)

(already with the 2002-2003 configuration, with part of the BTF line shared by the injection line to main rings)

✓ Improvements in 2003:
  ▪ High-intensity Cerenkov counter developed
  ▪ Beam profile monitor with scintillating fiber detector
  ▪ Infrastructure: gas system, motorized table, permanent DAQ system
Present status and perspectives

The 2004 upgrade should greatly improve the duty-cycle allowing the BTF operation almost independently from the collider:

- Separate line to optimize duty-cycle, 70%-80% efficiency expected
- Lower bound of the energy range extended to few MeV
- Low-Z exit window, for low energy beam optimization (100 μm Be)

Still to do:

- Re-commission the new BTF line in the full range of operation
- Deliver beam to experimental groups before summer shutdown
- Improve beam profiling detectors (silicon trackers)

2005 upgrade:

- Complete line separation with pulsed dipole installation
- Photon tagged source (collaboration with AGILE group)
Access to the facility should be asked to the **BTF Users Committee**:  
*P. Gianotti, G. Mazzitelli* (responsible), *S. Miscetti, M. Preger* (chairperson), *P. Valente*  
*P. Possanza*, secretariat

Technical documentation, photographs and more on the Web site:  
http://www.lnf.infn.it/acceleratori/btf/

The BTF was widely used as a TARI facility in the **EU 5th Framework Program**  
and will be involved in the **EU 6th Framework Program**.