DAΦNE Beam Test Facility

The BTF staff: G. Mazzitelli & P. Valente
What is the DAΦNE BTF?

A $e^+/e^-$ test-beam facility in the DAΦNE complex, profiting of the high current LINAC… …but mainly intended for single electron operation in the energy range 20-800 MeV

Multi-purpose facility:
- H.E. detector calibration and setup
- Low energy calorimetry & resolution
- Low energy electromagnetic interaction studies
- High multiplicity efficiency
- Detectors aging and efficiency
- Beam diagnostics

F. Sannibale, G. Vignola
‘DAΦNE-LINAC TEST BEAM’
LINAC beam attenuation

LINAC Beam 1-500 mA

tunable W target: 1.7, 2.0, 2.3 \( X_0 \)

W slits

45° magnet

W slits

detector

Selected energy (MeV)

DAΦNE Beam Test Facility (4)
Counting electrons

- Total energy in calorimeter, KLOE type, lead/scintillating fibers
  resolution: 4.7%/√E(GeV)
Relevant publications

- PAC 2003
  *The commissioning of the DAFNE Beam Test Facility*

- Nucl. Instrum. Meth. *A in press*, LNF-03-003(P)
  *Commissioning of the DAFNE Beam Test Facility*

- DAFNE Technical Note BTF-1
  *DAFNE Beam Test Facility Upgrade Proposal*

- DIPAC 2003
  *Beam Instrumentation for Single Electron DAFNE Beam Test Facility*

- Frontier Detector for Frontier Physics
  *Detectors for high multiplicity electron beam diagnostics*

- ECFA/DESY Workshop
  *First tests of LCCAL prototype at BTF*

- 28th ICRC
  *Air Fluorescence Induced by Electrons in a Wide Energy Range*

- Frontier Detector for Frontier Physics
  *Triple GEM detector operation for high rate particle triggering*

- 5th Amaldi Conference
  *RAP: Acoustic detection of particles at the DAFNE BTF*
Equipment

• 32 channel DAQ TDC/ADC for diagnostics
• NIM, VME, CAMAC Branch, VME controllers
• ‘Devil’ VME controller, NIM modules
• Remotely controlled trolley
• Gas system
• HV system…

- 48 ch. HV CAEN SY2527 neg.
- 40 ch. CAEN SY127 pos.
- Cabling BTF HALL-BTF CR
- Network: LNF and dedicated
- DAFNE Consoles and PCs available

\[ \text{C}_4\text{H}_{10}, \text{CO}_2, \text{Noble Gas}, \text{C}_2\text{H}_6 \]
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**Feb. 2002**
First beam delivered, commissioning of the line

**Nov. – Dec. 2002**
Beam characterization, and first user shifts during the DEAR run (Parasitic operation)

**Mar. – Aug. 2003**
Dedicated user shifts during the DAΦNE upgrade

**From Sep. 2003**
Parasitic operation restarted during the FINUDA run
2002-2003 run statistics

**Nov.-Dec. 2002**

- **Shutdown**
- **Commissioning**
- **Maintenance**

**Mar.-Sep. 2003**

- **Shutdown**
- **Maintenance**
- **Commissioning**

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**Nota Bene**

- **Shutdown** period in June 2003 includes the long RAP installation
- The greatest part of the runs (≈ 12 weeks) was in dedicated mode in Mar.-Aug. 2003 during DAΦNE upgrade
BTF (operated) parameters

e\(^{-}\) and e\(^{+}\)  

\[ n_{\text{average}} = \text{from 1 to } 10^5 \text{ particles} \]

Energy:  
20–800 MeV e\(^{-}\)/e\(^{+}\)

Repetition rate:  
49 Hz (+1 to energy measurement)

Pulse Duration:  
1–10 ns

Single particle production (1% energy selection)

100 m\(^2\) Experimental Hall

Up to \(10^{11}\) particles/pulse (500 mA)

Only \(10^3\) e\(^{-}\)/sec were allowed in 2002-2003, (authorizations asked for \(10^{10}\) e\(^{-}\)/sec)

Upgrade of exit window planned, to go to lower energy (1.5 mm Al → 0.1 mm Be)
Operation and users experience
AIR FLuorescence Yield Setup

lead

Fluorescence chamber

Cerenkov beam monitor

beam

BTF calorimeter

elliptical mirror chamber
The Cerenkov beam monitor

- In order to measure the air fluorescence yield, high multiplicity is needed.
- Calorimeter is no longer effective to monitor intensity (saturation effects): a new detector was designed, built, and used in collaboration with the AIRFLY group, based on Cerenkov light emission.

10^4 - 10^5 particles in the full energy range.
Beam spot (I)

- Beam pipe *horizontal* acceptance measured with the calorimeter: maximum divergence: 37 mrad

- Indirect beam spot measurement:
  \[ \sigma_x \sim 4.7 \text{ mm} \]
AIRFLY: first measurements

1. Calorimeter/Cerenkov calibration

No filter

Fluorescence Lifetime ≈5 ns at 340 mbar N$_2$

2. First fluorescence measurements

:10 optical filter

Attenuation factor = 0.096
Tiles + Si planes (not shown)

Fibers inside collector in front of PMs

User experience: LCCAL (hybrid EM calorimeter)

PM holders

Single electrons with different energies

VME (diagnostics)

HV

Calo2

VME + Camac (users)

LCCAL

DAΦNE Beam Test Facility (16)
LCCAL: energy resolution/linearity

Calibration applied, 1, 2, 3 e⁻ peaks: good linearity vs particle multiplicity

\[ \sigma_E/E \]

1. Photoelectron stat. negligible
2. Sampling term 11.5% as in MC
3. Uniformity of light collection still at a level < 10% using all layers. Effect on resolution to be evaluated at next Cern TB (Aug 2003)

\[ N_{\text{phe}}>5.1 \text{ layer} \rightarrow \text{Cal(45 layers)} \sim 250 \text{ MeV/Mip} \sim 800\text{Npe/GeV} \]

Light uniformity better than 20%

OK also @ BTF (E ~500 MeV)
**AGILE Silicon Tracker:** 14 planes, with two Si-layers per plane providing the X and Y coordinates. 9.5 x 9.5 cm², microstrip pitch equal to 121 µm, and thickness 410 µm. 384 readout channels (readout pitch equal to 242 µm).
Beam spot (II)
(AGILE Si tracker)

410 \mu m thick, single-side, AC coupled strips, 121 \mu m pitch, 242 \mu m readout pitch

2 layers (x and y) \times 384 strips, analog readout

\sigma_x \approx \sigma_y \approx 2 \text{ mm}
Electron Beam @ 500 MeV
49 Hz single electron with ~1 ns pulse duration
Time resolution and Efficiency

**Time resolution**

- **Threshold = 150 mV**
- **Threshold = 180 mV**

**Efficiency in 20 ns**

- 3.6 ns (RMS)
- 1.15 cluster size

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DAΦNE Beam Test Facility (21)
User experience: CAPIRE

Camere a Piani Resistivi
design, test and industrialization of
Resistive Plate Chambers for high
energy physics

Few electrons, with different energies

Glass Restive Plate Chamber efficiency
in wide range of multiplicity and
repetition rate (up to 10 Hz/cm²) as a
function of gas mixture and
position (i.e. near spacers and edges)
CAPIRE large glass chamber efficiency

new large glass chamber

old small chamber
RAP (Acoustic detection of particles)

$10^5 \rightarrow 10^8$ electrons; maximum energy

7-stage suspension

cryostat

beam

aluminum bar

piezoelectric
RAP Installation @ BTF

DAΦNE Beam Test Facility (25)
Flag = metallic high fluorescence plate viewed by a camera
Different fluorescence targets tested (berillium, cromox) for very low current beam diagnostics
User experience: SDD test (for SIDDHARTA experiment)

Silicon Drift Detectors: fast and **triggerable** detectors, foreseen to replace CCD readout in atomic physics experiment (to reduce asynchronous background)

BTF beam

SDD setup

- Pb
- Cu
- Fe and Sr sources
- secondaries

Remotely controlled trolley

1÷100 electrons
Prototype SDD area trigger test (SIDDHARTA)

a) Without asynchronous background beam only (16 h)

b) With asynchronous background, i.e. beam + the $^{55}$Fe and $^{90}$Sr sources, and trigger off (20')

c) same as in b), but with trigger on (16 h)
User experience: Nanotube beam bending (NANO)

We are able to run multiple experiments by taking advantage of the two separate beam exit ports and of the motorized trolley.

**RAP cryostat raised**

**NANO setup**

**Remotely controlled trolley**
User experience: Nanotube beam bending (NANO)

Beam spot size and position monitored by means of a scintillating fiber detector

10^5 positrons; maximum energy

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More diagnostics and future plans
Beam profiler prototype (scintillating fiber detector)

horizontal scan

1 mm scintillating fibers

$\sigma_x = 2\ mm$

Multianode read out

3x4 collected fiber, 3mm pixel
Beam profiler prototype (II)

Integrated into the general BTF control toolbox

Now building a second detector for vertical coordinate measurement
‘Parasitic’ operation in 2003 (DEAR run)

- Switch to $e^+$: 3.5 min
- Switch to $e^-$: 3.5 min
- BTF run: 22 min
- Switch to BTF: 1.5 min

50% duty cycle
$5 \times 10^5$ single $e^-$/day
Upgrade layout

- Estimated duty cycle:
  - ✔️ 80% FINUDA
  - ✔️ 70% KLOE
- March 2004?
Summary and Perspectives

All the user groups were satisfied…

The facility has demonstrated:
• high level of reliability
• high versatility in very different running configurations

We are grateful to all the Divisione Acceleratori staff, in particular we thank all the DAΦNE Operators

We are also acknowledge the first experimental groups for their help in setting up the BTF beam

1. Upgrade: separate line to optimize duty-cycle
2. Low-Z exit window, for low energy beam optimization (100 µm Be)
3. Improve beam profiling detectors (silicon trackers)
4. Permanent DAQ system
Access to the facility

‘Users Commission’:
  P. Gianotti
  G. Mazzitelli (responsible)
  S. Miscetti
  M. Preger (chairperson)
  P. Valente

P. Possanza, secretariat

All requests should be addressed to the commission and/or the facility responsible

The BTF has been a facility in the EU 5th Framework Program (TARI)

…and will be largely involved in the EU 6th Framework Program
The DAFNE Beam-Test Facility (BTF) is a beam transfer line which has been designed in order to optimize the operation mode in which single electrons are stochastically produced for detector calibration purposes.

**Energy Range**
- 25-800 MeV $e^-$
- 25-550 MeV $e^+$

**Max. Repetition Rate**
- 50 Hz

**Pulse Duration**
- 1-10 ns

**Current/pulse**
- $1 \times 10^{10}$ particles

**Allowed Current**
- $10^9$ particles/second

**Documentation**
- Publications
- Pictures
- Technical Documentation
- How to get here

**BTF Commissioning**
- Jan.-Feb. 2002 Commissioning
- 2003 Schedule
- List of runs

**Users Committee**
- Members
- Beam-time request
- Beam-time requests DB
Spares
Calorimeter performance

Calorimeter 2:
Good linearity up to \( \sim 10 \) particles and more
Energy range

Trying to explore all the available energy range, down to few tens of MeV…

Good linearity changing $e^-$ selected energy

Calorimeter resolution scales as $\sqrt{E}$

We could each an energy as low as 25 MeV
Example: 50, 80 MeV starting from a LINAC energy of 320 MeV (not optimized!)
Energy resolution

- The resolution is very close to the intrinsic calorimeter resolution ($\Delta E/E \sim 1\%$)

471 MeV
Aim:
measure energy dependence of fluorescence in air/nitrogen in the energy range relevant for the core of an extensive air shower (the most probable energy of electrons in the EAS core is 80 MeV)

User experience: AIRFLY

Requests:
Multiplicity between a few electrons and $10^4$-$10^5$
Energy in the range 50 – 800 MeV

Common systematics
• Electron energy
• $p$ and $T$, gas
• and $\lambda$ dependence
Measurements at the first test beam

Understanding and optimization of beam associated background. Improved shielding along the BTF line and around PMTs.

Successful BTF commissioning of 1 ns bunch for fluorescence lifetime measurement

Operation of fluorescence chamber with nitrogen and dry air. Remote control of gas and pressure. First measurements with interference filters. First energy scan.

Successful test of elliptical mirror concept (factor 10 higher light collection)

Inter-calibration of calorimeter and Cerenkov beam monitor.
Background reduction

Bending 1

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DAΦNE Beam Test Facility (46)
Without target…

…with target: low $\beta$, high divergence

**Optics**

Comisióncientífica Nazionale I

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