Optimization of Beam Instrumentation for Light Sources

Laura Torino

May 8, 2014
3rd oPAC Topical Workshop on Beam Diagnostics
Vienna, Austria

SYNCHROTRON LIGHT SOURCES

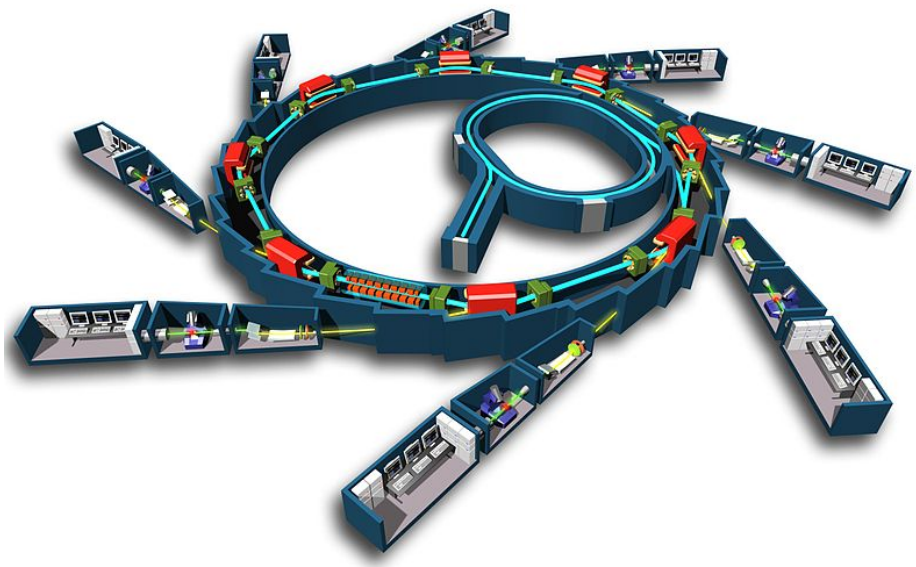
BEAM DIAGNOSTIC @ SLS

SUMMARY

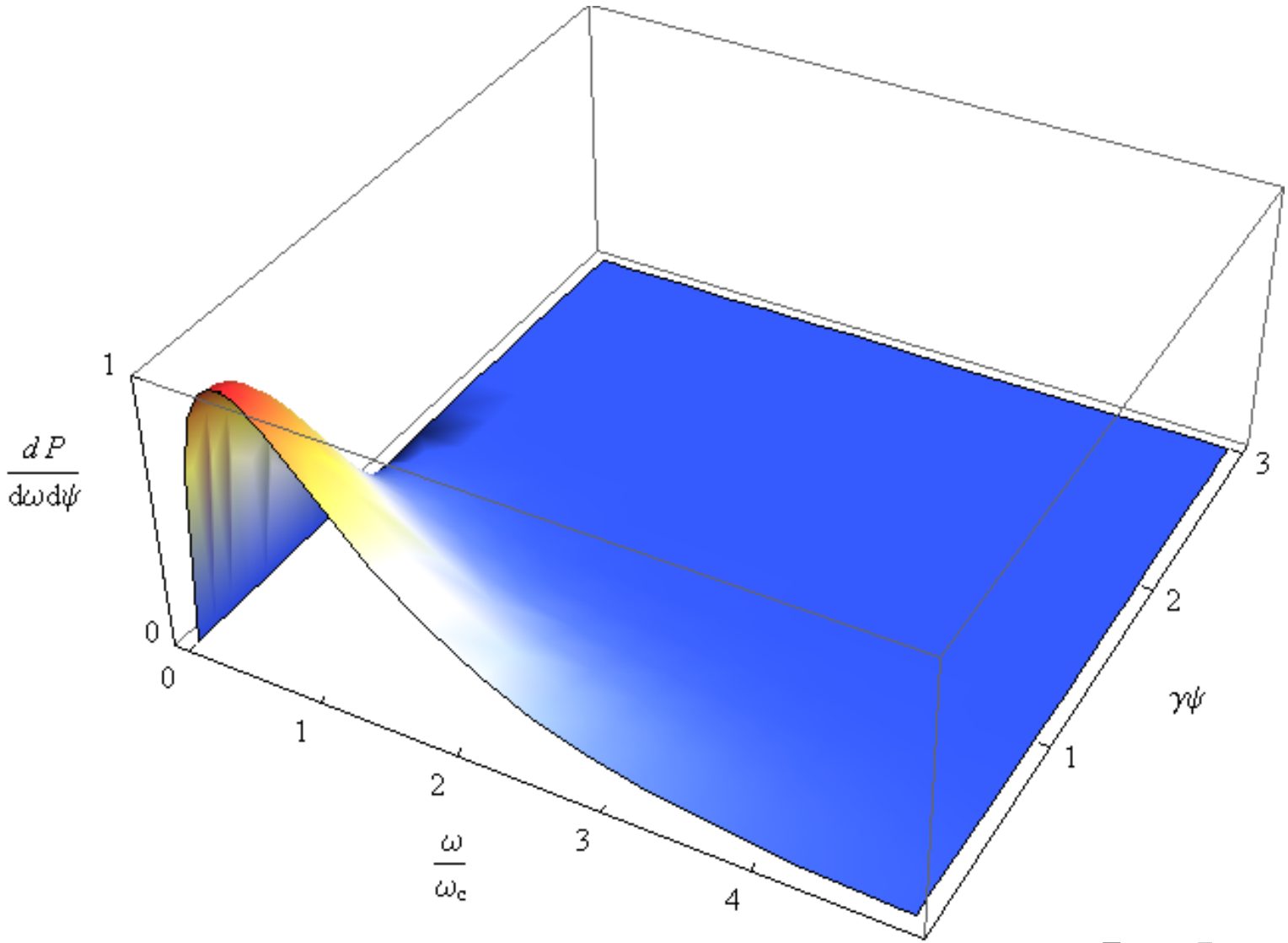
SYNCHROTRON RADIATION

The electromagnetic radiation emitted when a high energetic charged particle is accelerated radially is called *Synchrotron Radiation*

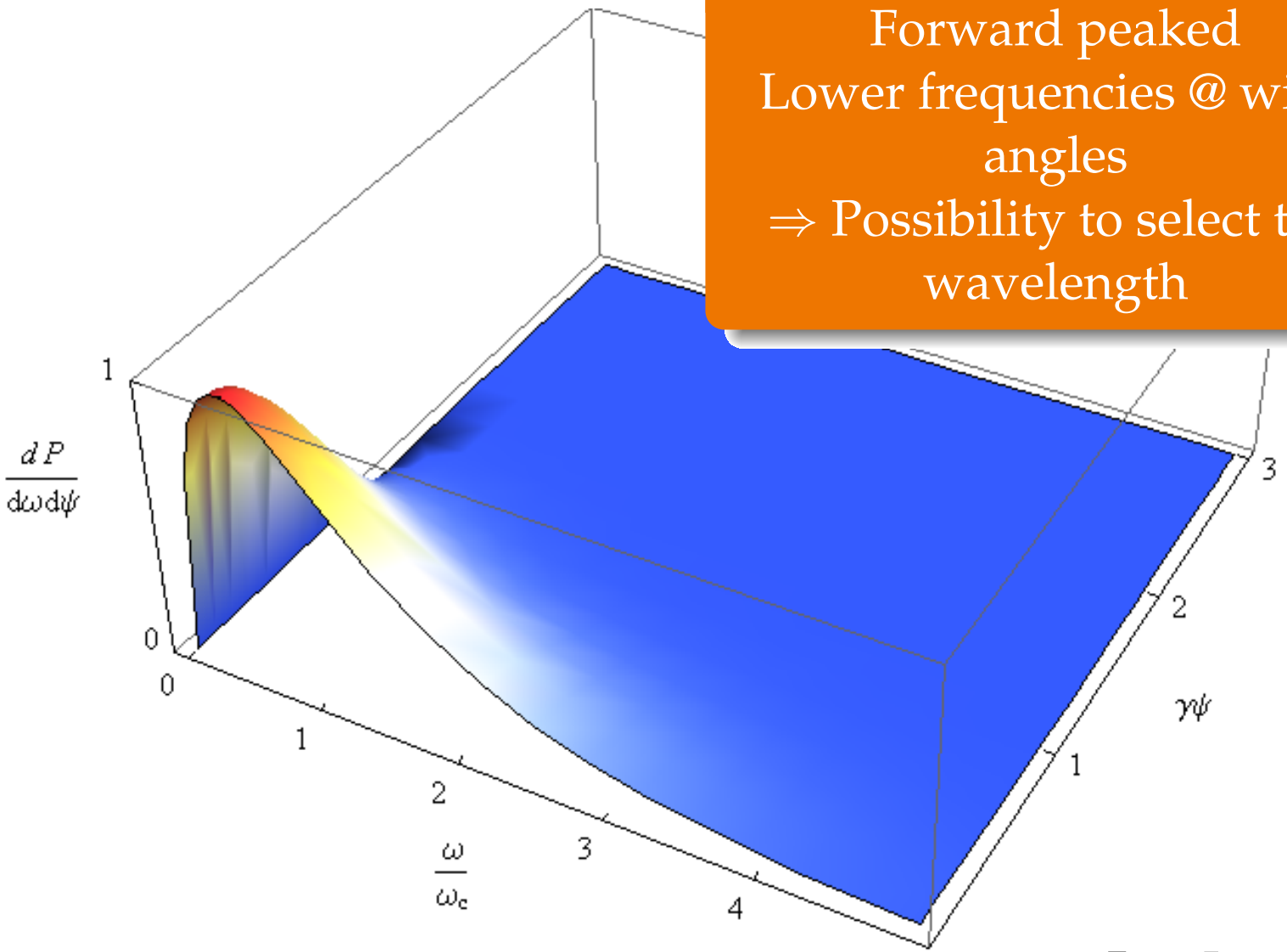
- High radiation flux
- High brilliance
- Wide radiation spectrum
- Tunability
- Defined polarization



POWER DISTRIBUTION



POWER DISTRIBUTION



BEAM DIAGNOSTIC USING SR

SR characteristics
⇕
Beam characteristics

Advantages

- Produced "for free"
- Wide spectrum
- Real-time
- Non-invasive

Disadvantages

- Need of a source
- Radiation exposure
- "Only" for light particles
- Machine design

BEAM DIAGNOSTIC USING SR

SR characteristics
⇕
Beam characteristics

Advantages

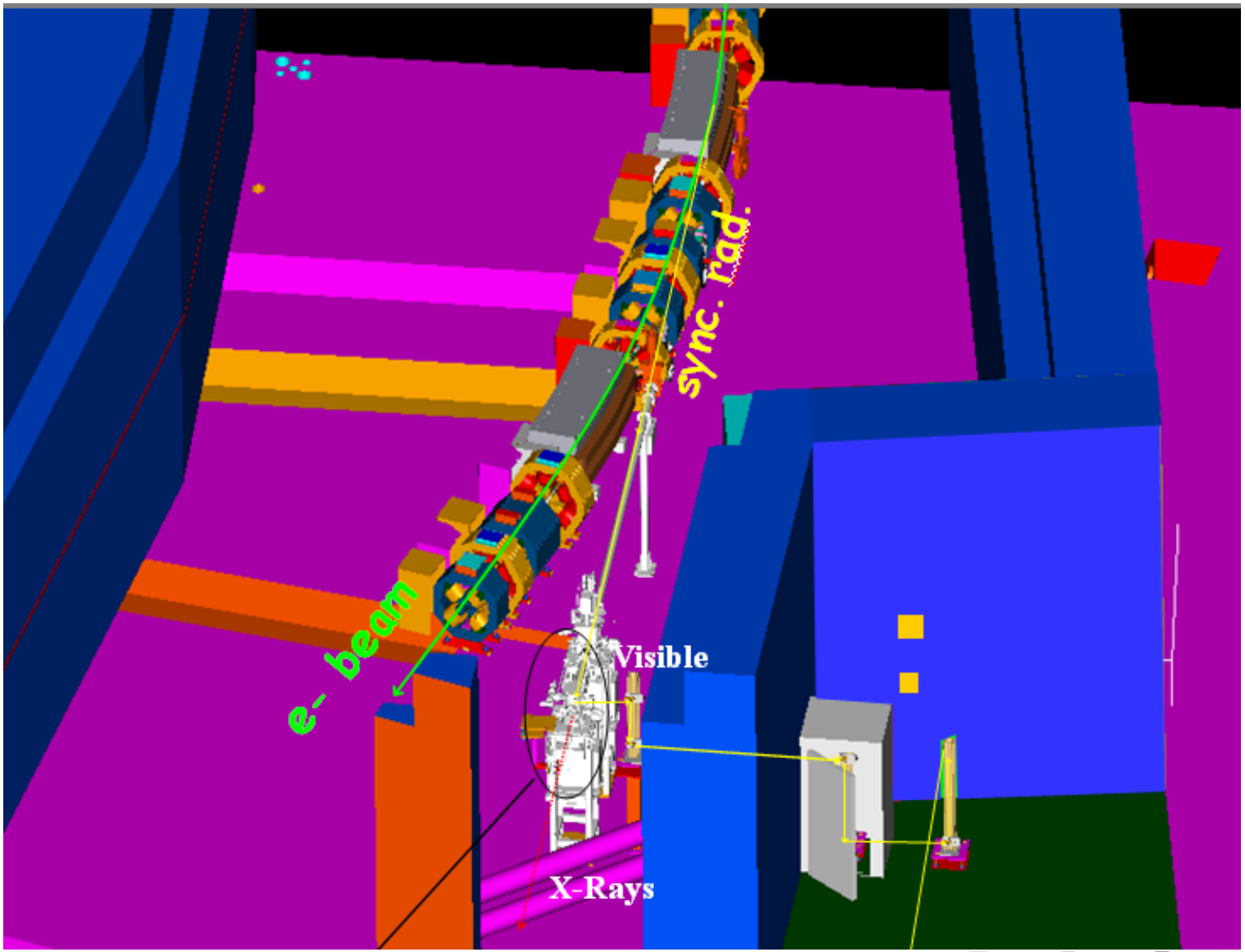
- Produced "for free"
- Wide spectrum
- Real-time
- Non-invasive

Disadvantages

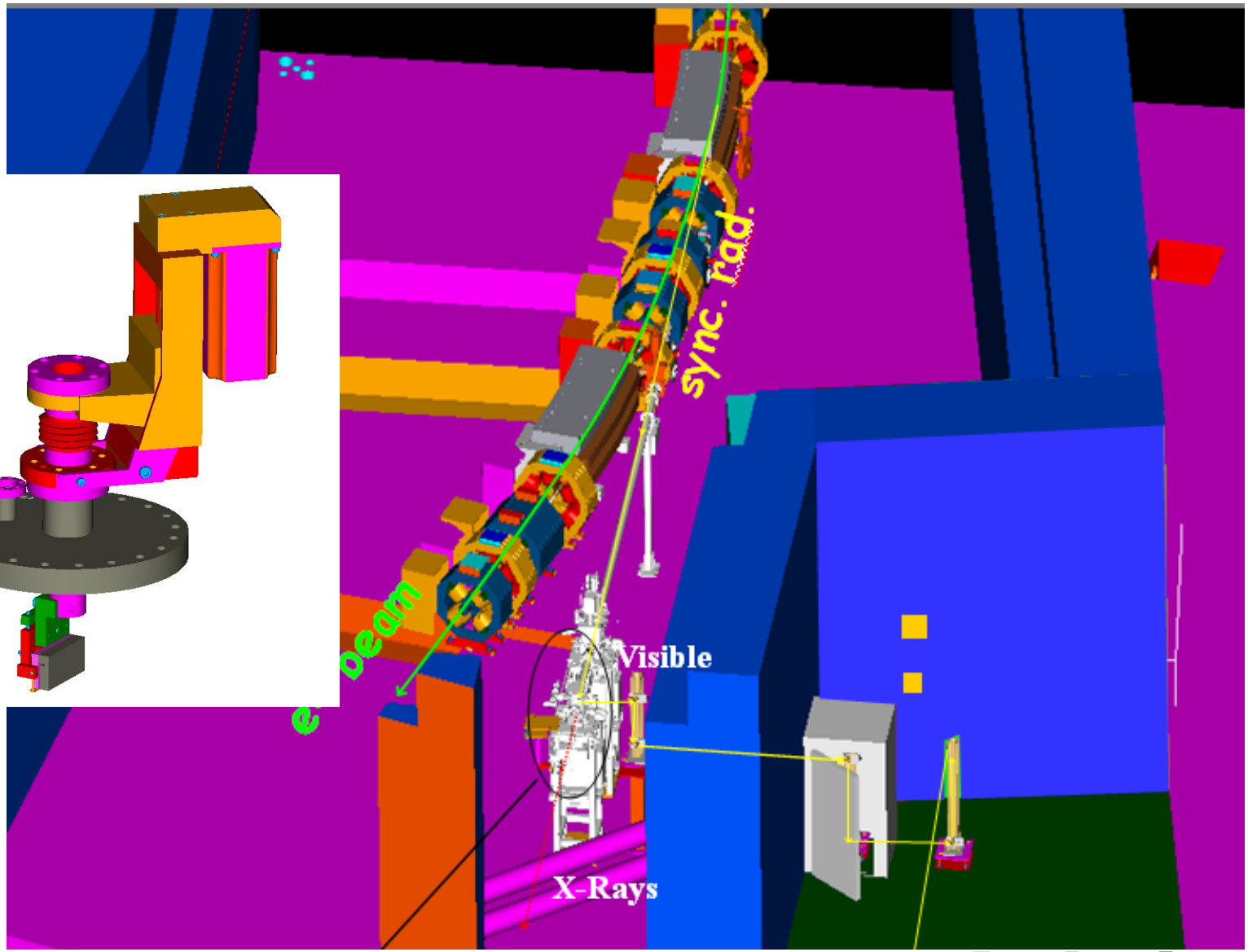
- Need of a source
- Radiation exposure
- "Only" for light particles
- Machine design

Visible radiation coming from a bending and extracted through a mirror chicane

DIAGNOSTIC BEAMLINE



DIAGNOSTIC BEAMLINE



DIAGNOSTIC USING SR

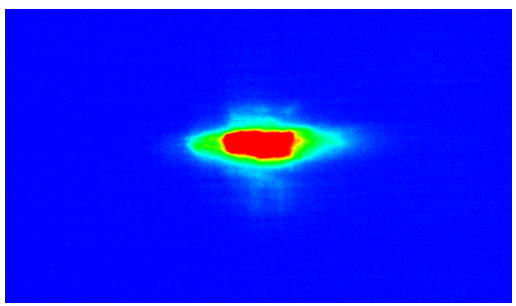
Transverse beam measurements

- Beam size (Visible)

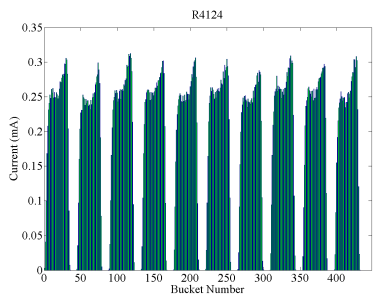
Longitudinal beam measurements

- Filling pattern

Imaging



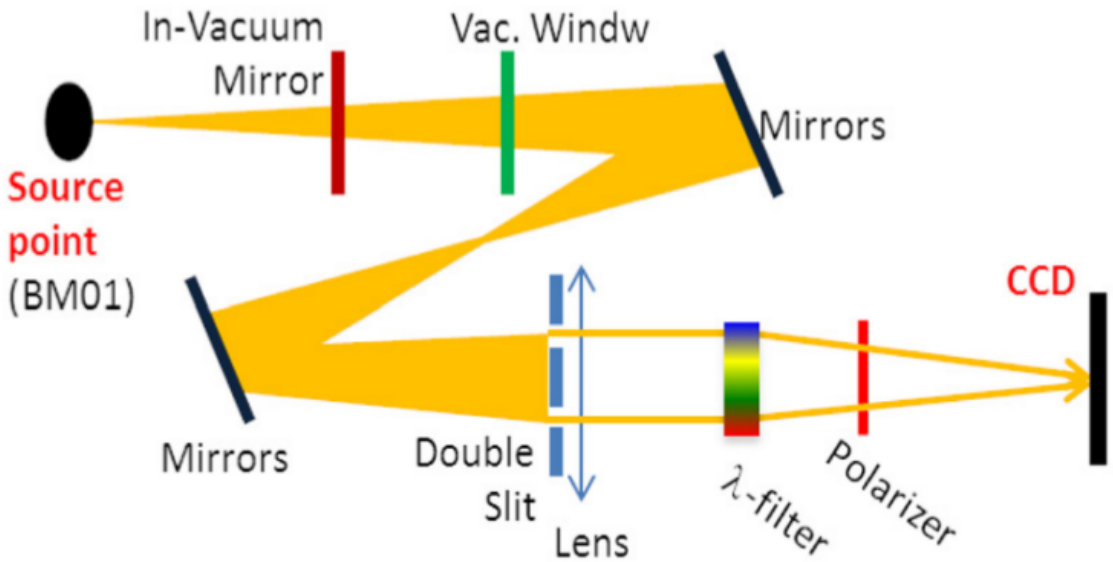
Timing



BEAM SIZE-INTERFEROMETRY

Measurement of the first order of spatial coherence of the synchrotron radiation using a double slit interferometer

$$\sigma = \frac{\lambda d_0}{\pi D}\sqrt{\frac{1}{2}\ln\frac{1}{V}} \qquad V = \frac{I_{Max} - I_{Min}}{I_{Max} + I_{Min}}$$



BEAM SIZE-INTERFEROMETRY

Measurement of the first order of spatial coherence of the synchrotron radiation using a double slit interferometer

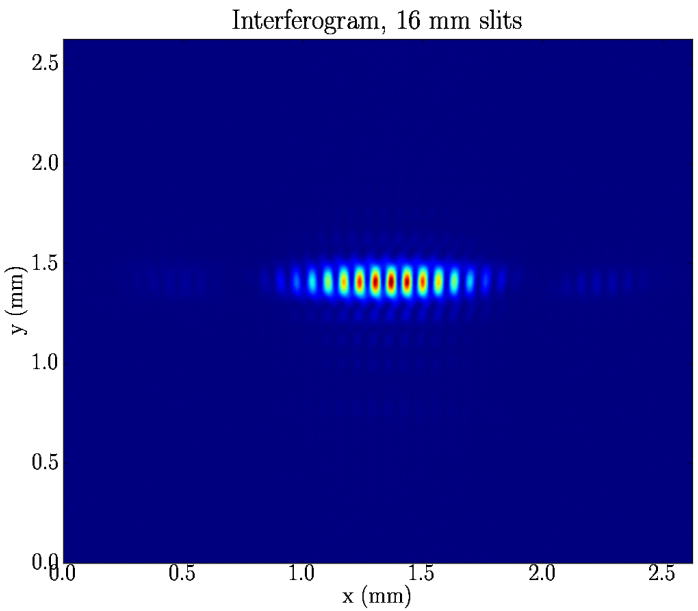
$$\sigma = \frac{\lambda d_0}{\pi D}\sqrt{\frac{1}{2}\ln\frac{1}{V}}$$

$$V = \frac{I_{Max} - I_{Min}}{I_{Max} + I_{Min}}$$

Using good quality optical components

$\Downarrow$

Beam size $< 10\,\mu$m can be achieved



BEAM SIZE-INTERFEROMETRY

Measurement of the first order of spatial coherence of the synchrotron radiation using a double slit interferometer

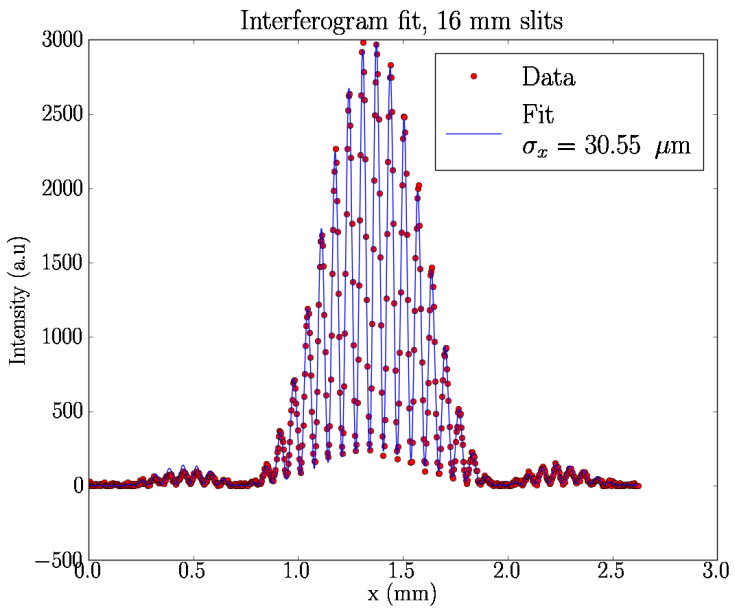
$$\sigma = \frac{\lambda d_0}{\pi D}\sqrt{\frac{1}{2}\ln\frac{1}{V}}$$

$$V = \frac{I_{Max} - I_{Min}}{I_{Max} + I_{Min}}$$

Using good quality optical components

$\Downarrow$

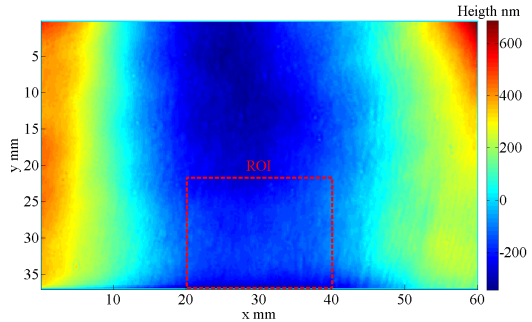
Beam size $< 10\,\mu$m can be achieved

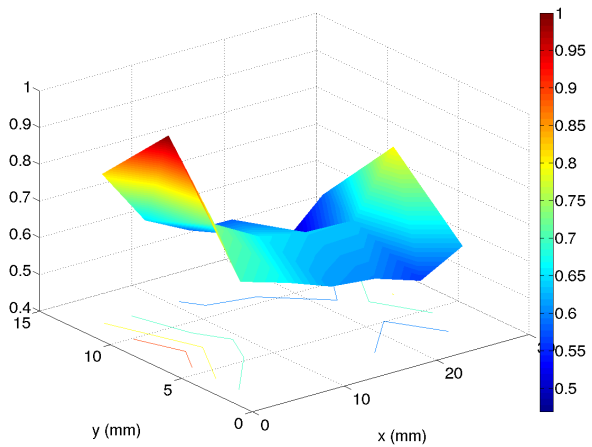


OPTIMIZATION

Optics

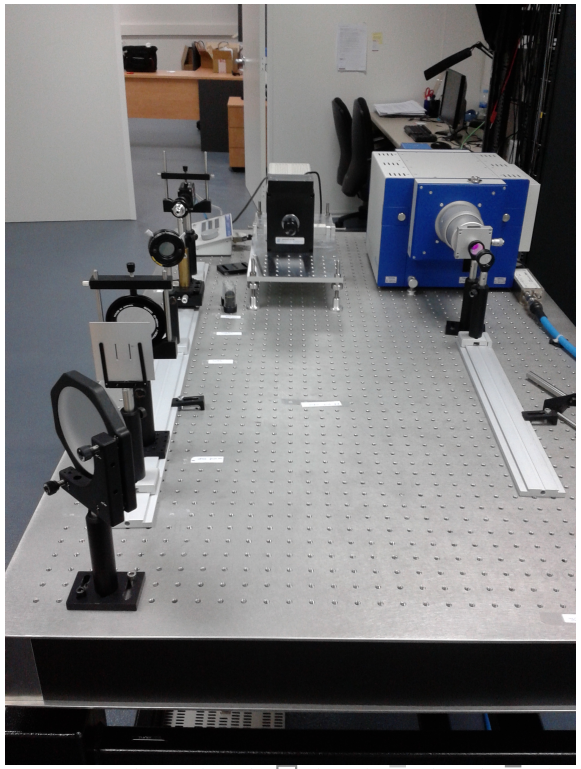
Use of high quality optical components not to deform the waveform





Acquisition

Use of a Fast Gated Camera to perform Bunch by Bunch transverse size measurements

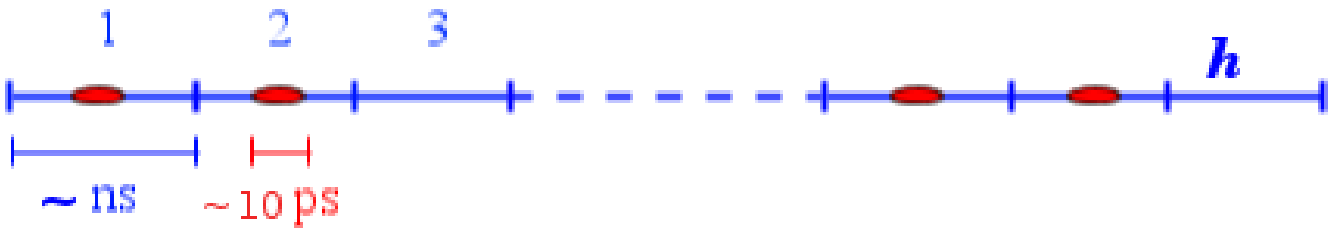


LONGITUDINAL MEASUREMENTS

The longitudinal structure of a circular accelerator is defined by the beam revolution period and the accelerating RF-frequency

$$h = T \times f_{RF}$$

The machine is divided into h ***Buckets***.
Each bucket can be filled with a bunch

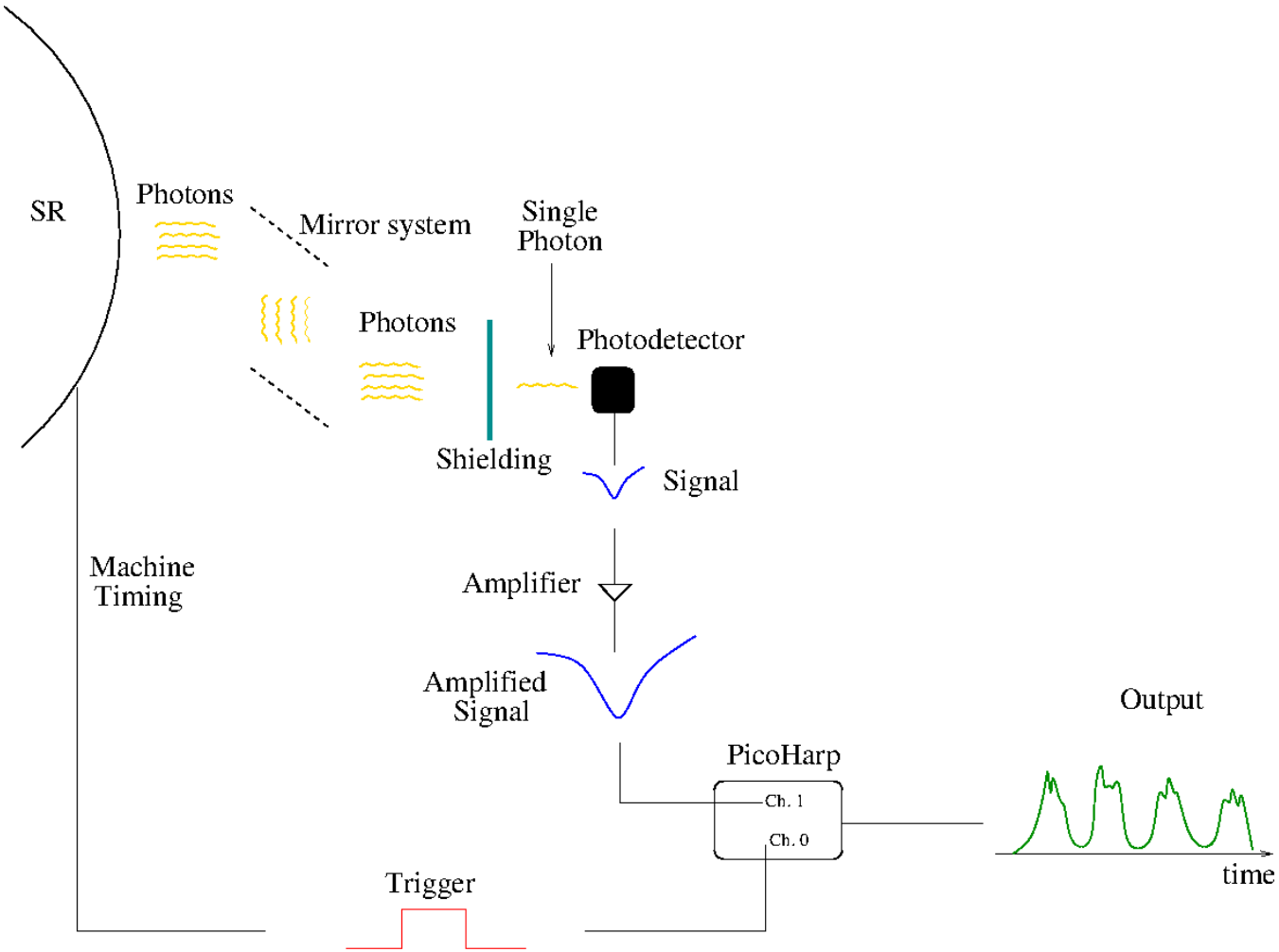


Filling Pattern

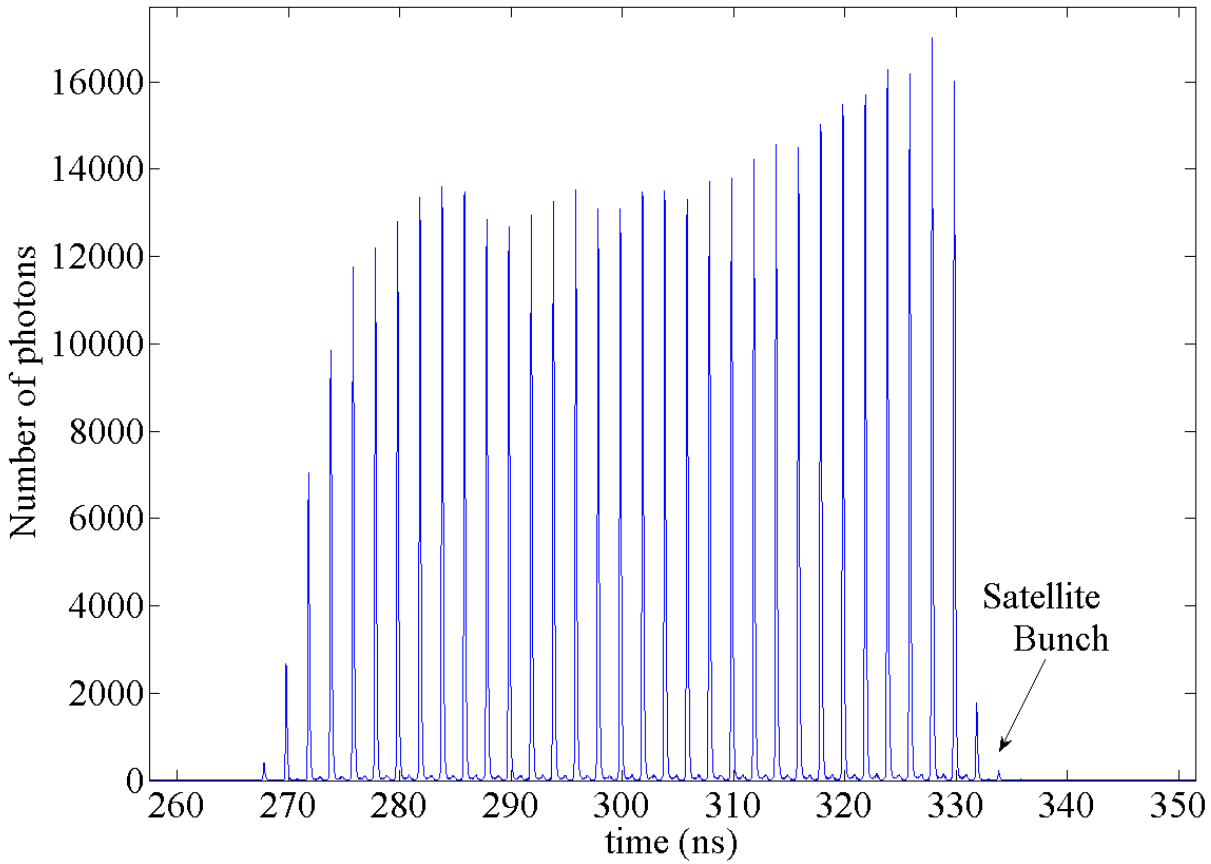
The scheme of distribution of bunches among the machine buckets

FILLING PATTERN-TCSPC

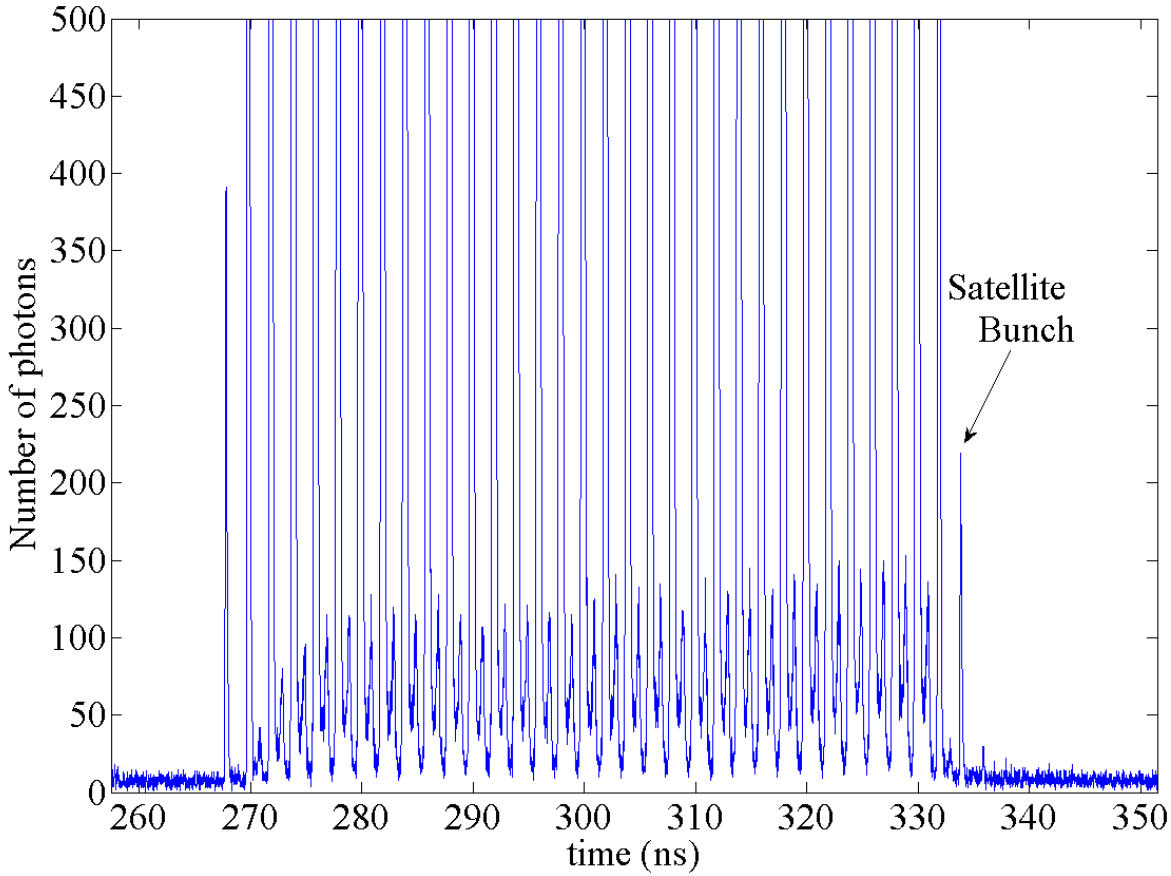
Time Correlated Single Photon Counting



FILLING PATTERN-TCSPC



FILLING PATTERN-TCSPC



Dynamic Range better than 10^3 $\Rightarrow$ Also bunch purity experiments

OPTIMIZATION

Filling Pattern Measurement Evolution

Fast Current Transformer

⇓

"Standard" TCSP

⇓

TCSPC using X-Rays

OPTIMIZATION

Filling Pattern Measurement Evolution

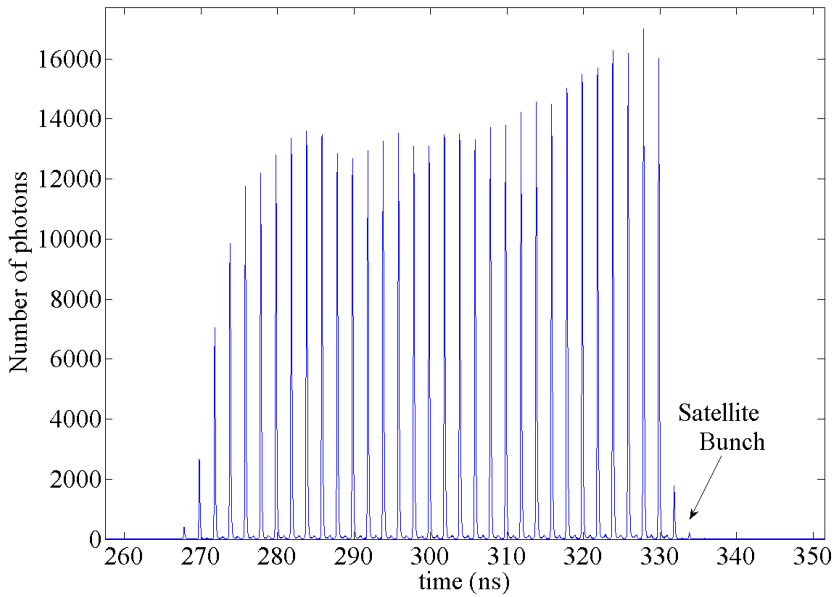
Fast Current Transformer

⇓

"Standard" TCSP

⇓

TCSPC using X-Rays



OPTIMIZATION

Filling Pattern Measurement Evolution

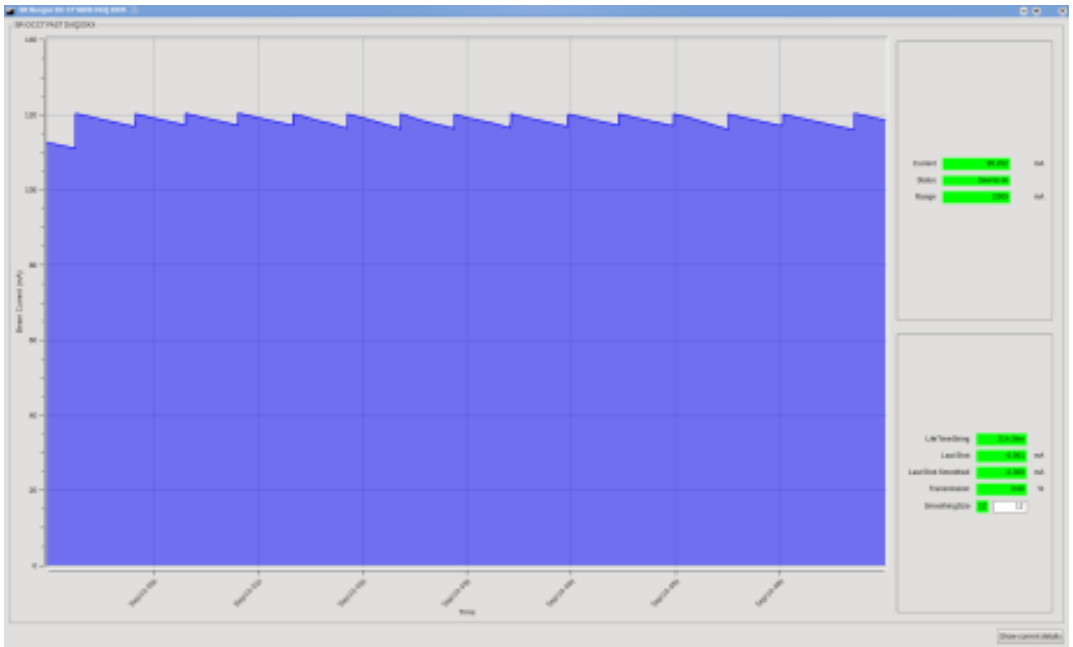
Fast Current Transformer

⇓

"Standard" TCSP

⇓

TCSPC using X-Rays



TCSPC X-Rays

- More stability for Top-Up operation
- Inside the tunnel

OPTIMIZATION

Filling Pattern Measurement Evolution

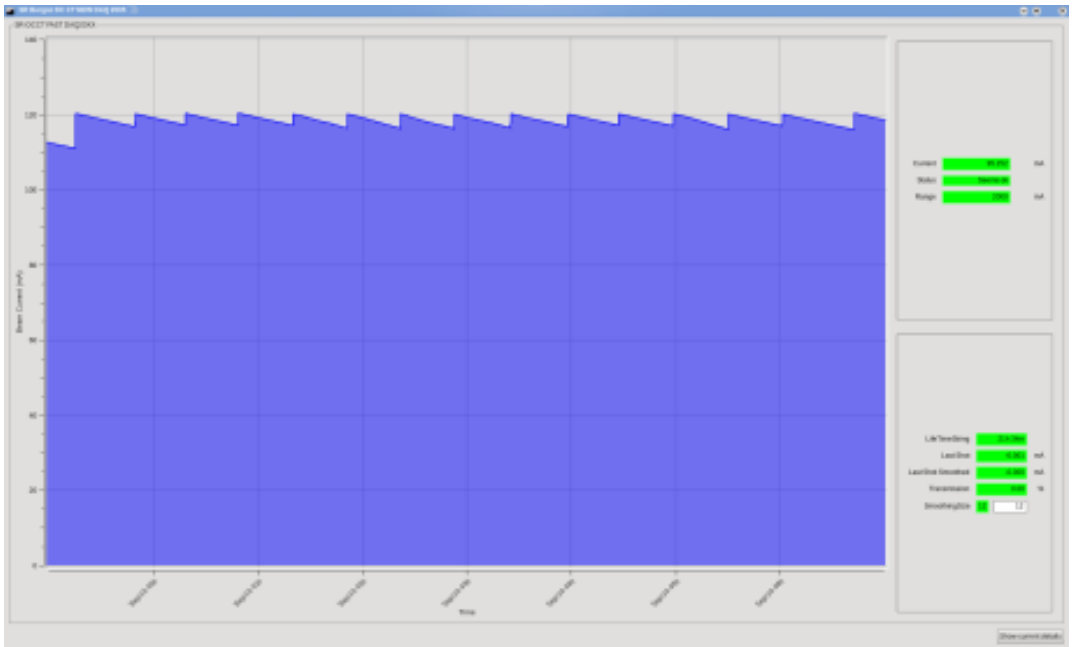
Fast Current Transformer

⇓

"Standard" TCSP

⇓

TCSPC using X-Rays

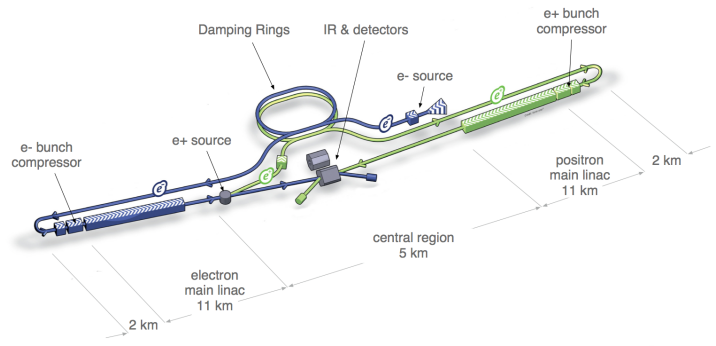


TCSPC X-Rays

- More stability for Top-Up operation
- Inside the tunnel
- More space...

NOT ONLY SLS!

Electron Machines/Linear Collider



LHC

- Bunch Purity with TCSPC
- Imaging
- Interferometry

Possibility of using undulators to increase the photon flux

Muon Storage Rings

Need to know the muon energy $\Rightarrow$ Measure the μ g-2 using SR emitted by muon decay electrons

$$\omega_a = a_\mu \gamma \omega_{cic}$$

SUMMARY

- Synchrotron radiation
  - Physical characteristics
- Application in machine diagnostic
- Transverse beam size
  - Further optimizations
- Longitudinal measurements
  - Further optimizations

SUMMARY

- Synchrotron radiation
  - Physical characteristics
- Application in machine diagnostic
- Transverse beam size
  - Further optimizations
- Longitudinal measurements
  - Further optimizations

This project is funded by the European Union under contract PITN-GA-2011-289485