BSRT
Optics Design

BI Days

24th November 2011

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BE-BI-PM

Summary

- **BSRT Overview**
  - Light sources, optics
- **Present system: spherical mirrors**
  - Advantages
  - Limitations and encountered problems
- **New system under study: lenses**
  - Advantages
  - Limitations
  - Abort gap monitor line modification

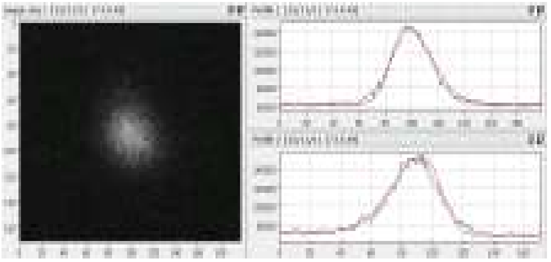
BSRT Layout

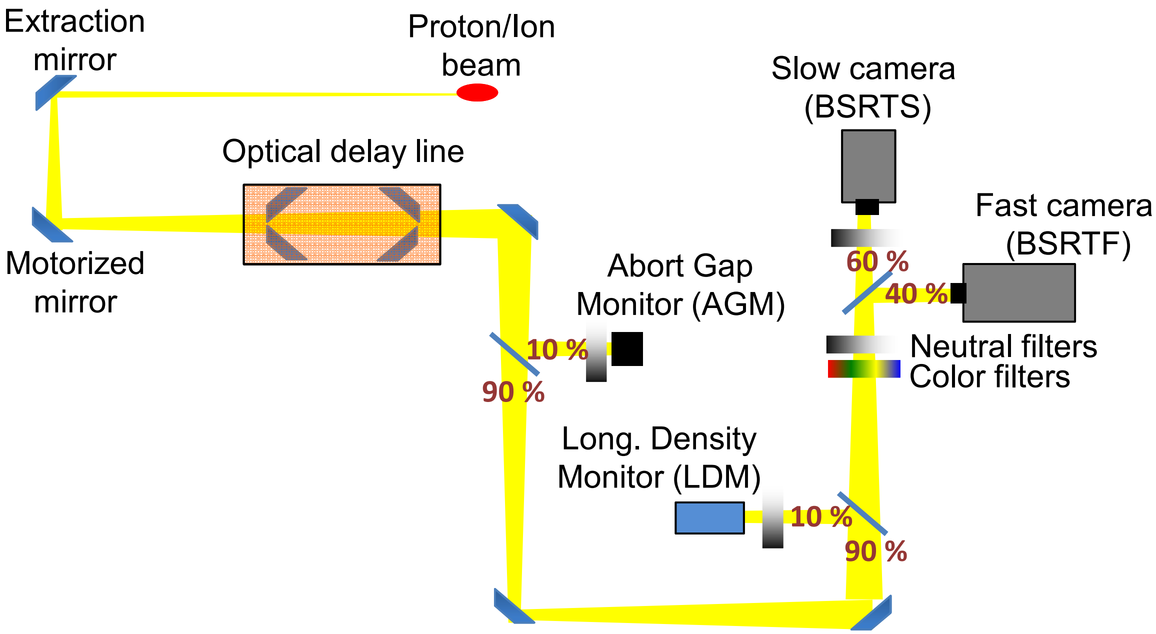
BSRT: Beam Synchrotron Radiation Telescope

Beam transverse profile monitoring with synchrotron light

Optical line shared with:

- Abort gap monitor
- Longitudinal density monitor



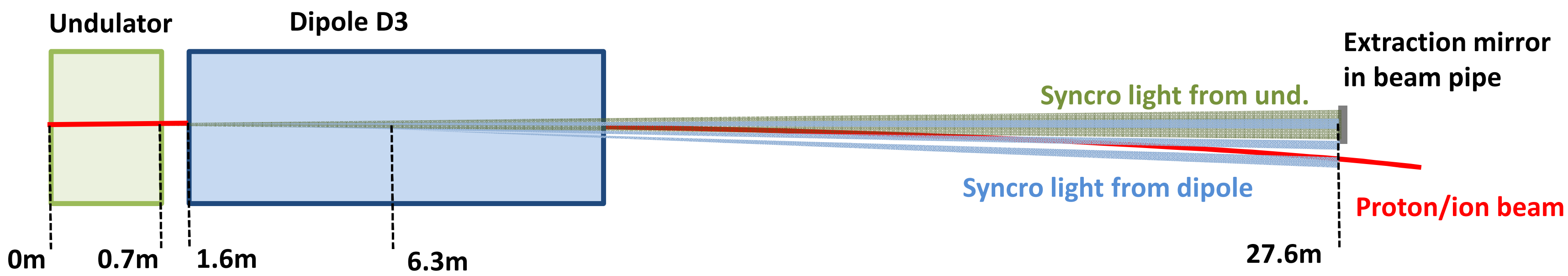


- ✓ Two systems in LHC
- ✓ One system in lab

Synchrotron light sources

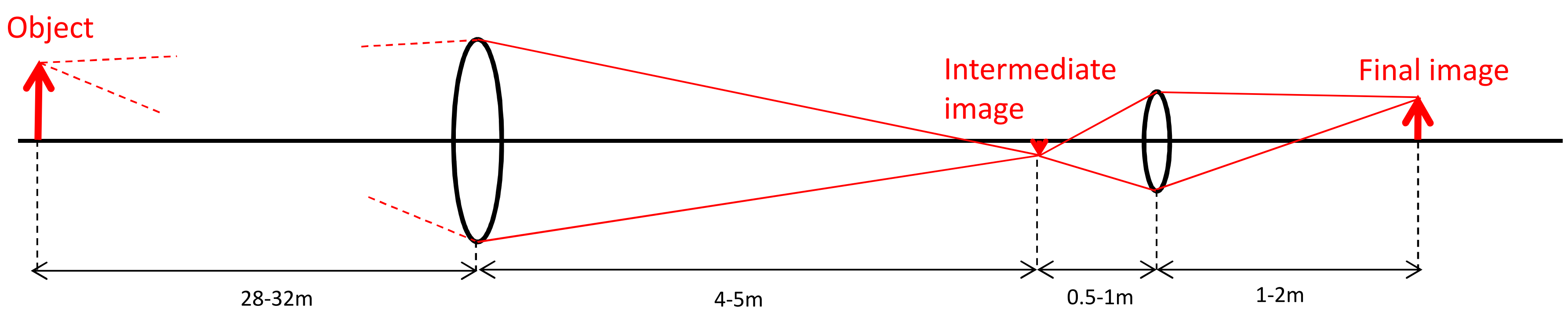
Light sources:

- Dipole (edge to center): Visible light from 1.3 to 7 TeV
- Undulator especially design to create visible light from 450 GeV to 1.3 TeV



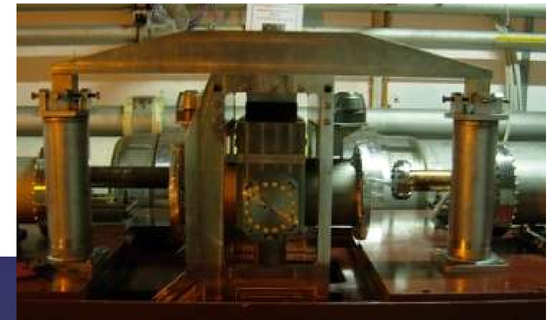
Imaging system

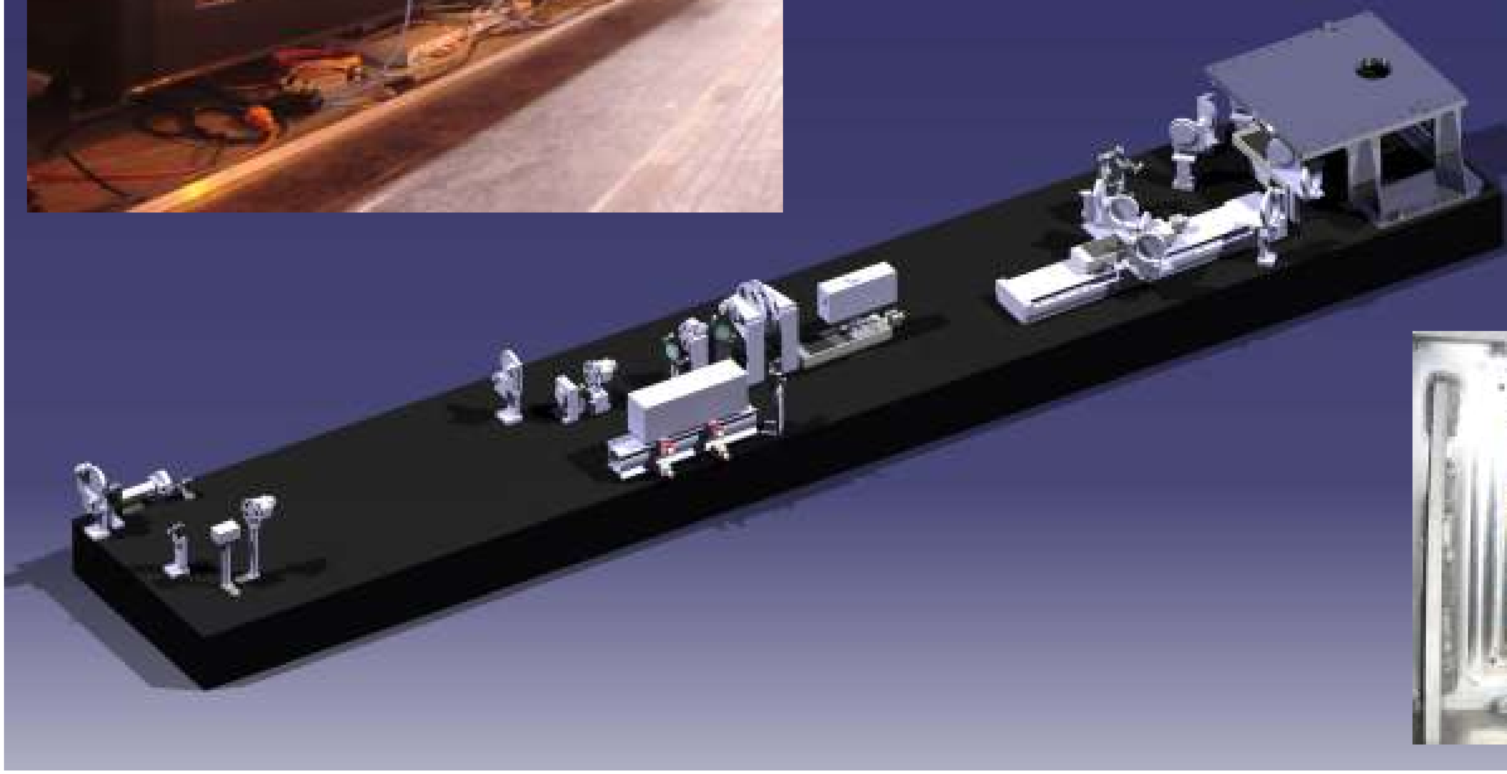
- **first focusing element: f= 4 - 5m**
  - inverted intermediate image with mag = 0.15 - 0.2
- **second focusing element: f= 0.3 - 0.8m**
  - final image with mag = 0.3 - 0.6



The system is limited by diffraction: the smaller the wavelength, the smaller the aberration => use of bandpass filters

Some pictures

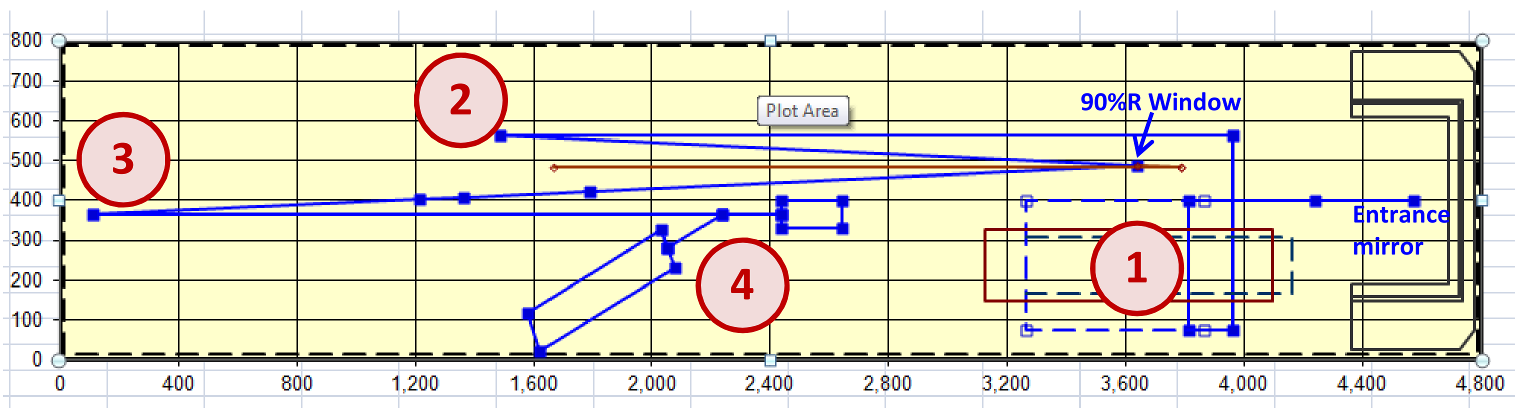




Present design: spherical mirrors

1. Motorized 8 mirrors “trombone” to follow light source
2. Spherical mirror f=4000mm (F1)
3. Spherical mirror f=750mm (F2)
4. Cameras

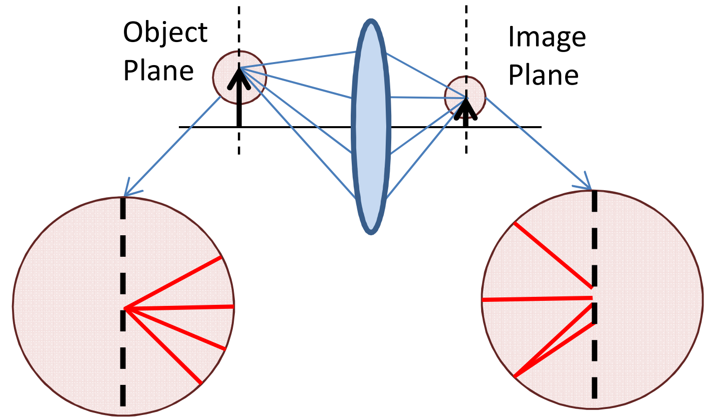
- Total magnification: 0.3 (0.14 @ intermediate image plane)

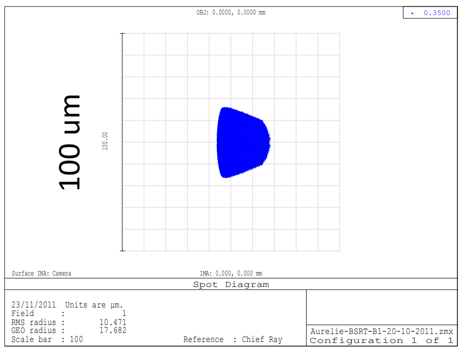


Present design: Advantages

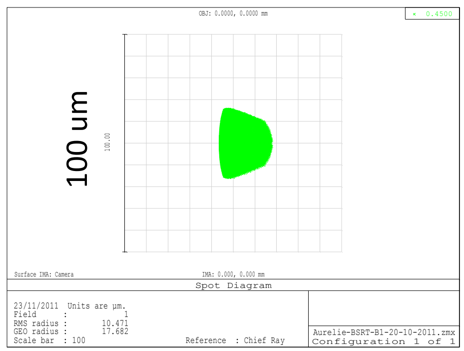
No chromatic aberrations

PSF ≈ 18um for all wavelength’s

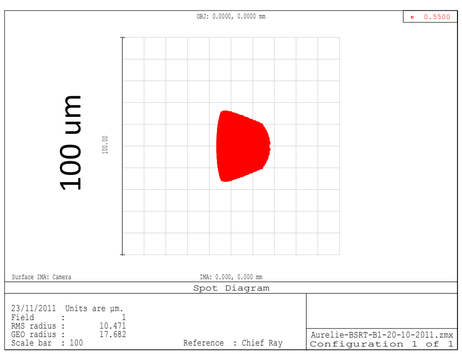




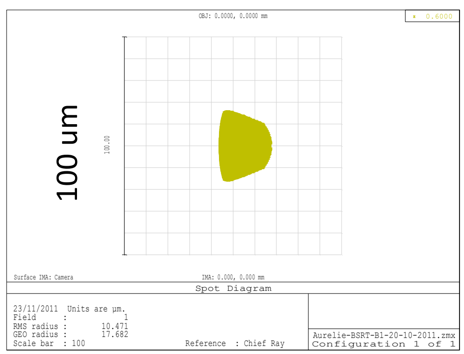
350nm: PSF = 18um



450nm: PSF = 18um



550nm: PSF = 18um



600nm: PSF = 18um

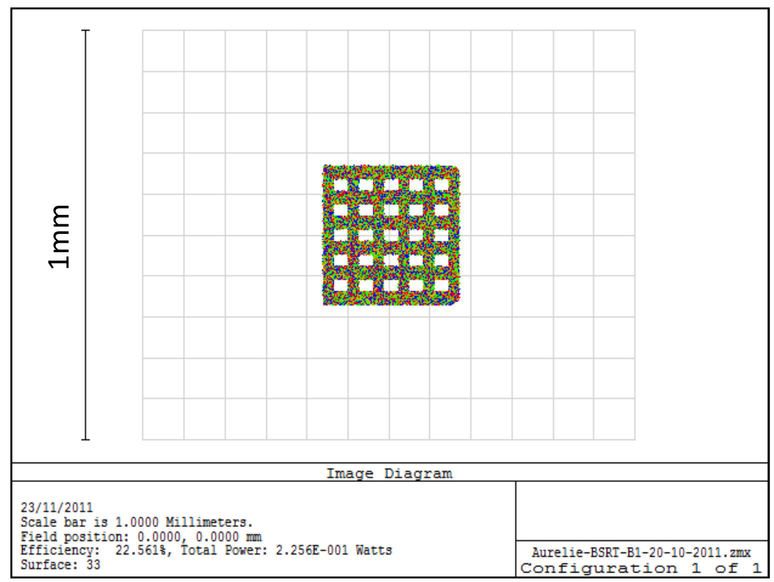
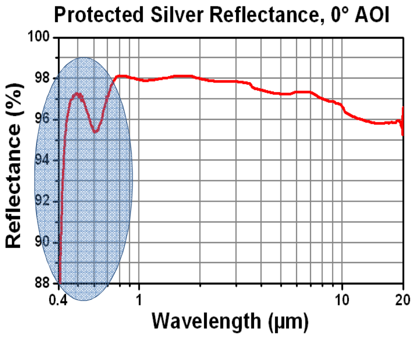


Image of 1mm grid object

Present design: Limitations

- **Transmission**:
  8 mirrors trombone = 30% intensity loss
  (even more @ 400nm)



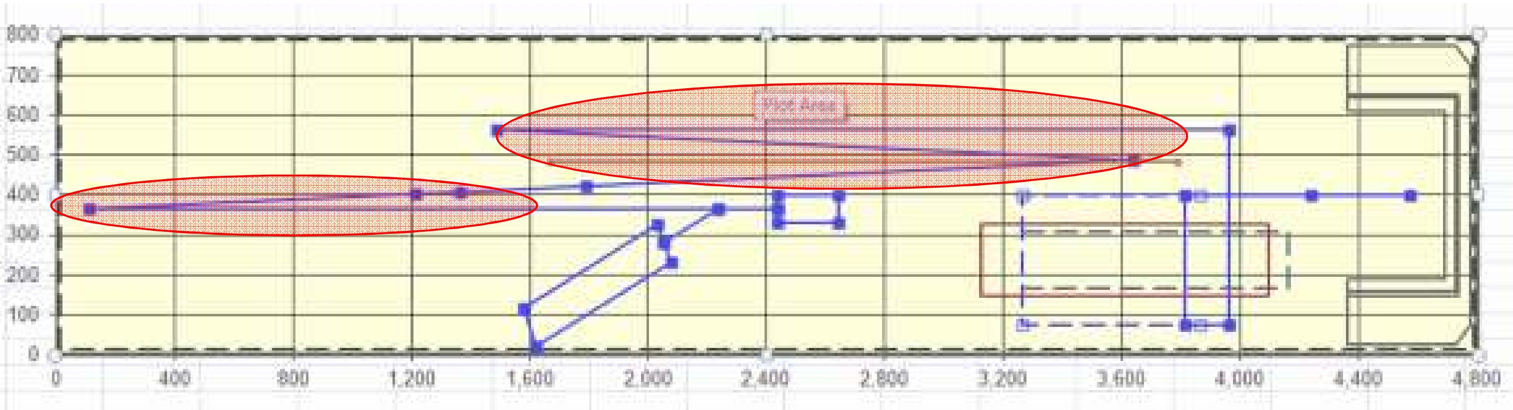
- **Aperture**: only 26% efficiency @ 450GeV for one pass trombone, even less with two pass trombone

- **Alignment** of the trombone really difficult and needs frequent retuning => efficiency is even more reduced

Less light collected => larger bandpass filter
=> bigger aberration due to diffraction

Present design: Limitations

- **Design in reflection**
  - ➢ small angles in X plane, back and forth optical path's really close to each other
  - ➢ Tight space for inserting elements without intercepting the light



- **Abort Gap coupled to BSRT**
  - ➢ steering done with the 1st mirror, in common with BSRT

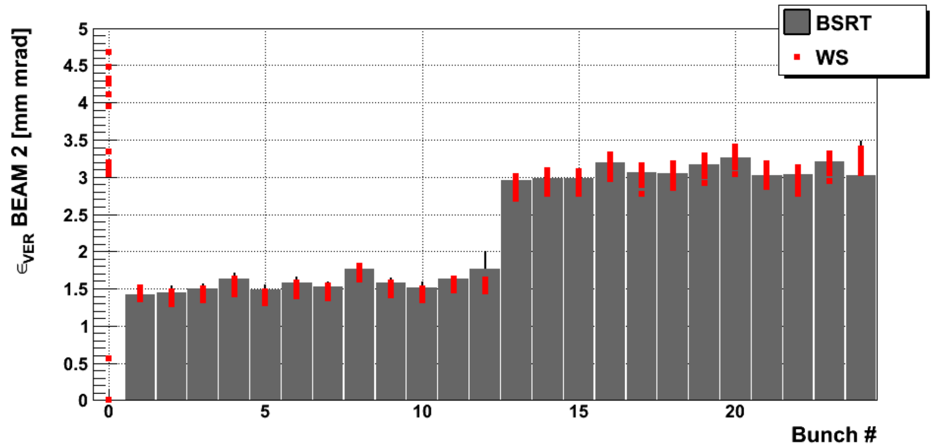
Present design: Limitations

Emittance measurement: $$\sigma^2_{beam} = \sigma^2_{meas} - \sigma^2_{PSF}$$

At present, σ_{PSF} is more than 300um and not constant

Possible causes:

- Diffraction
- Vibrations
- Alignment changes



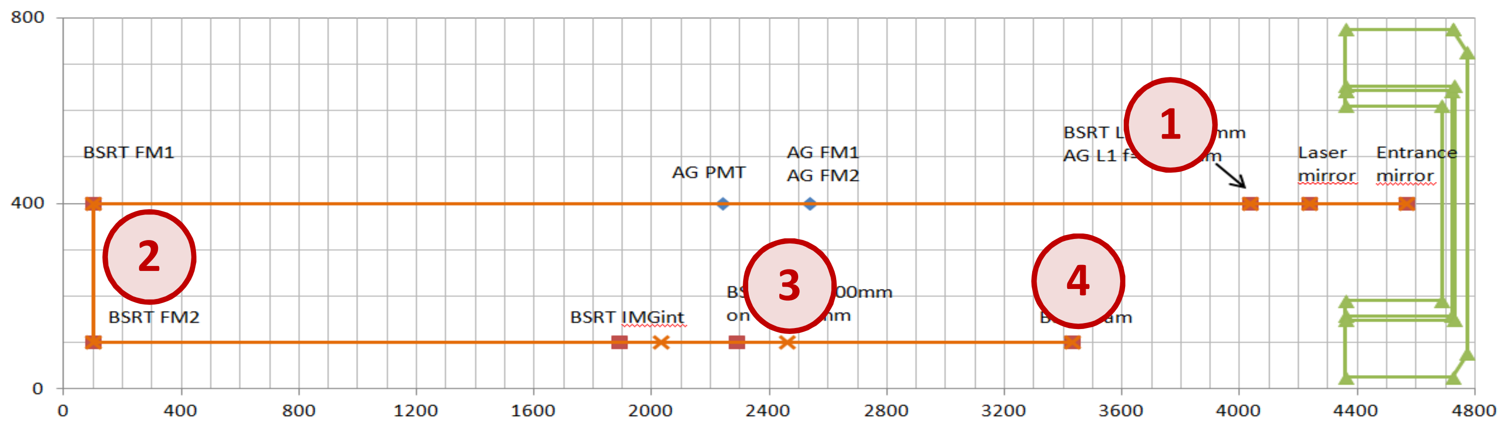
Idea: Simplify the optical system :

- More reliable alignment
- Reduce vibration

New design: Lenses

1. Lens optimized between 350 and 600nm, f=5000mm (L1)
2. 2 fold mirrors
3. Optimized lens f=300mm (L2) on motorized TS to follow light source
4. Camera

- Total magnification: 0.6 (0.21 @ intermediate image plane)
- Separate line for abort gap monitor by adding splitter before 1st mirror



New design: Advantages

- **No more trombone**: only 2 mirrors in the system instead of 8

  => intensity loss ≈ 10%

- **Aperture increased**: 1st lens closer to entrance mirror

  => efficiency @ 450 GeV ≈ 42%

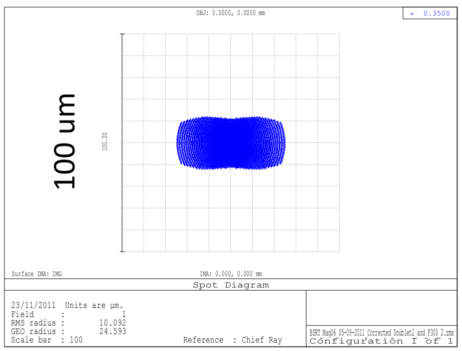
- **Much easier alignment**

- **No more small angles in X plane due to reflection**: more room for inserting elements

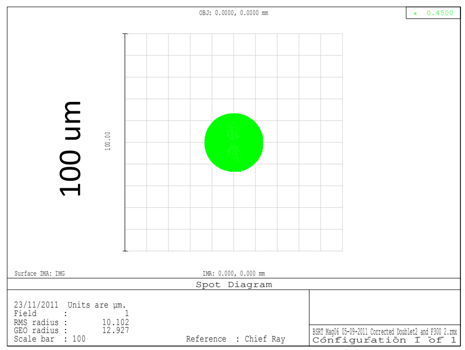
- **Abort gap monitor decoupled:** in view of future interlock system

New design: Limitations

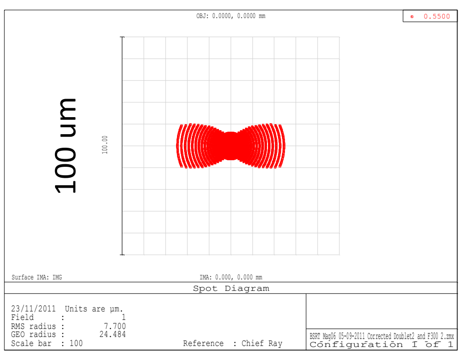
- **Chromatic aberrations**: lenses for 350 to 600nm region, but not as good as spherical mirrors, PSF ≈30um



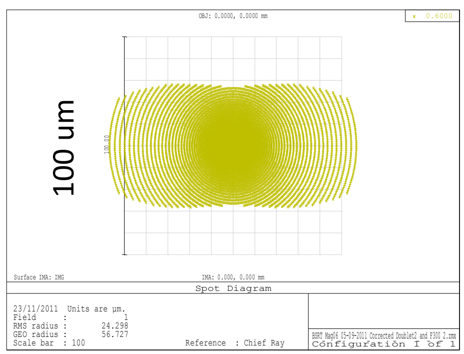
350nm: PSF = 25um



450nm: PSF = 13um



550nm: PSF = 25um



600nm: PSF = 57um

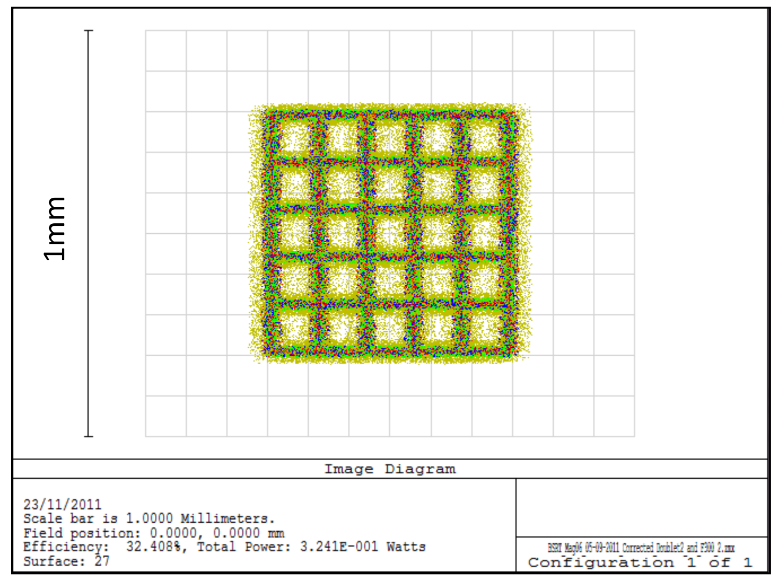
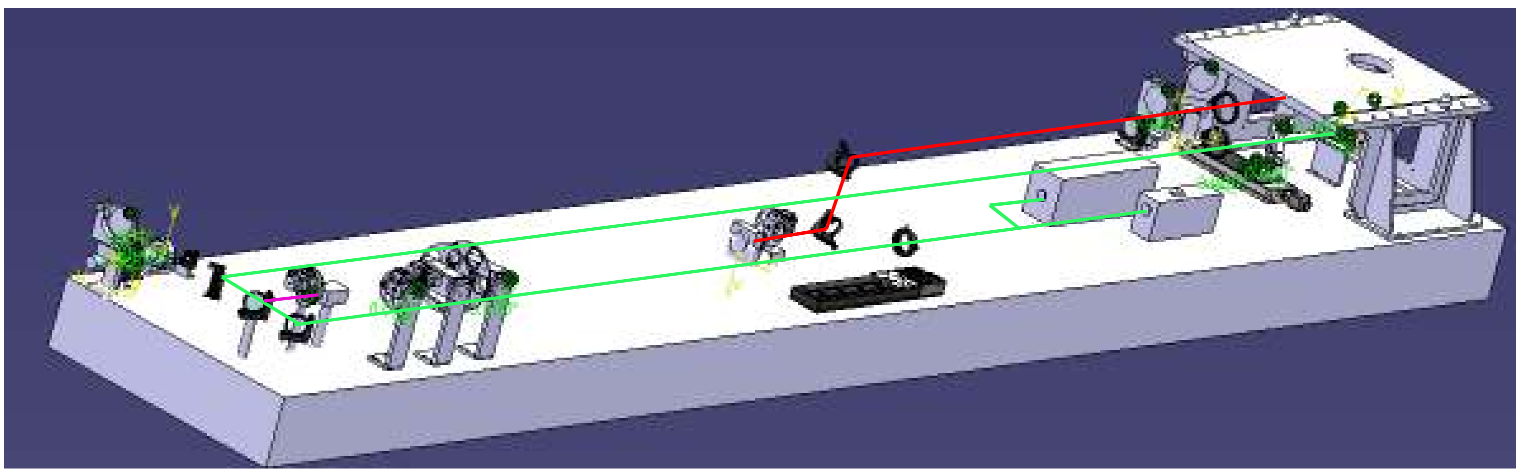


Image of 1mm grid object

New Design for Abort Gap

- Beam splitter T=92% above entrance mirror
- F=2000mm plano-convex lens
- 2 fold mirrors (one motorized)
- Camera to check beam presence and alignment



Lab and tunnel test plan

BSRT:

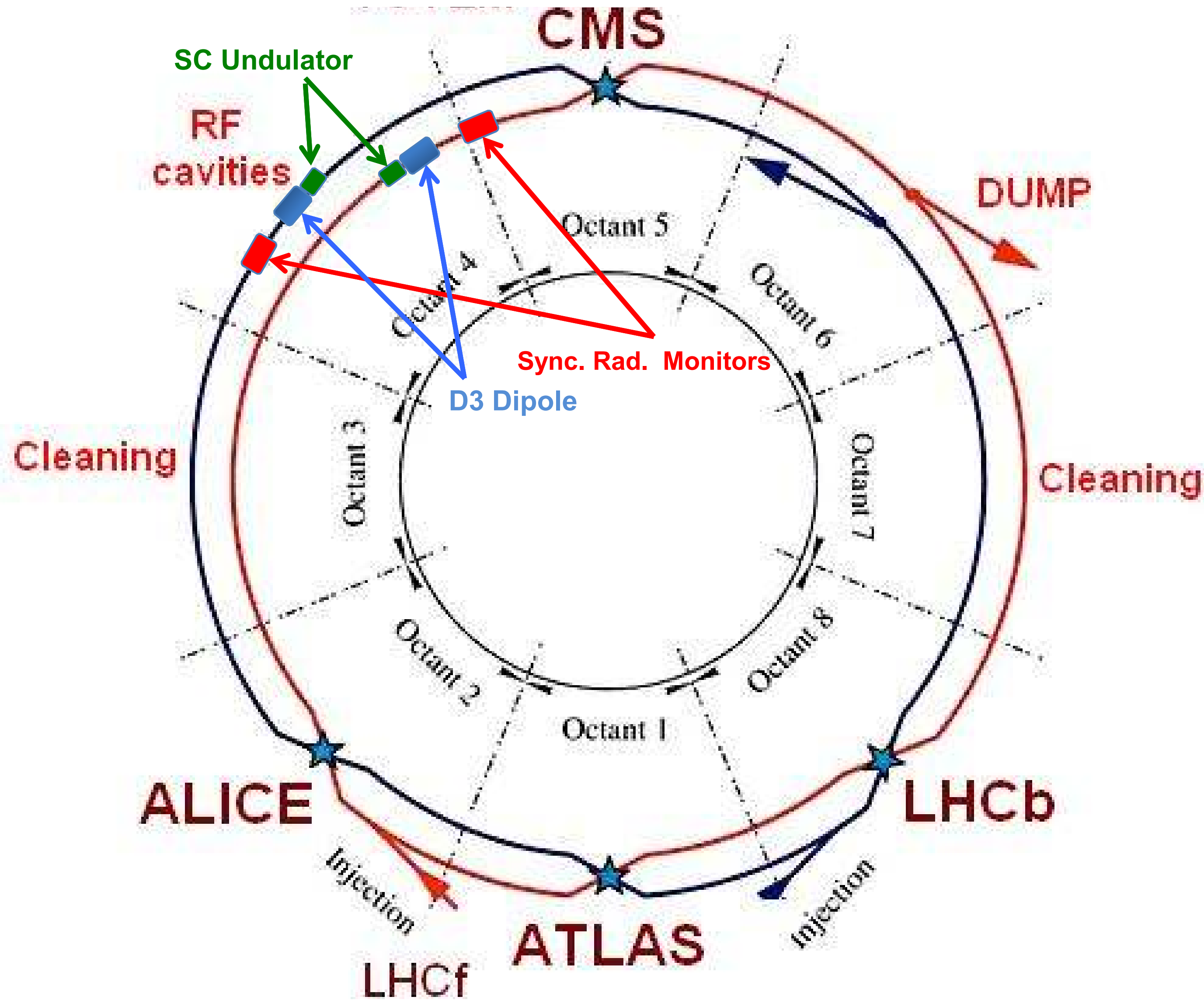
- Test in lab to validate the system as completely as possible
  - Magnification, aberrations, transmission, alignment procedure...

Abort Gap Monitor:

- Test in lab (mostly alignment procedure)
- Installation in the tunnel on one side during the shutdown
  - In addition to the present system

spare

BSRT in LHC



CMS
SC Undulator
RF cavities
DUMP
Octant 5
Octant 4
Octant 6
Sync. Rad. Monitors
D3 Dipole
Cleaning
Octant 3
Octant 7
Cleaning
Octant 2
Octant 8
Octant 1
ALICE
LHCb
Injection
Injection
ATLAS
LHCf