Beam diagnostics at DAΦNE with fast uncooled IR detectors

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M. Piccinini, A. Raco, R. Sorchetti

Content

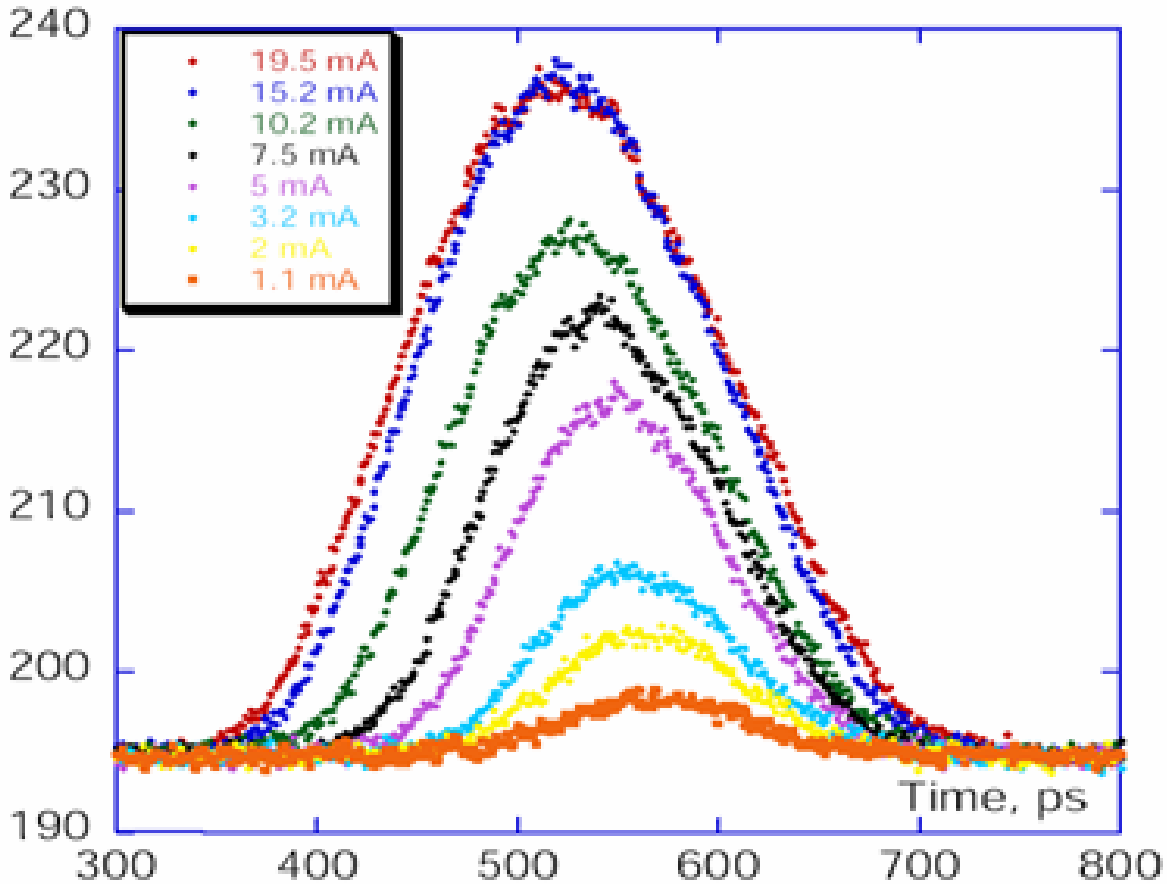
- Requirements of beam diagnostics
- Beam diagnostics with synchrotron radiation
- Longitudinal diagnostics with fast IR detectors
- Diagnostics @ DAΦNE on the positron ring
- Future applications

Ideal diagnostic

- Suitable for all accelerators
- Compact and robust
- Easy to manage
- Vacuum compatible
- Fast
- Low cost

SR BEAM DIAGNOSTICS @ DAΦNE

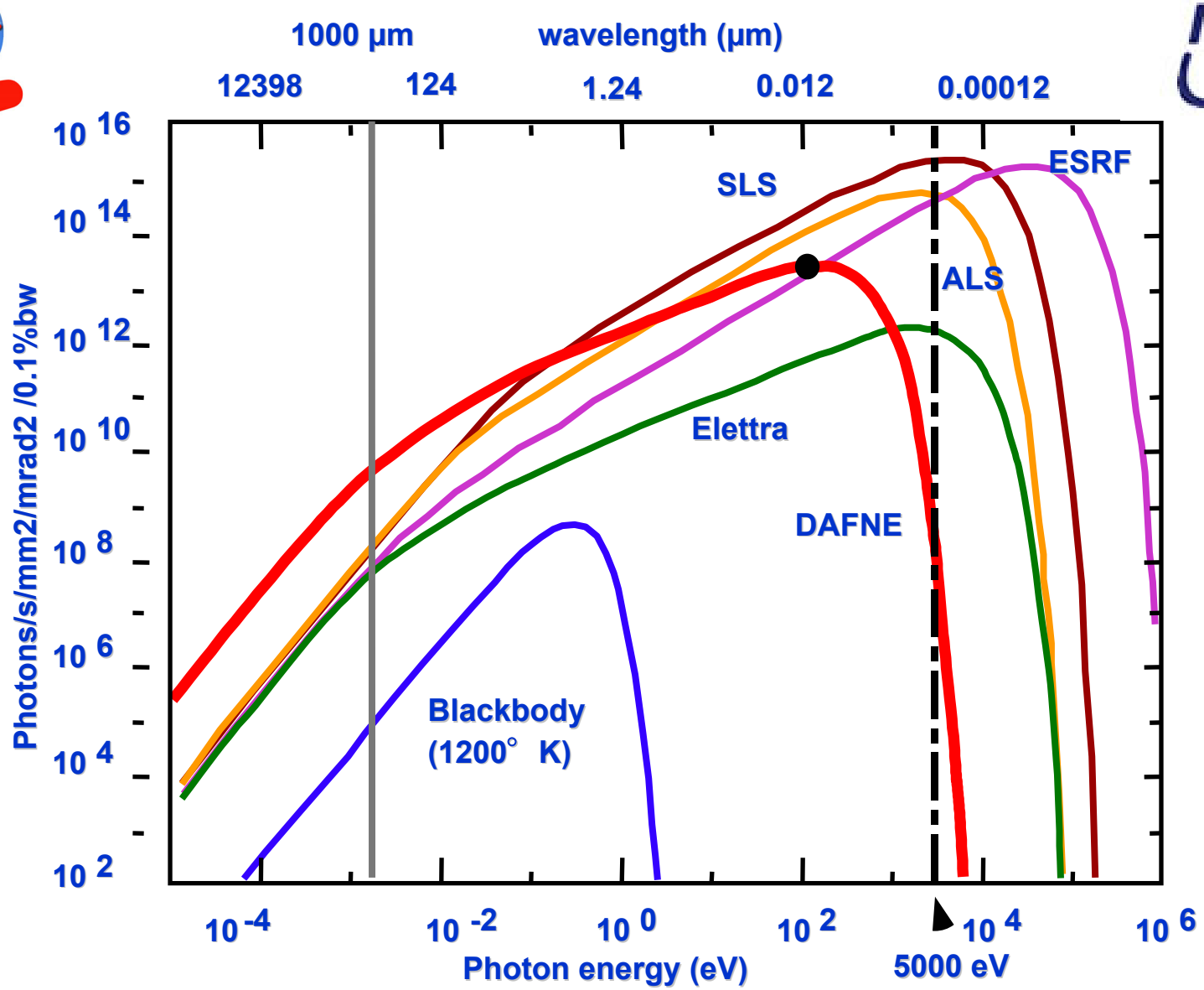
Positron bunch lengths of a single bunch at DAΦNE



BUNCH LENGTHS
few mm → few ps
NEED OF FAST PHOTON DETECTORS!

Streak Camera: ps resolution....BUT.... expensive, not easy to manage, etc.

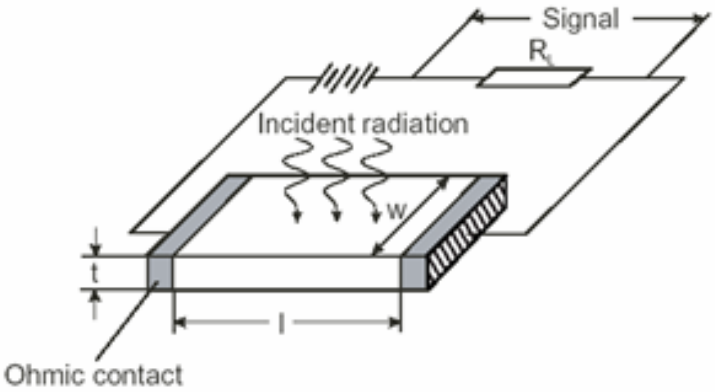
IRSR BRILLIANCE

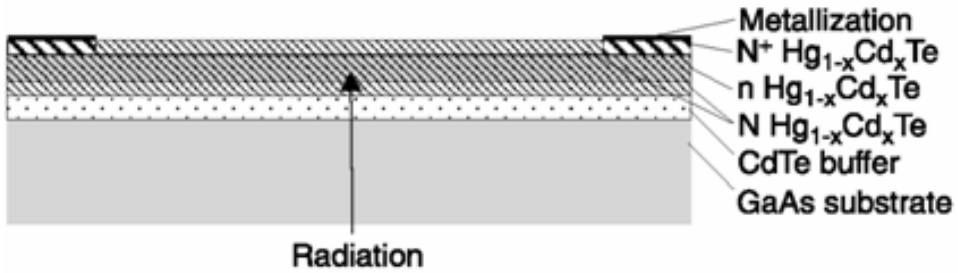


Fast IR detectors are suitable for BEAM DIAGNOSTICS

Fast Uncooled IR Photon Detectors

HgCdTe Uncooled IR Photon Detectors 2 – 12 micron
Optimized @ 10.6 micron





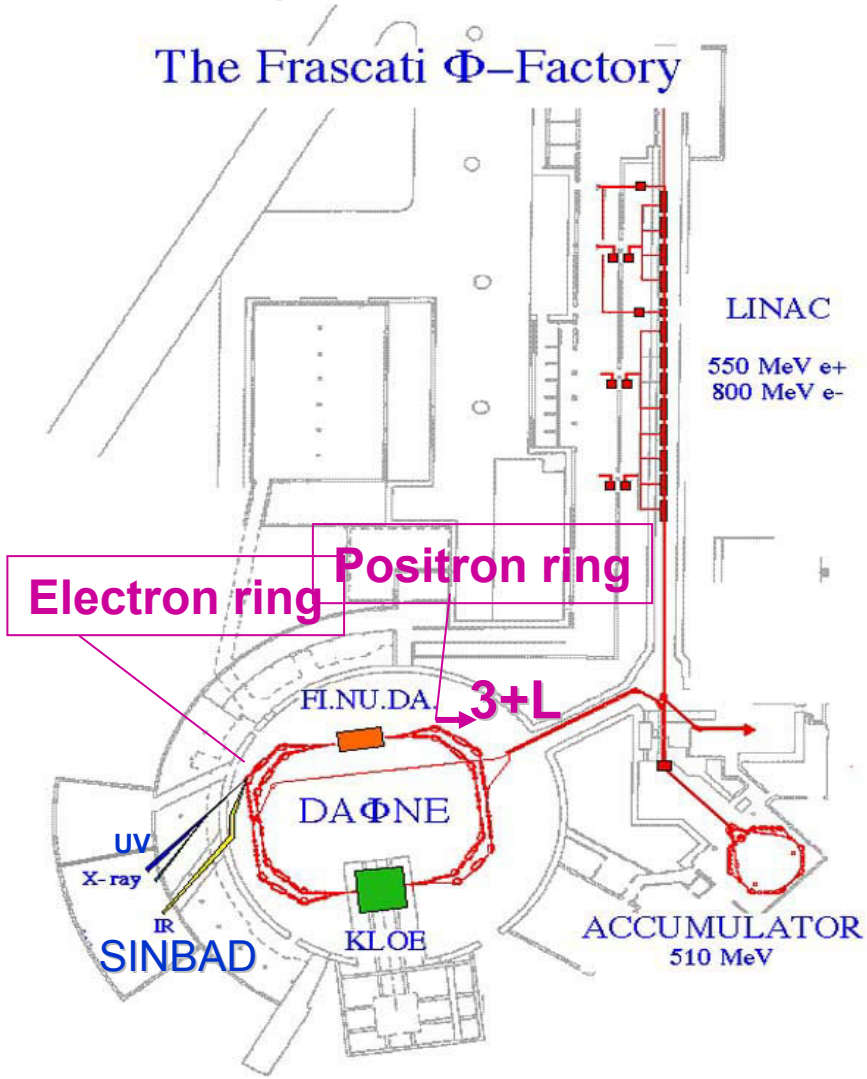
Minimun response time
τ ~ 500 ps

PC DETECTOR

Active area
from 50 x 50 micron^2
to 1 x 1 mm^2

SINBAD: IR-BEAMLINE AT FRASCATI

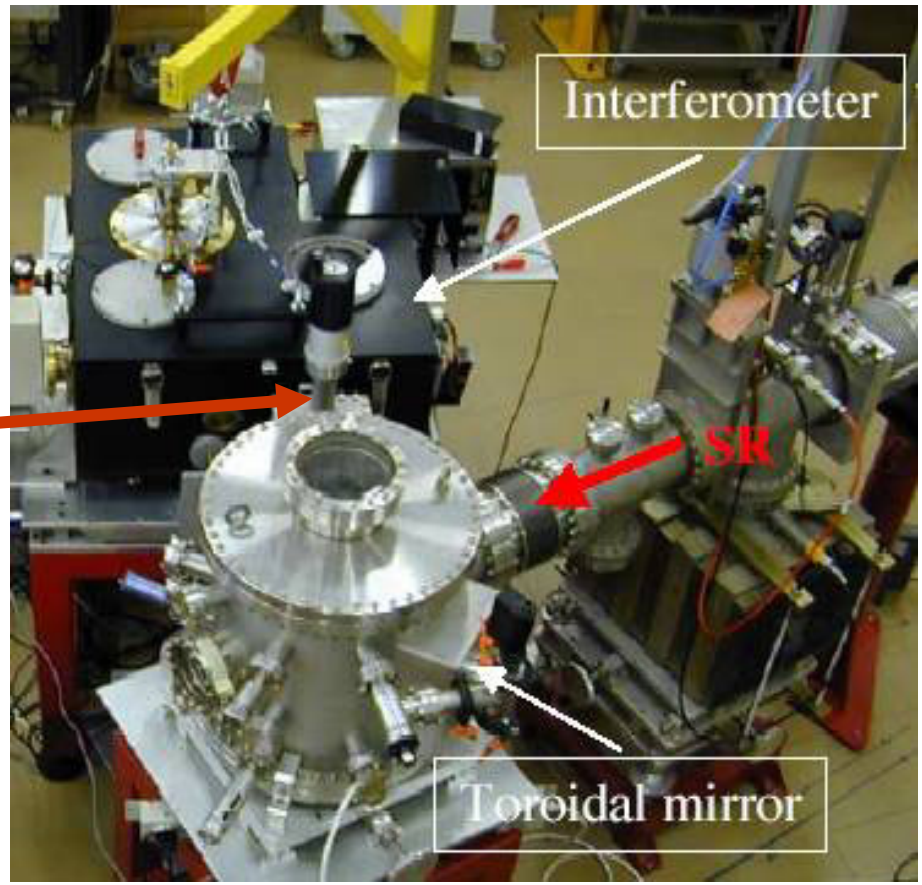
e^--e^+ collider
Low Energy Rings: E=0.51 GeV
High Current: I > 1 A



e⁻ SINBAD beamline @ DAΦNE

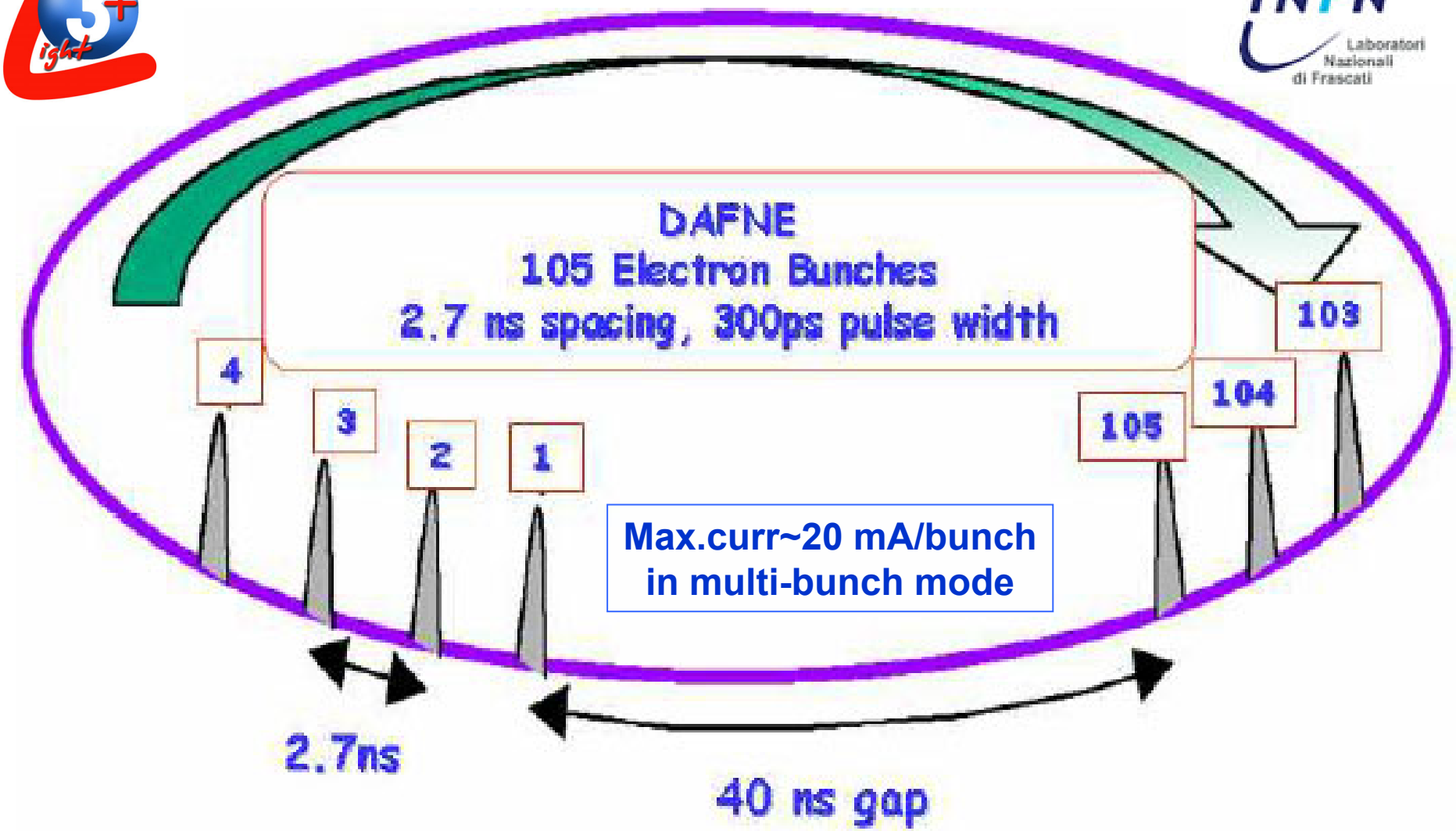
Longitudinal diagnostics and IR detectors characterization

IRSR Light

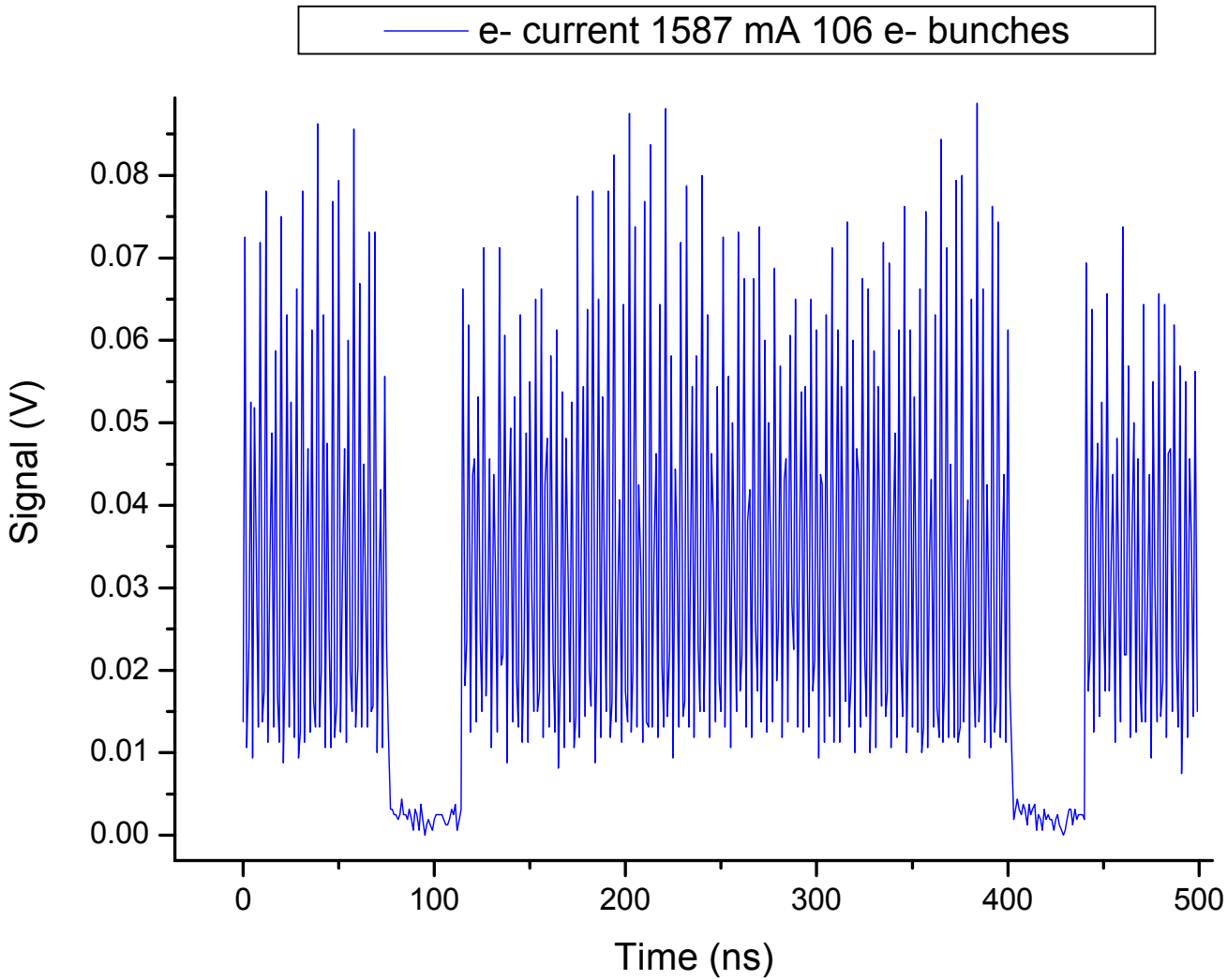


Uncooled PC or PV MCT IR detectors → Low Noise Amplifier 0.01-2500 MHz Bandwidth → SCOPE 6 GHz Bandwidth → Acquisition data based on LabView Platform

TIME STRUCTURE OF ELECTRON BUNCHES AT DAΦNE



IR RADIATION EMITTED BY 106 ELECTRON BUNCHES

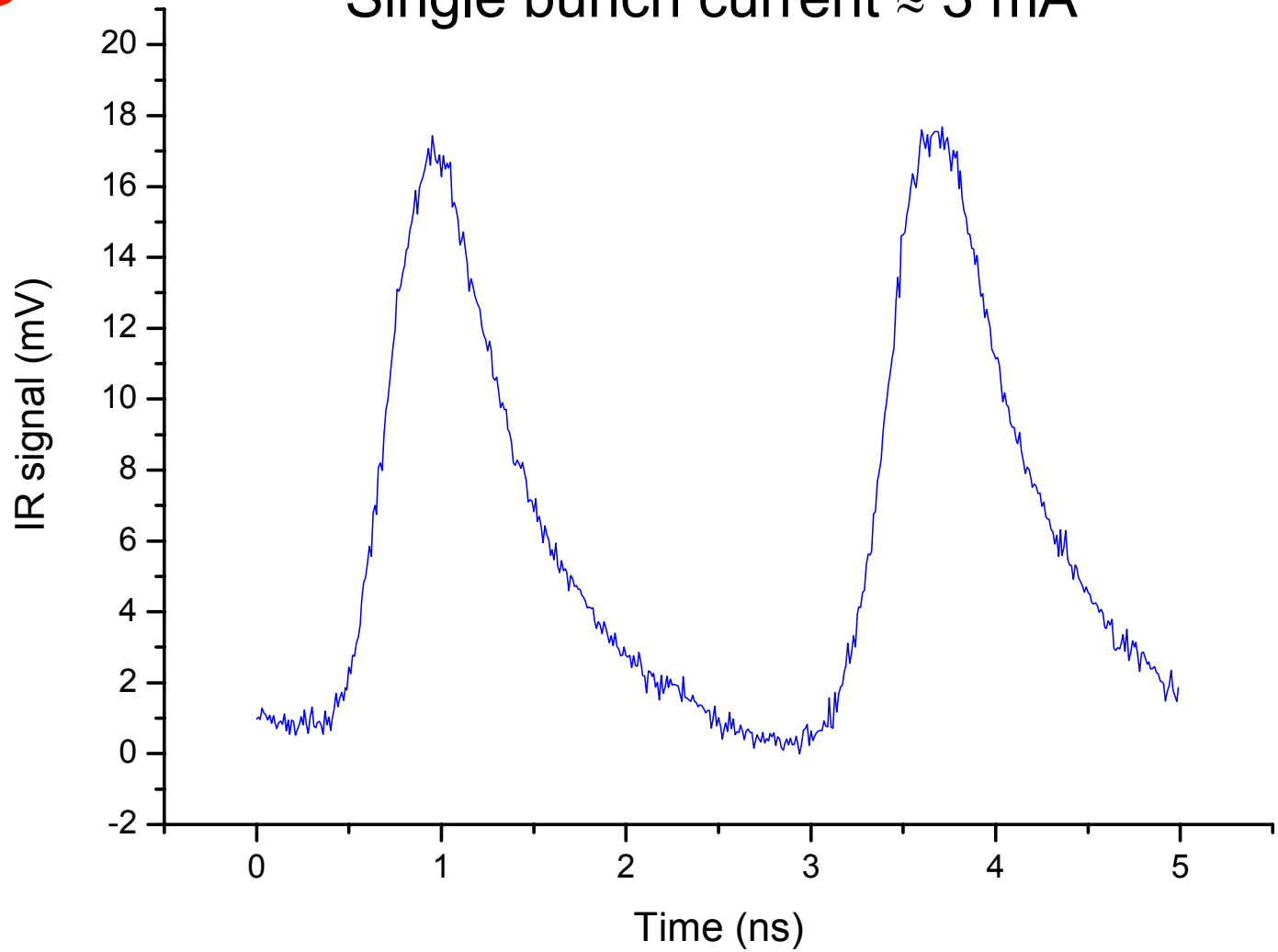


Electron current 1587 mA – 106 bunches
Average current per bunch about 15 mA

BUNCH LENGTH MEASUREMENTS

Electron pulses observed with a PC detector

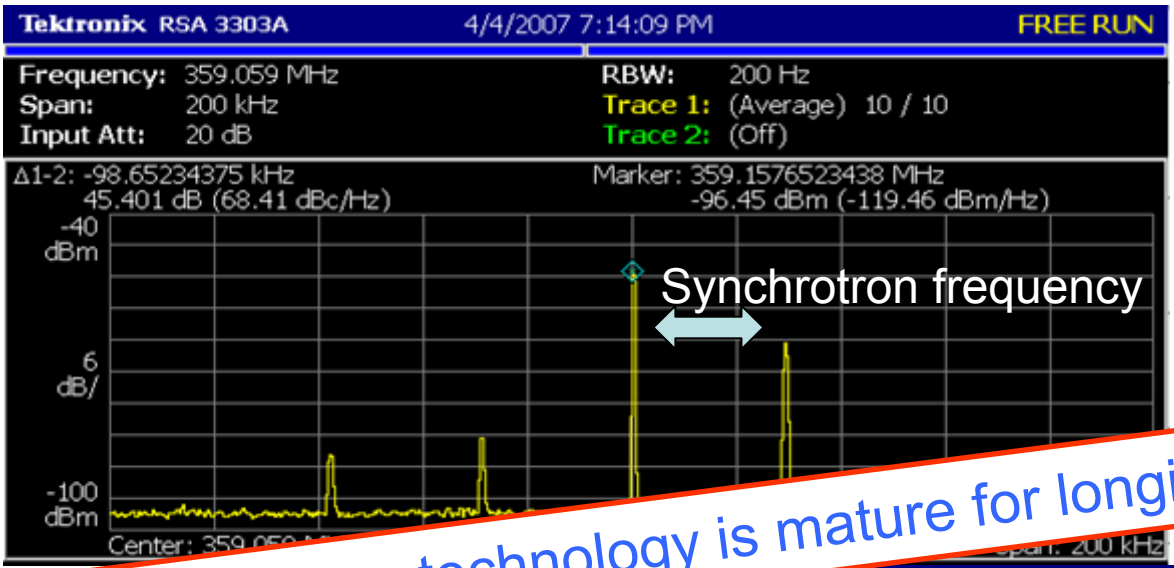
Single bunch current ≈ 3 mA



Rise time ~200-250 ps, response time 600 ps

Longitudinal Feedback

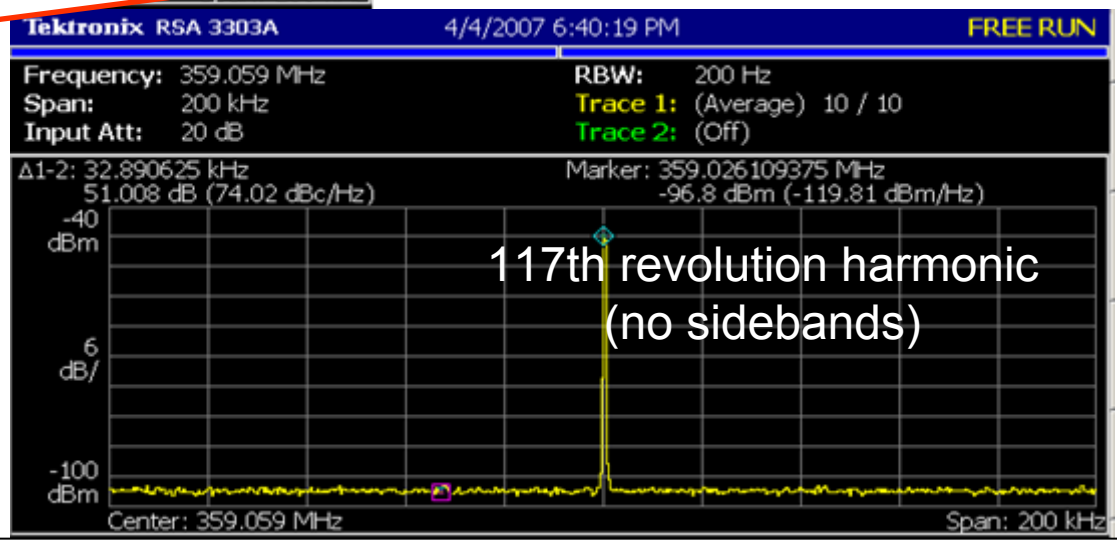
Amplified signal from the photoconductive infrared detector showing the behaviour of the longitudinal feedback system at DAΦNE using a spectrum analyzer



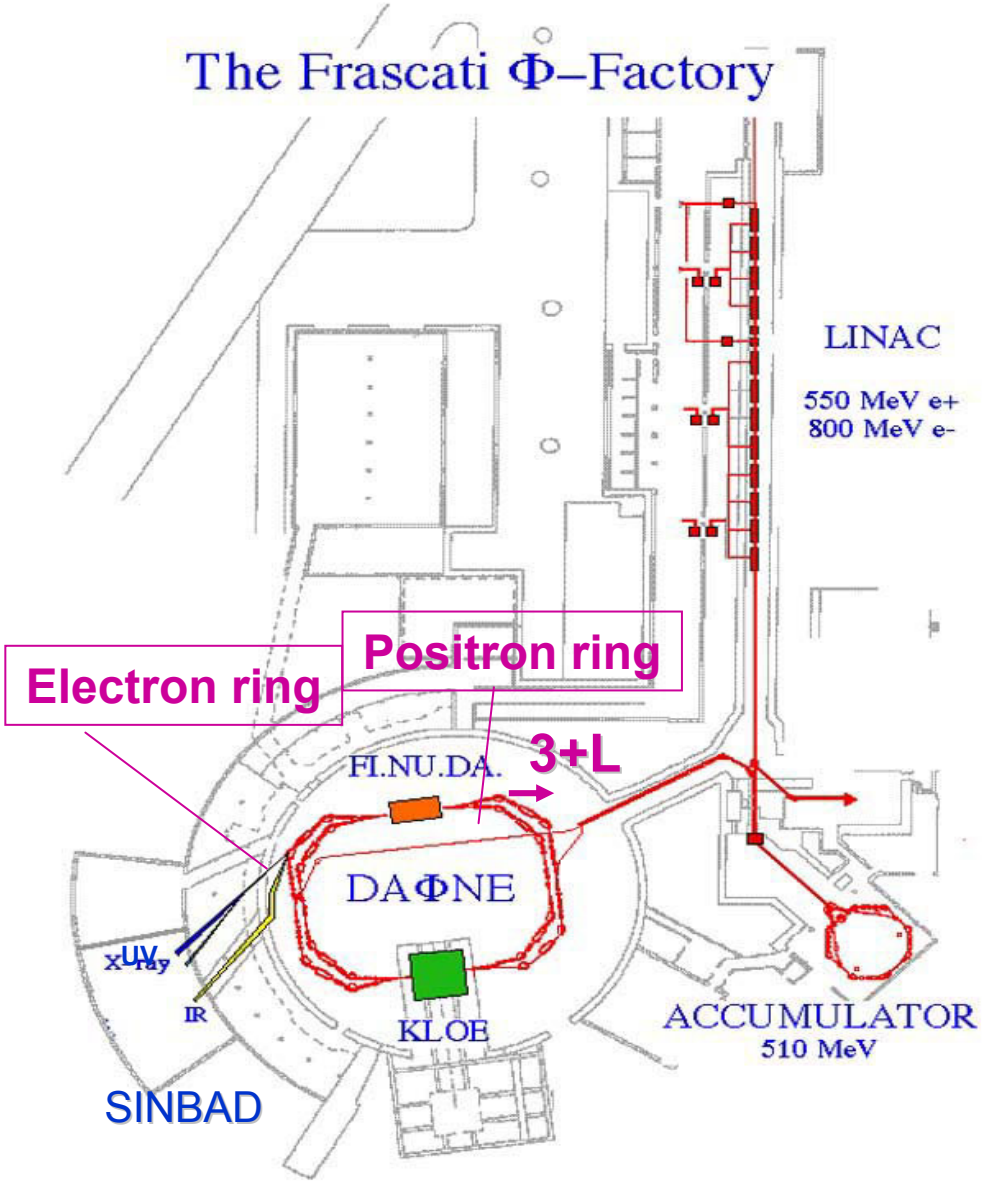
Longitudinal feedback OFF with 734 mA e- beam current, 106 bunches

IR detectors technology is mature for longitudinal beam diagnostics

Longitudinal feedback ON with 1227 mA e- beam current, 106 bunches

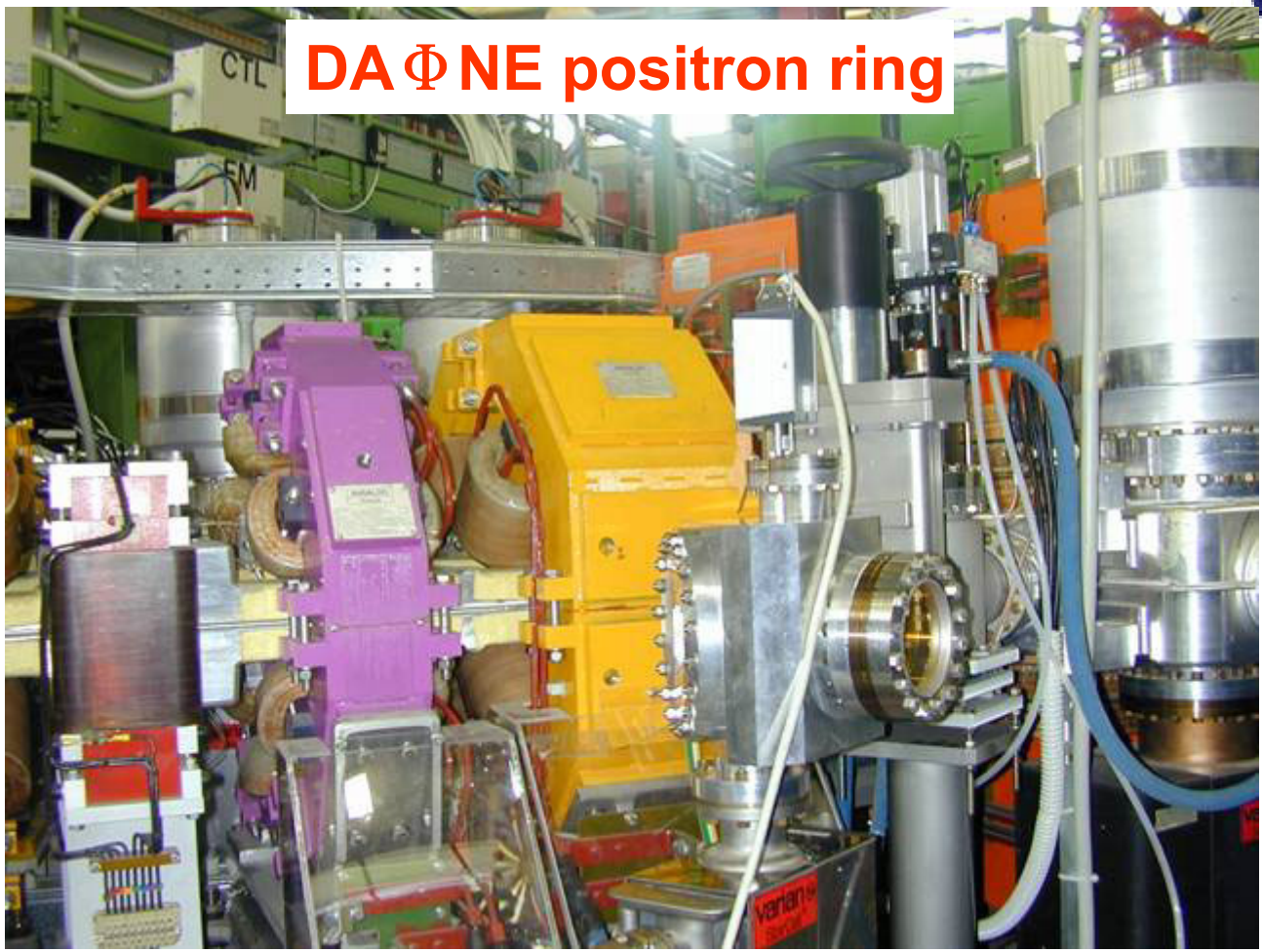


DIAGNOSTICS ON THE POSITRON RING



"3+L"...TIME RESOLVED e+ LIGHT

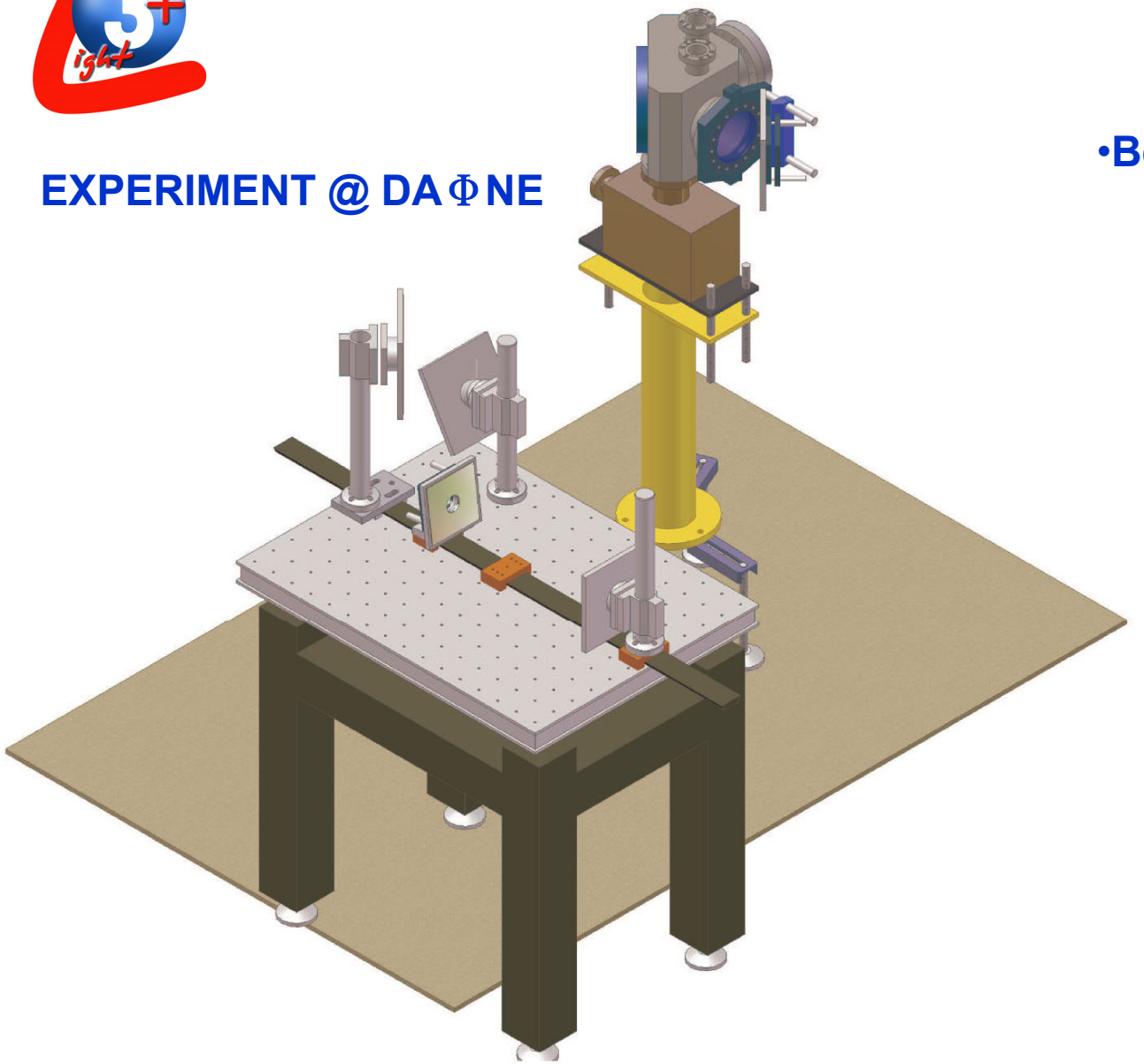
SR light from e+ source



Study of positron bunch lengths and instabilities to improve DAΦNE diagnostics, (i.e., increasing the current in the e+ ring, collider luminosity, ….)

"3+L"...TIME RESOLVED e^+ LIGHT

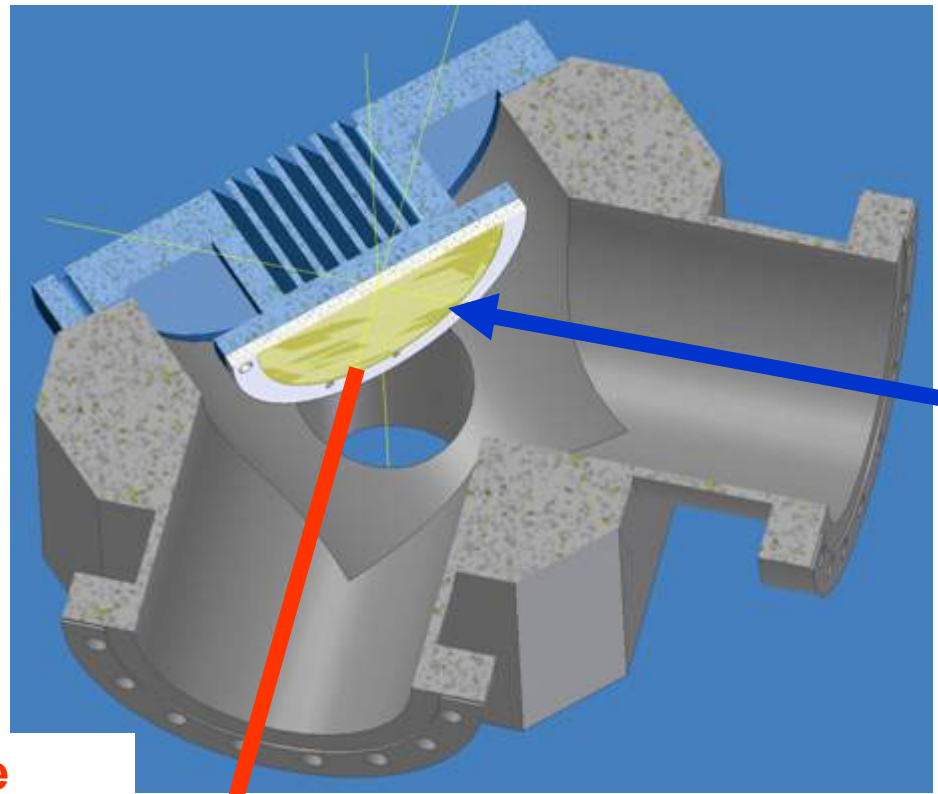
EXPERIMENT @ DAΦNE



- Bending magnet SR port on the e+ ring
- HV chamber

HIGH VACUUM CHAMBER

Gold coated mirror and ZnSe window are used
to reflect and transmit the SR light in the IR domain



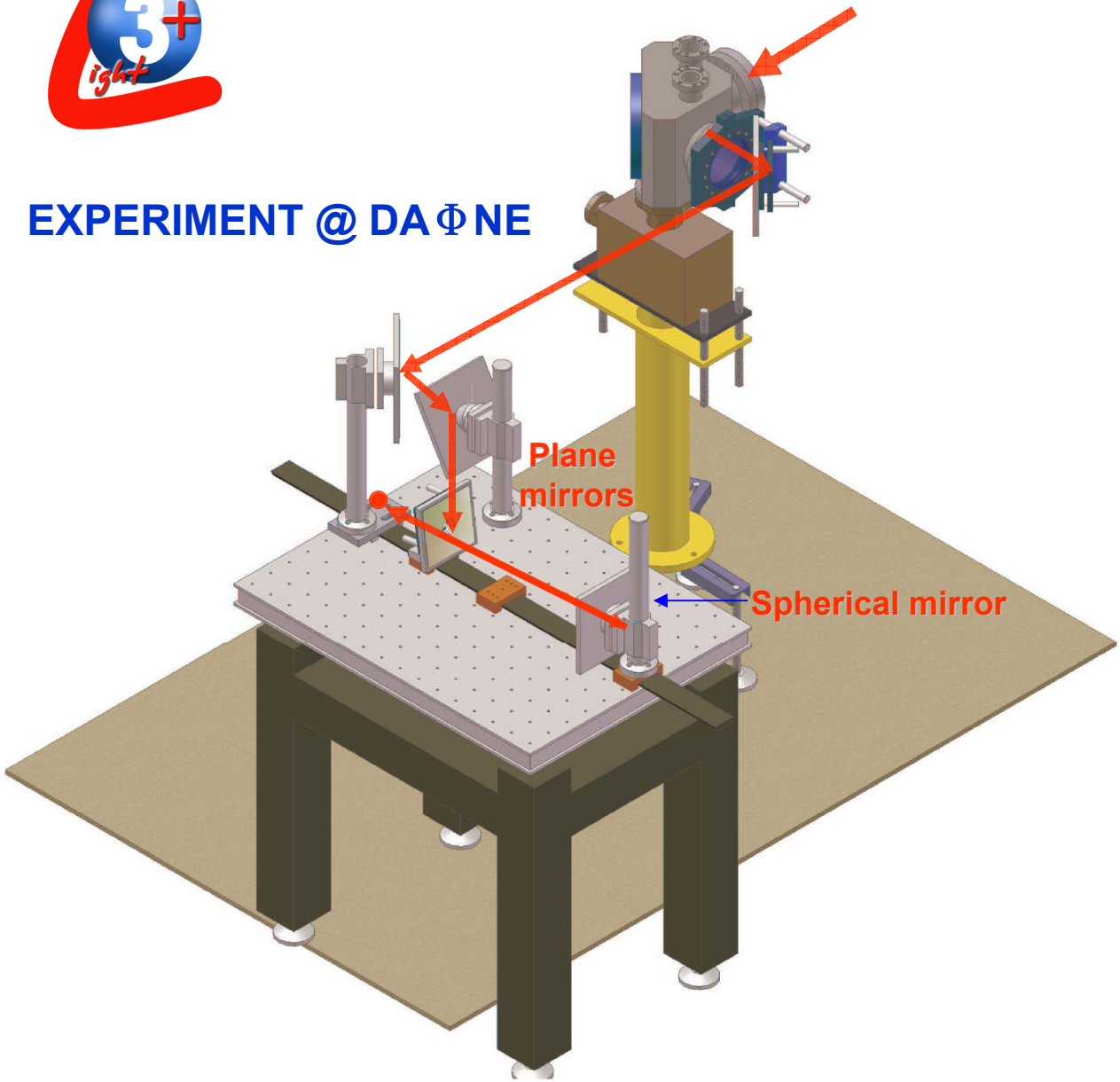
SR Light

ZnSe
IR window

IR Light 0.6 to 12 microns

"3+L"...TIME RESOLVED e+ LIGHT

EXPERIMENT @ DAΦNE



- Bending magnet SR port on the e+ ring
- HV chamber
  Gold-coated plane mirror
  IR ZnSe window
- Reflecting Optics
- Fast IR detectors

"3+L"...TIME RESOLVED e+ LIGHT

Optical Beam Path

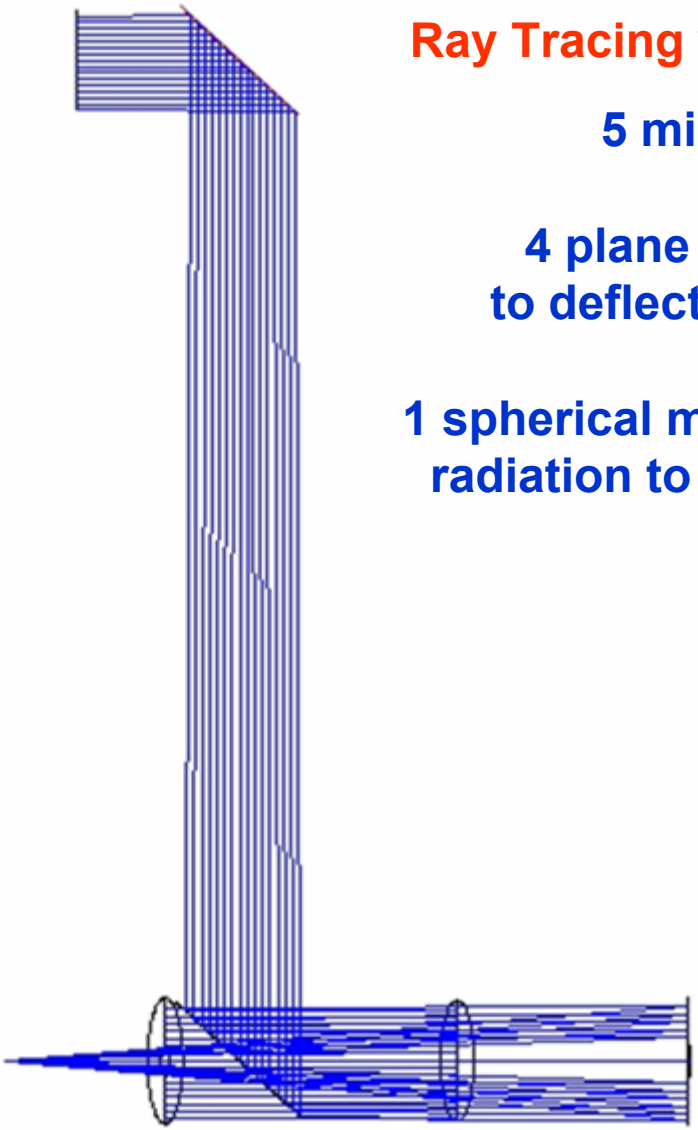
Ray Tracing with ZEMAX

Top view

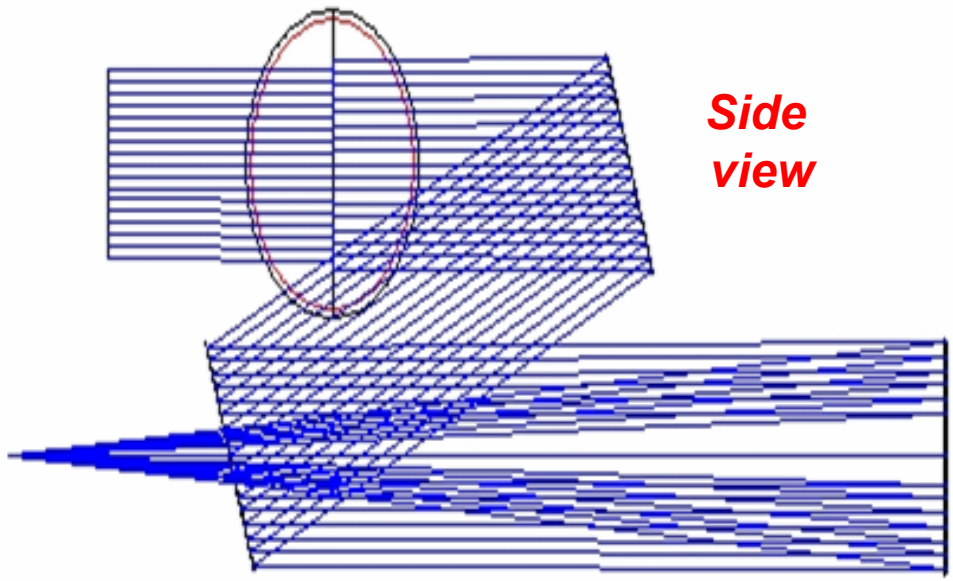
5 mirrors

4 plane mirrors to deflect radiation

1 spherical mirror to focus radiation to the detector

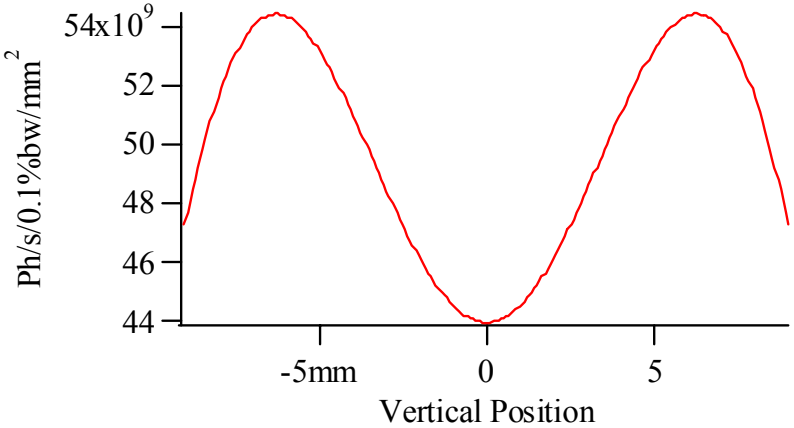


Side view

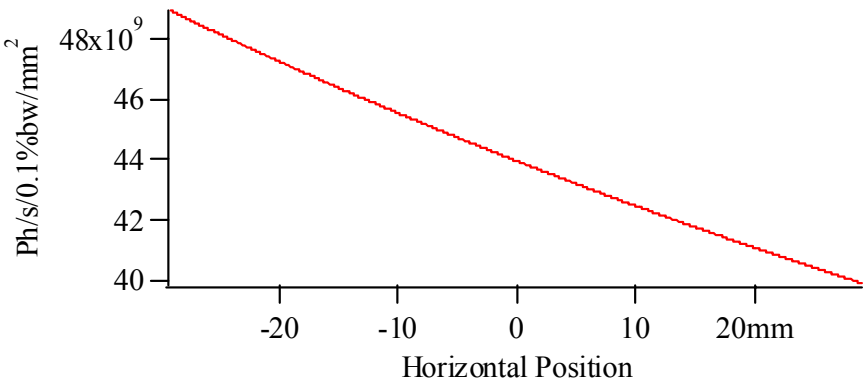


"3+L"...TIME RESOLVED e+ LIGHT
SRW simulations

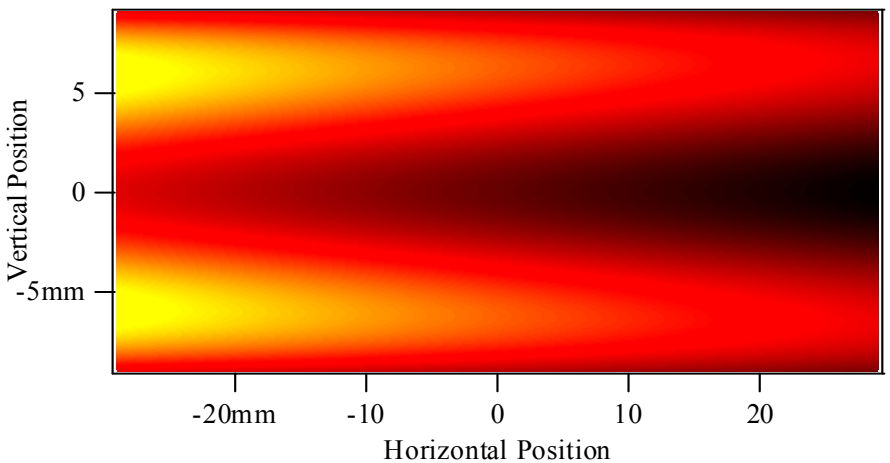
20 mrad vertical



65 mrad horizontal



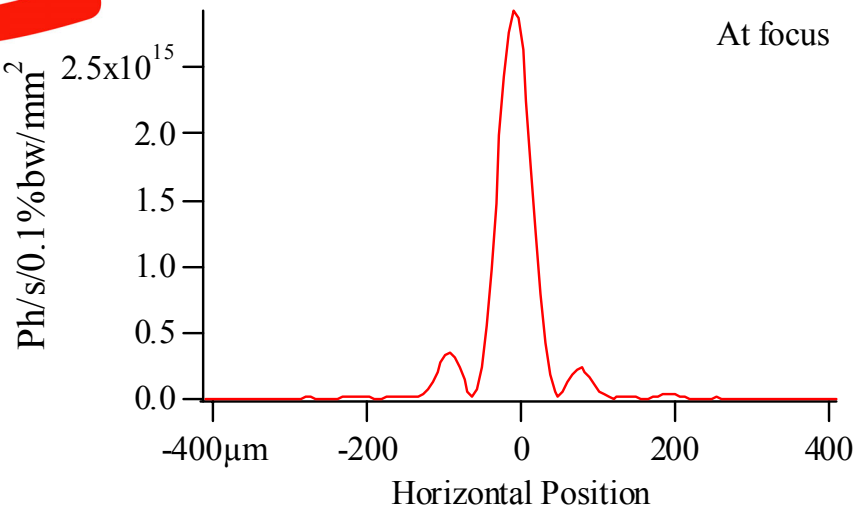
Light source intensity at 10 micron

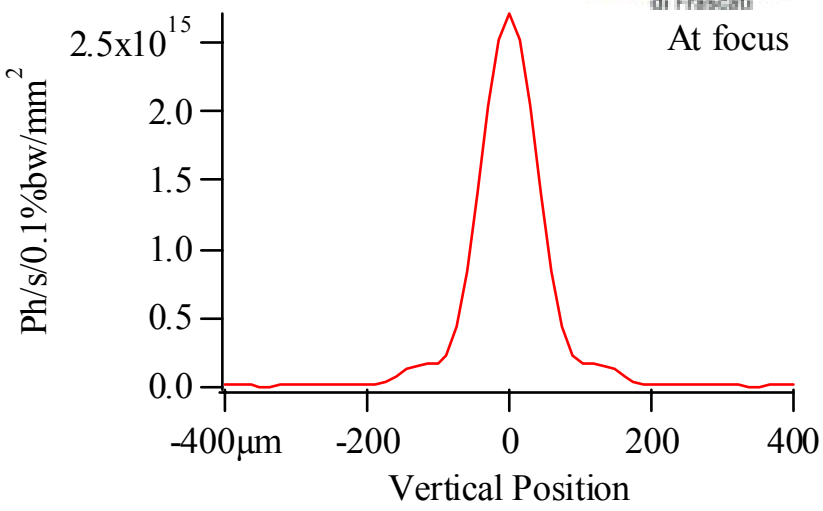


SRW: O. Chubar, P. Elleaume, proc. of the EPAC98 Conference, 22-26 June 1998, p.1177-1179
http://www.esrf.eu/Accelerators/Groups/InsertionDevices/Software/SRW

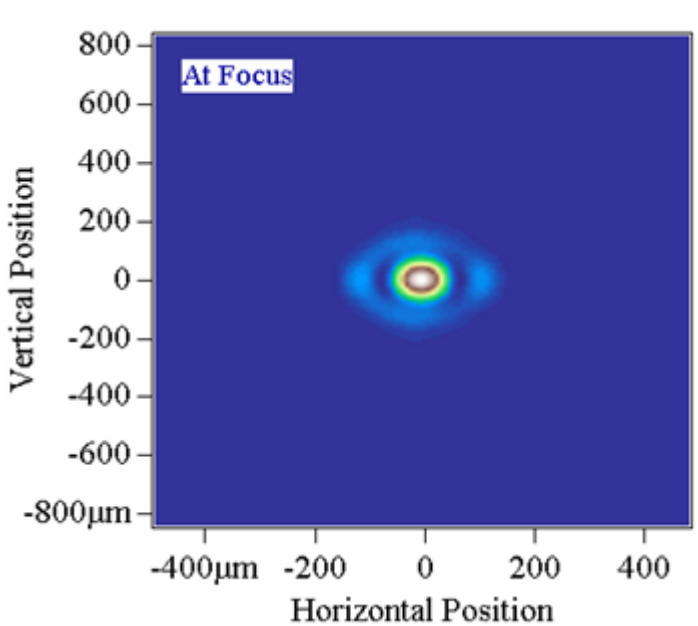
"3+L"...TIME RESOLVED e+ LIGHT

SRW simulations





Energy distribution at the focus spot at 10 micron



Detector dimension 1x1mm^2

Collected Energy 54 % from 0.6 to 10 microns

Summary

- Time domain diagnostics with sub-ns resolution of e- bunches with IR signal is possible
- Frequency domain diagnostics from IR signal for longitudinal feedback measurements using a spectrum analyzer has been achieved
- Costruction and commissioning of an IR port for beam diagnostics on the DAFNE e+ ring is in progress

Future applications

- Fast PV IR detectors will be used to improve longitudinal beam diagnostics

  (response time <100 ps)

- An R&D to fabricate an IR array detector is open to use it for transverse diagnostics

COLLABORATION with VIGO SYSTEM S.A. COMPANY

A. PIOTROWSKI et al.,
OPTO-ELECTRONICS REVIEW 12(1), 111–122 (2004)

MOCVD SYSTEM @ VIGO

METALLORGANIC CHEMICAL VAPOUR DEPOSITION
Multilayer HgCdTe heterostructures
on
GaAs, Si, sapphire
SUBSTRATES

Cooperation with LNF-INFN to develop, optimize and test fast uncooled and Peltier cooled IR detectors for high frequency applications (λ_{opt}. 2-14 micron)

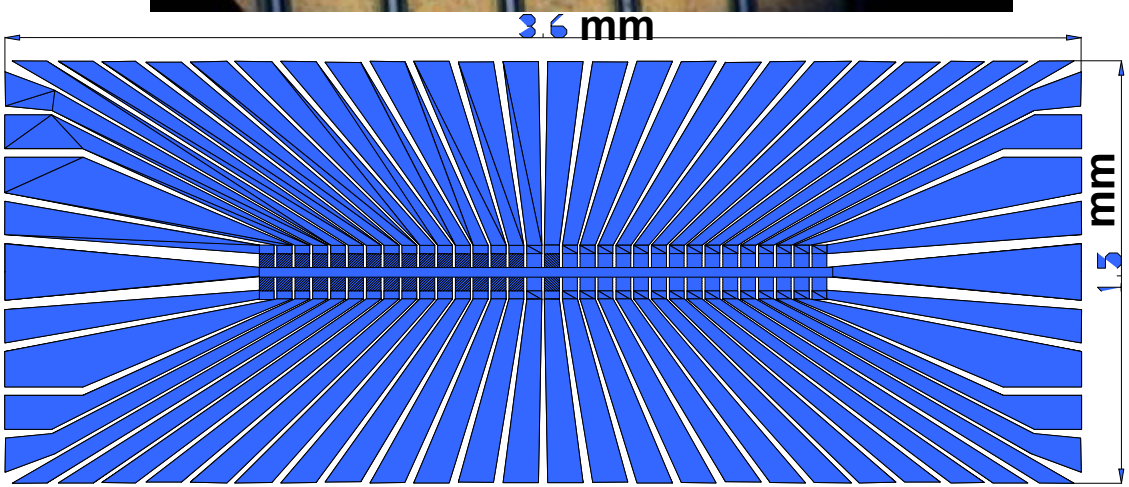
Sub-ns to few ps response times

Fast IR Array detector

Pixel pitch 50 μm x 50 μm

MCT
ARRAY DETECTOR
2X32 PIXELS

RESPONSE TIME
of a single PIXEL ~500 ps



An electronic board has been designed to amplify and read the 64 channels of the array

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Augusto Marcelli @ LNF

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Accelerator Division Staff @ LNF

DAFNE Light Staff @ LNF

REFERENCES

Contacts: alessio.bocci@lnf.infn.it

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