Background characterization in ATF2

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13/1/2016

Outline

- Overview
- Beam halo measurements and investigation: Dimond Sensor (DS)
- BDSIM background simulations
- Beam halo collimation
- Summary

Overview

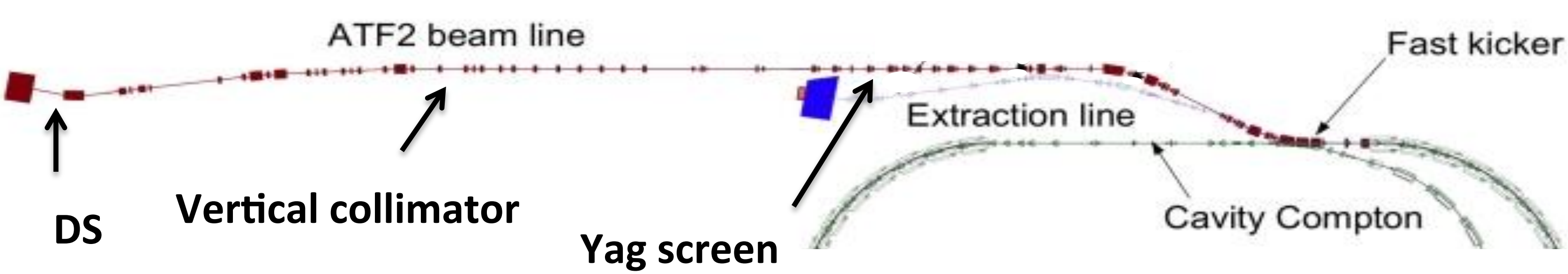
Beam halo is an important issue for **beam loss and background control in accelerator machines as ATF2** and the **Future Linear Colliders (FLC)**

Different activities are been carried out in the context of beam halo investigation and background control and reduction at ATF2:

- **Beam halo measurements and model investigation**
  - -with Diamond Sensor (DS) (post IP) (LAL team)
  - -Yag screen (EXT line) (T. Naito)

- **Validation of BDSIM background simulations in a real machine** (RHUL team)

- **Beam halo collimation** (IFIC and LAL)
  - -reduce and control the background in ATF2
  - (collimator wakefield study)



Overview

These three projects are connected:

- **Beam halo measurements and model investigation**
  - -with DS (post IP) (LAL team)
  - -Yag screen (EXT line) (T. Naito)

-Validation of BDSIM background simulations in a real machine (RHUL team)

- **Beam halo collimation** (IFIC and LAL)
  - -reduce and control the background in ATF2 (collimator wakefield study)

- Beam halo collimation is required for Compton electron measurements with the DS
- DS is needed to test the performance of the collimator

- BDSIM simulations could be useful for the understanding of DS measurements
- BDSIM has been used to study the performance and efficiency of the beam halo collimation system tacking into account the emission of secondary particles

Beam halo measurements and investigation: DS

Motivation

- Beam halo transverse distribution unknown → **investigate halo model**
- Probe **Compton recoil electron** generated in the IPBSM (prepare future investigations of higher order contribution to Compton process)

Status

- **Horizontal DS** prototype was installed in 2014
- **Vertical DS** prototype installed in 2015
- First measurements have been taken with both DS in 2014 and 2015
- Currently data taking process need trained operator
- Currently **pick up signal** does not allow to extend dynamic range to lower than few thousand electrons

Beam halo measurements and investigation: DS

2015 measurements campaign

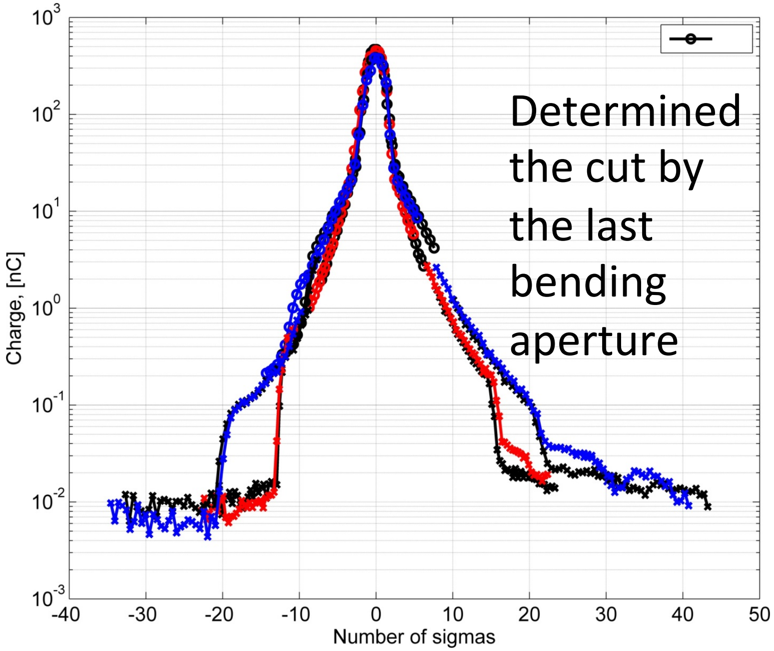
Data taken for different:

- vacuum pressures of DR
- optics
- round collimator position

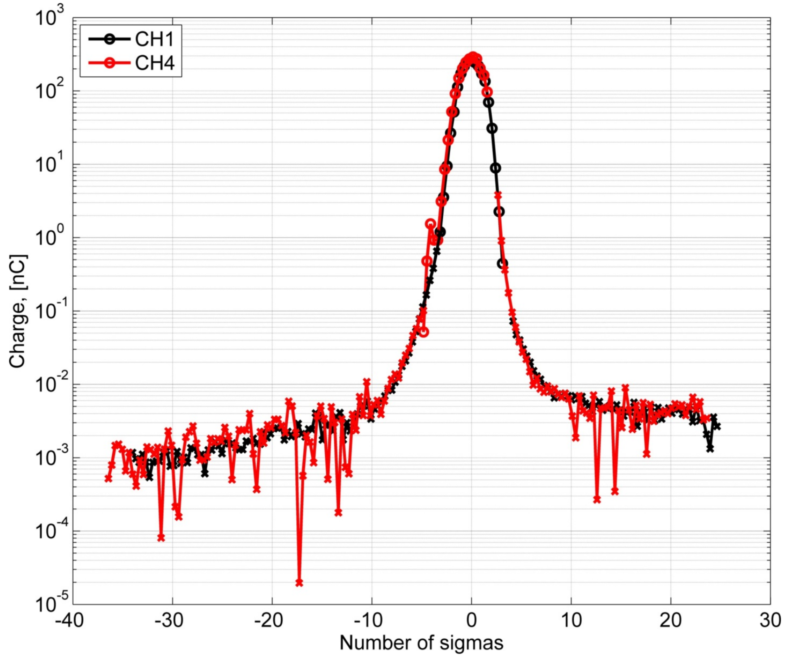
Vertical beam halo scan. N ≈ 8e9

Red: 10x1 optics, σ= **1.46 mm**

Blue: 10x4 optics, σ=**0.98 mm**



Horizontal beam halo scan. N = 2e9; Vacum =7.87e-7



Beam halo measurements and investigation: DS

Future work

- **Detailed and systematic beam halo studies** for different beam conditions and optics
- Data taking process automation
- **Integration of the DS control and data tacking software in the ATF2 control room** to facilitate the use to ATF2 members for beam core measurements
- **Pick up signal investigation**
- LAL team will join the beam run of February/ March

Background simulations with BDSIM

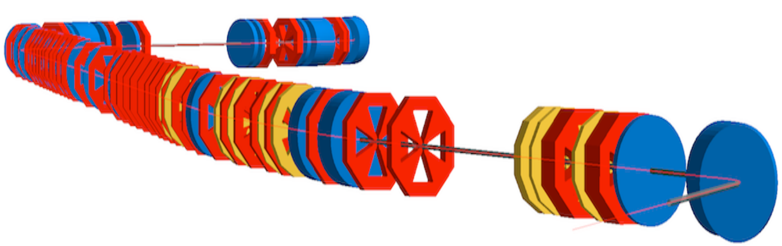
BDSIM is a **Geant4** extension toolkit for in-vacuum **thick-lens tracking as well as the full physics processes of Geant4 when the particles propagate in material**

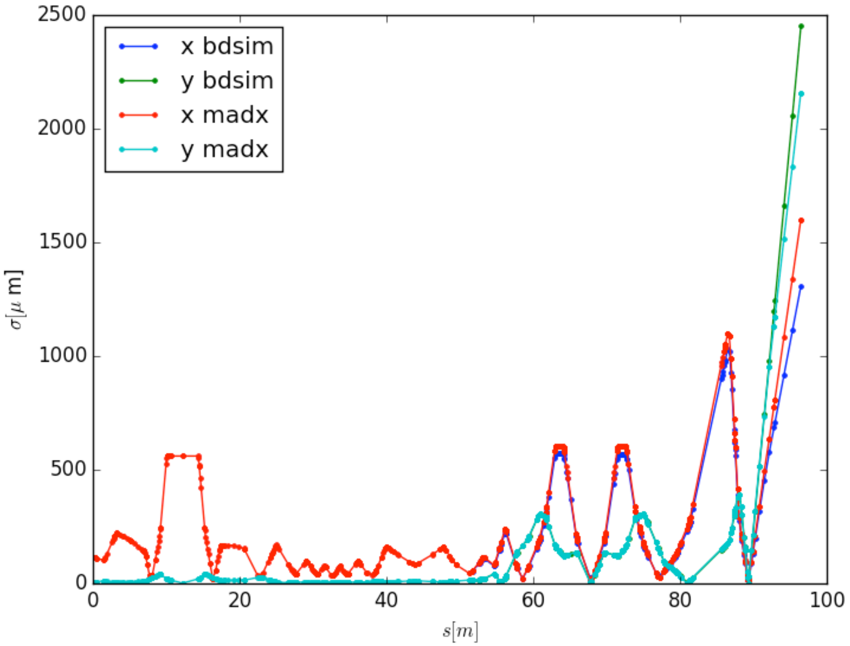
Motivation

- Significant recent development of BDSIM need to be **validate against a real machine**

Status

- **ATF2 model** has been update and reproduces the nominal optics from particle racking

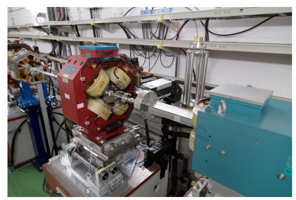


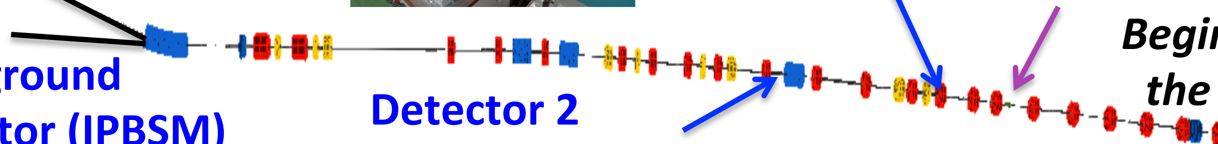


Background simulations with BDSIM

Status

- Two **cherenkov based detectors** have been installed in ATF2 (Pb, aerogel, PMT). The detectors are not absolutely calibrated so only relative measurements can be made
- **Data was taken in June 2015** (J. Snuverink & L. Nevay) 6hrs beam time
- Correctors were used to scan the beam to create **varying patterns in both detectors**
- Background measurements were taken with each **OTR screen inserted**





Future work

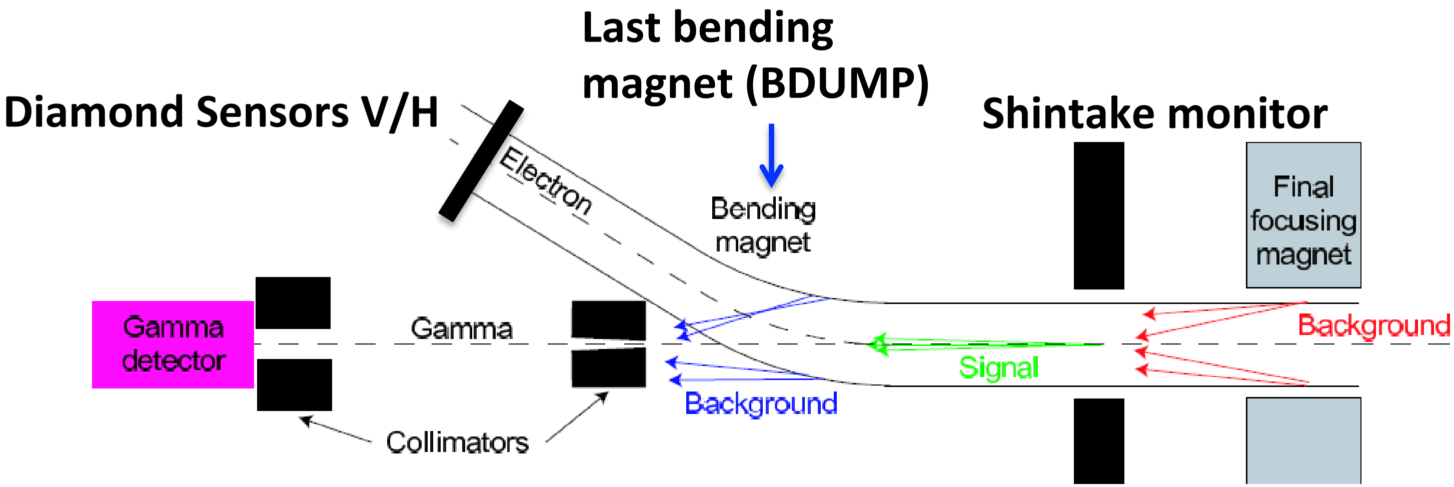
- First finish work on BDSIM itself (modernizing and testing)
- Analyze and compare fully all ATF2 data from 2015
- Finish the accurate model of the ATF2 collimator system

Detailed and validated model of the ATF2 expected to be completed by late February

Beam halo collimation

Motivation and main objectives

ATF2 post-IP beamline

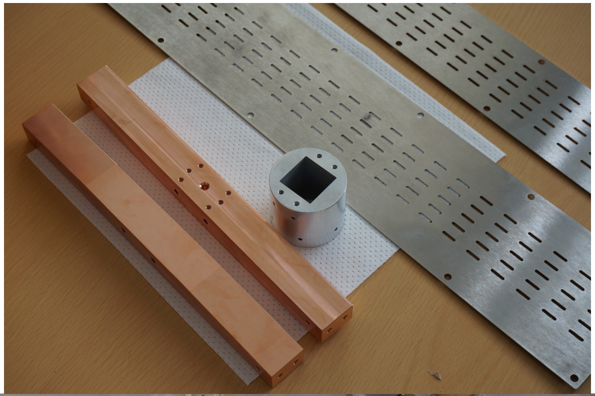


- ***Beam halo control and study*** in the vertical and horizontal plane
- ***Beam halo reduction*** to reduce the bremsstrahlung background that could be created at the **last bending magnet (BDUMP)**
- ***Beam halo reduction, especially in the horizontal plane*****,** to enable Compton electron measurements at the **horizontal DS**

Beam halo collimation

Status

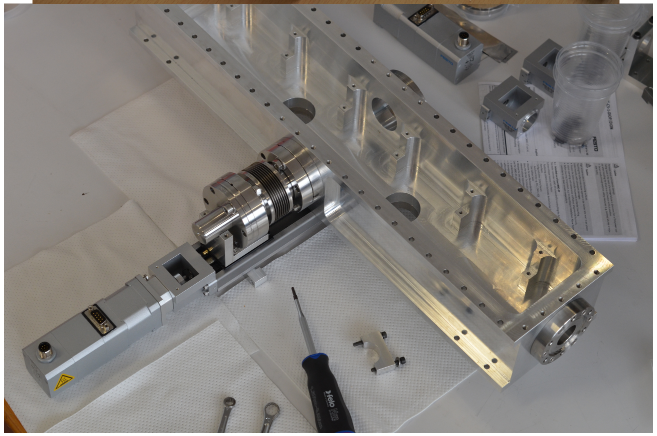
1. **Beam dynamics simulation and realistic tracking studies** to evaluate the efficiency of betatron and energy collimation in ATF2 has been made (MADX, BDSIM)
   - The **transverse collimation** is most efficient system
     - A **single vertical system** has been considered to be the **first priority**
     - In a second stage a single horizontal system will be considered



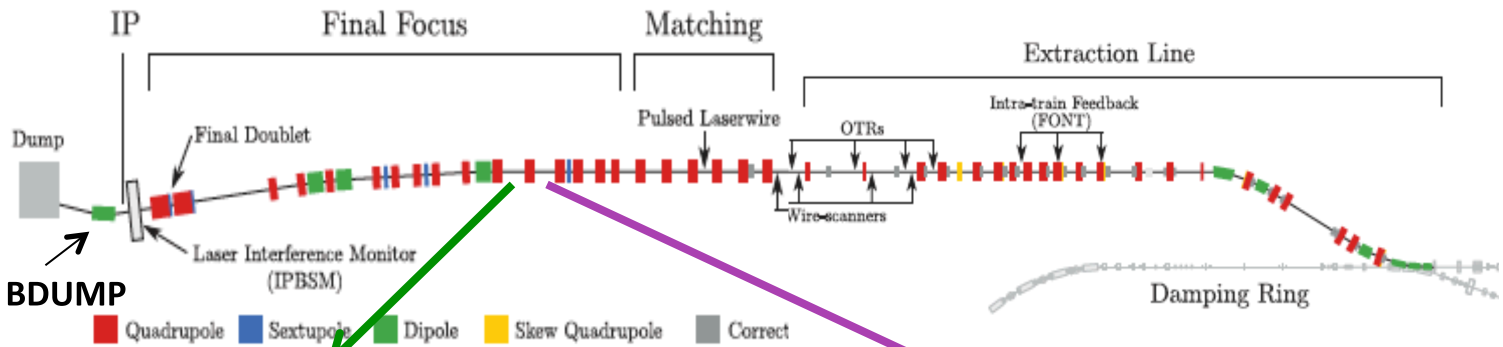
2. **Design of a vertical retractable halo collimation device has been done** (IFIC-LAL)
   - **Collimator wakefield minimization**
   - **Wakefields beam impact** induced study

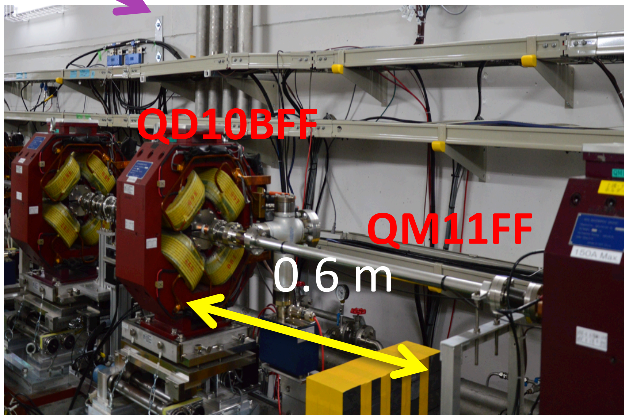
Work in progress

3. **Construction and calibration of a vertical halo collimation device** (IFIC-LAL)
   - All the components have been received
   - Mounting and alignment of the jaws planned to be finished before 12th February



Beam halo collimation





Horizontal halo collimation system in the FFS

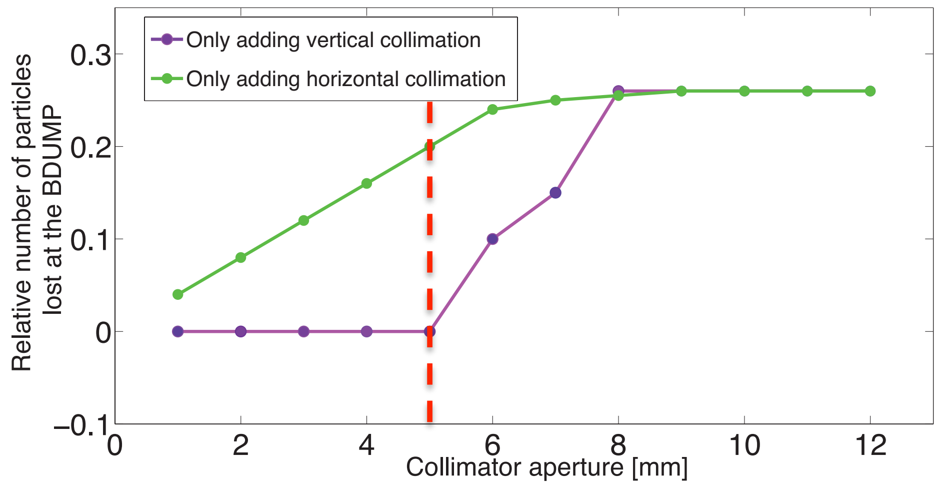
- Between **QD10AFF-QF9BFF (FF)**
- β_x=135 m
- $\Delta\mu_x$=3π BDUMP and DS
- 0.7 m free space length

Vertical halo collimation system in the FFS

- Between **QD10BFF-QM11FF**
- β_y=7126.51 m
- $\Delta\mu_x$=3π BDUMP and DS
- 0.8 m available free space length

Beam halo collimation

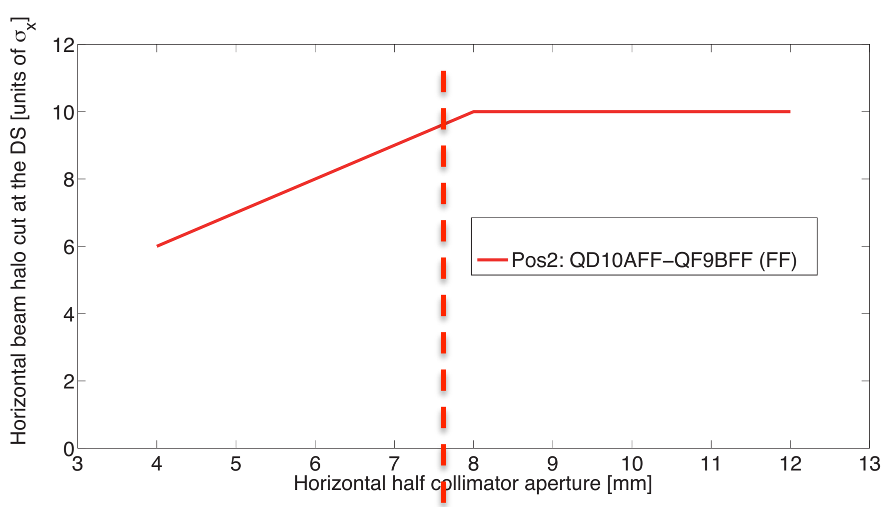
First collimation target: reduce the losses at the BDUMP



Only a **vertical collimation** system with **aV=5 mm** is required to avoid losses at the last bending magnet (BDUMP)

(Realistic halo model)

Second collimation target: cut the horizontal beam halo at the level of $8\sigma_x$ at H-DS



A **horizontal collimation** system with an aperture of **aH=7 mm** is required

(Realistic halo model)

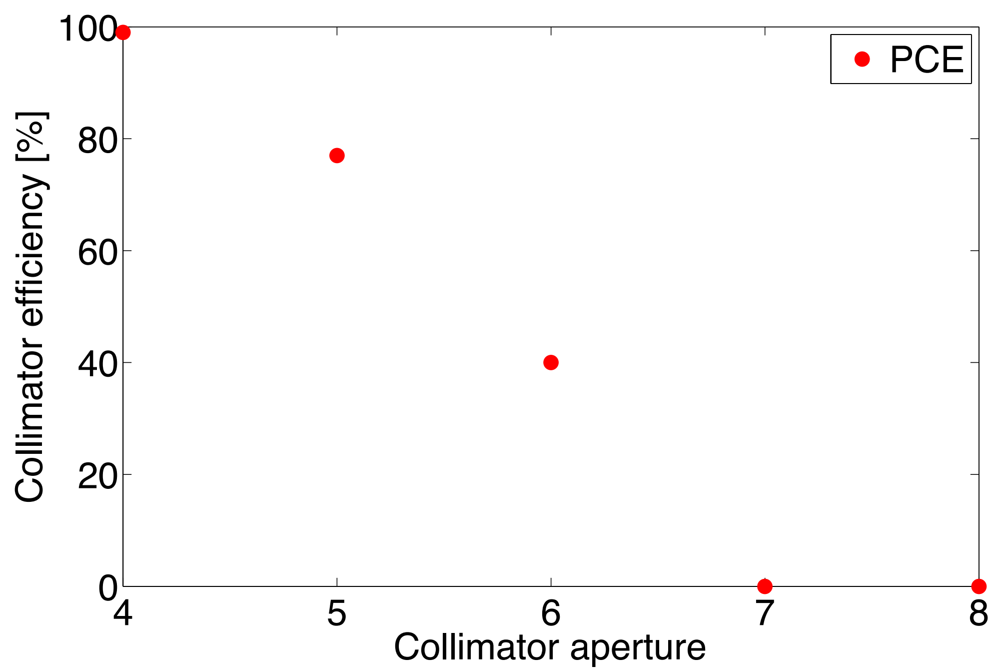
Beam halo collimation

BDSIM vertical collimation system efficiency study:

From the preliminary **simulations performed with BDSIM** the vertical collimation system with a half aperture of **5 mm (10^6 particles and 10x1 optics):**

Primaries cleaning efficiency at the BDUMP

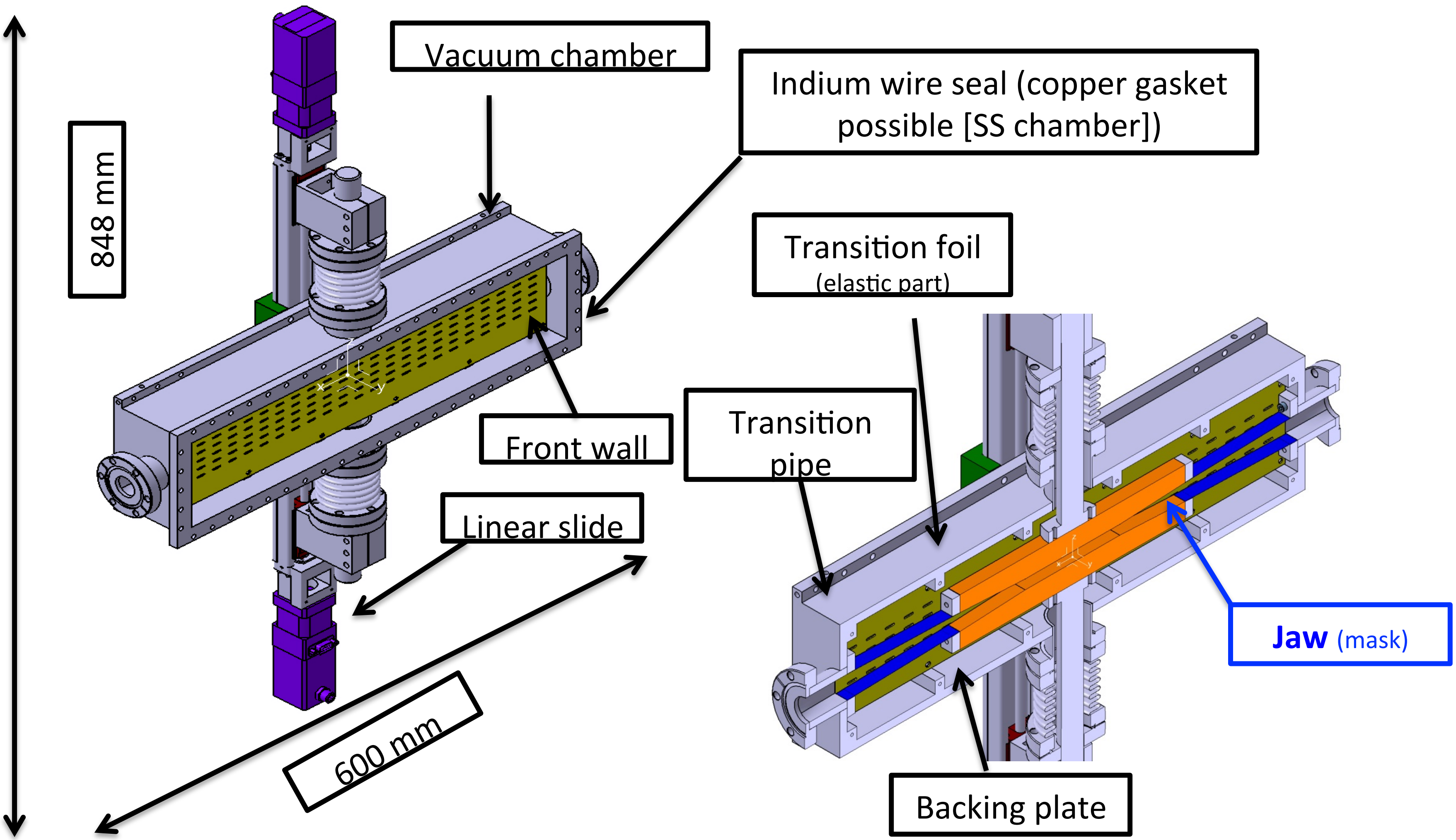
$$PCE = 100 \times \left[1 - \frac{P^{BDUMP}_{with\ collimator}}{P^{BDUMP}_{no\ collimator}}\right]$$



- **Reduction of losses at the last bending magnet about 77%**
- No additional background photons will reach the IPBSM monitor

Beam halo collimation

*Based on preliminary design for the ILC collimators, Full structure simulations of **ILC collimators**" J.D. A. Smith, Lancaster University/Cockcroft Institute, Warrington, UK, Proceedings of PAC09*



CST PS simulation-> Optimized jaws (mask): $\mathbf{L_f}$=100 mm; **α**=3°; **a**=12-3 mm; **h**=12 mm; $\mathbf{L_T}$=238 mm; Cu

Beam halo collimation

Future work

4. Software design of the halo collimation device control system (IFIC-LAL)

✓Collimator control implementation in the ATF2 control room

5. Installation and commissioning in ATF2 (IFIC-KEK-LAL)

- Shipping date estimated for the 12th of February
- Installation planed for the 1-5th of March

People working on the installation and commissioning: S. Wallon, F. Bogart, P. Cornebise P. Bambade, R. Yang, V. Kubytskyi (LAL) and A. Faus-Golfe, N. Fuster- Martínez (IFIC)

6. Experimental studies: background studies and collimator wakefield measurements (IFIC-KEK-LAL)

Beam halo collimation

Tentative shift plan for two weeks run in March 2016

1.5-2 shifts per week

- Jaws position control: DS measurements
- Wakefield kick impact : orbit measurements for different collimator apertures
  - Different intensities
- Background studies: IPBSM / RHUL Cherenkov detectors
  - Different optics
  - Different intensities
  - To be compared with BDSIM simulations and can be useful to validate BDSIM)

Summary

- Two **DS** have been installed in ATF2 in order to perform **dedicated beam halo investigations** and first data has been taken. Some technical aspects as the pick up signal still need to be understood and the data taking process automatized and integrated in the ATF2 control room

- The **investigation of the formation and transport of the beam halo** in the ATF2 beam line will be investigated combining the **DS (post-IP) and YAG screen (EXT line) measurements**

- The BDSIM ATF2 model has been update and **two cherenkov detectors were installed by the** RHUL team in June 2015 and data taken to be compared with simulations. Detailed and validated model of ATF2 expected to be completed by late February

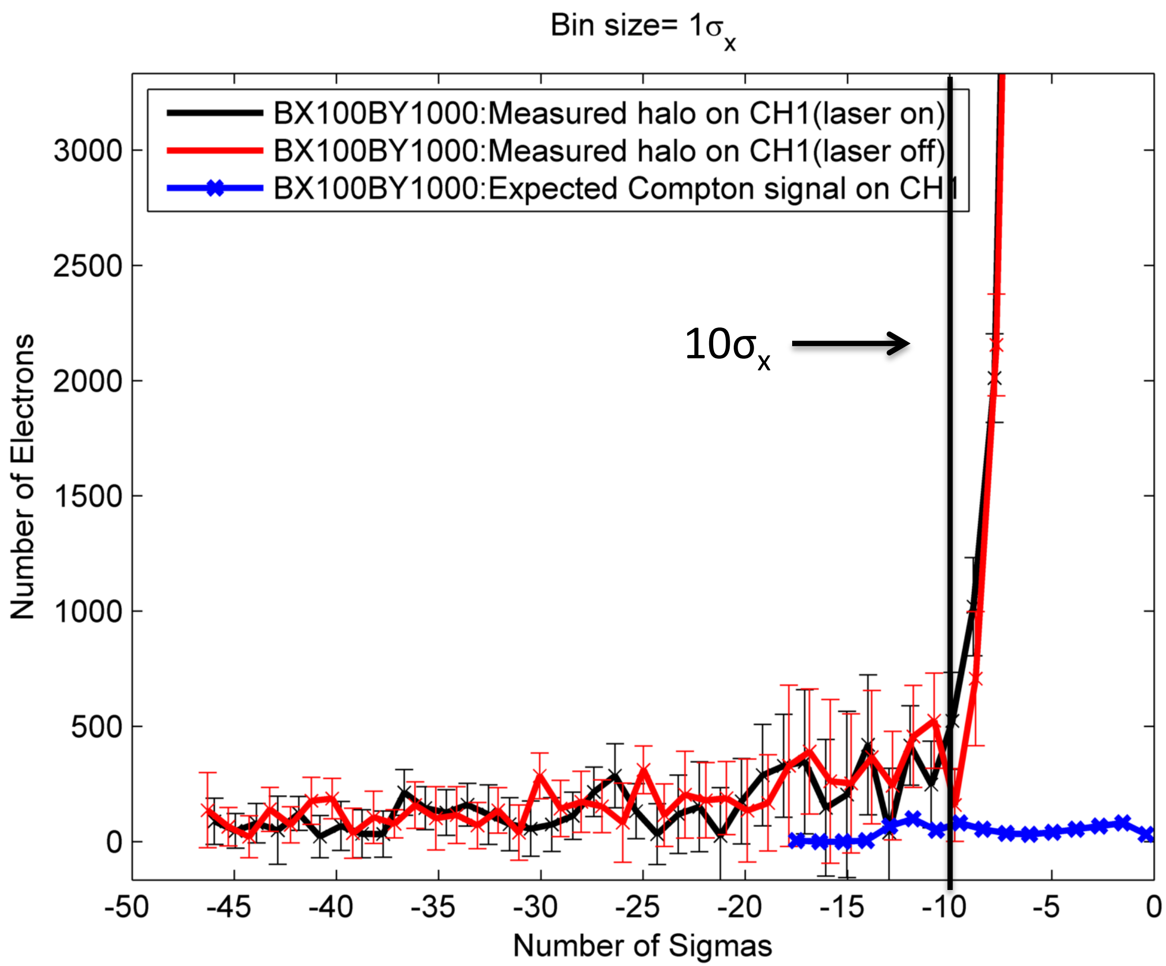
- The **vertical collimation system will be installed in ATF2 in March 2016** and the performance will be tested in terms of **halo cleaning** (background reduction) and **wakefield impact**

Thank you very much for your attention!

Back up…

Motivation

December 2014 run: horizontal beam halo measurements



S.Liu, phd thesis "Development of Diamond Sensors for Beam Halo and Compton Spectrum Diagnostics after the Interaction Point of ATF2",LAL,08-2015

Beam dynamics simulation and realistic tracking studies

Halo collimation betatron depth

Aperture (mm)	Vertical (σ_y=0.3265)	Horizontal (σ_x=0.5592)
5	$15\sigma_y$	$9\sigma_x$
6	$18\sigma_y$	$11\sigma_x$
7	$21\sigma_y$	$13\sigma_x$
8	$24\sigma_y$	$15\sigma_x$
10	$30\sigma_y$	$18\sigma_x$
12	$37\sigma_y$	$21\sigma_x$
15	$46\sigma_y$	$27\sigma_x$

Optics considerations studies and location optimization

The choice of the best location for a collimation system is a tradeoff between the the optics, the collimation depth required and the wakefield impact induced

For a given collimator aperture, $a_{x,y}$, the **betatron collimation depth**, $N_{x,y}$, is defined:

$$N_{x,y} = \frac{a_{x,y}}{\sigma_{x,y}} = \frac{a_{x,y}}{\sqrt{\epsilon_{x,y}\beta_{x,y} + (D_{x,y}\delta_E)^2}} \propto \frac{a_{x,y}}{\sqrt{\beta_{x,y}}}$$

The wakefield beam impact of a <u>rectangular collimation system</u>:

Amplification factor $$A_{\beta_{x,y}} \propto \frac{N_b}{\gamma}\beta_{x,y}\kappa_T \propto \frac{N_b}{\gamma}\frac{\beta_{x,y}}{a^2_{x,y}}$$

Where κ_T depends on the geometry and material of the collimator $$\kappa_T \propto \frac{1}{a^2_{x,y}}$$

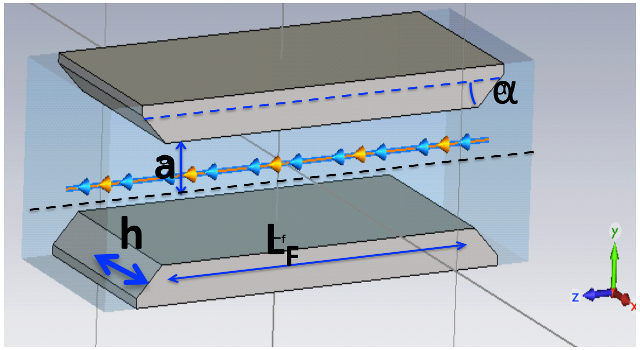
(*Collimator Wakefield Calculations for ILC-TDR Report, P. Tenenbaum, LCC-0101, August 2002*)

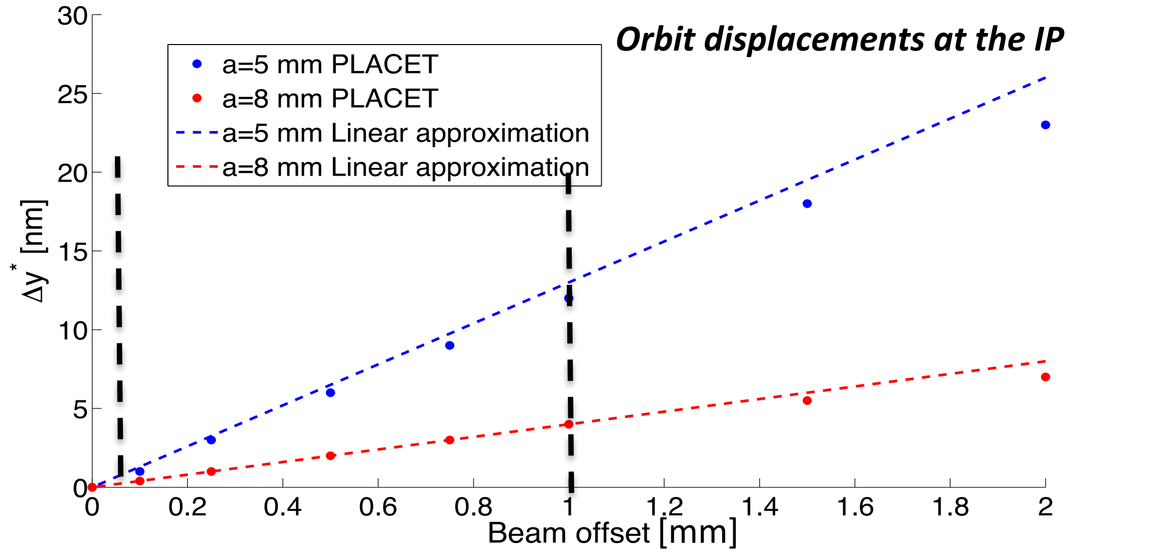
Optics considerations for a single rectangular betatron collimation jaw:

- High $\beta_{x,y}$ for a given *N* with bigger *a*
- $\Delta\mu_{x,y}=n\pi$ in phase with the collimation point (BDUMP and DS)
- $D_{x,y} \cong 0$ for a pure betatron collimation

Wakefield design considerations and impact study

CST PS simulation-> Optimized jaws (mask): **L_f**=100 mm; **α**=3°; **a**=12-3 mm; **h**=12 mm; **L_T**=238 mm; Cu

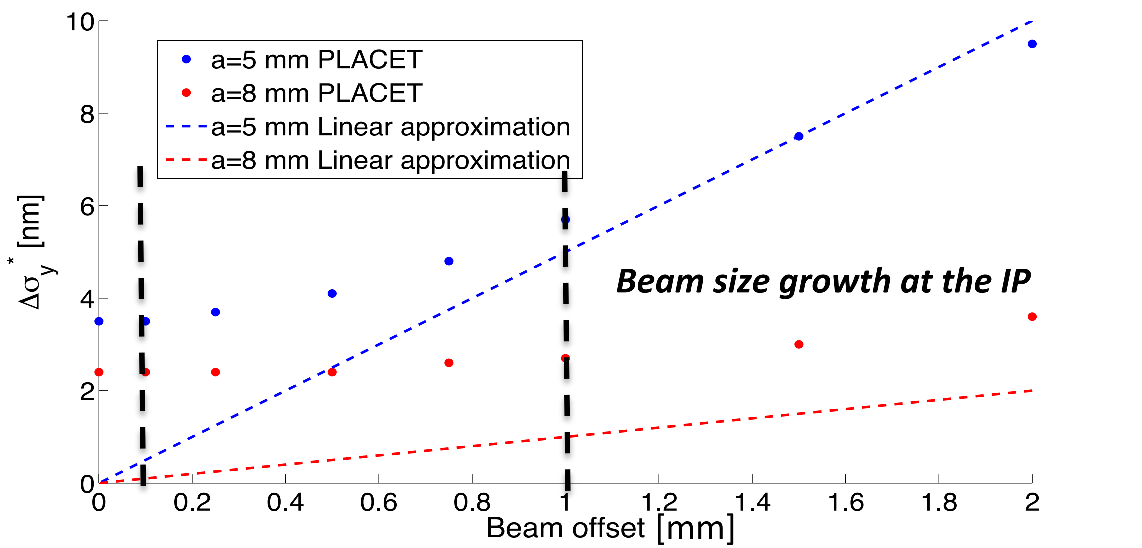




PLACET tracking code

- $N=6x10^9 e$
- σ_z= 7 mm
- ***<u>10x1 optics</u>***

aV=5 mm		
y_{offset} [mm]	1	0.1
Δy * [nm]	12	2
$\Delta\sigma_y$ * [nm]	6	3.5



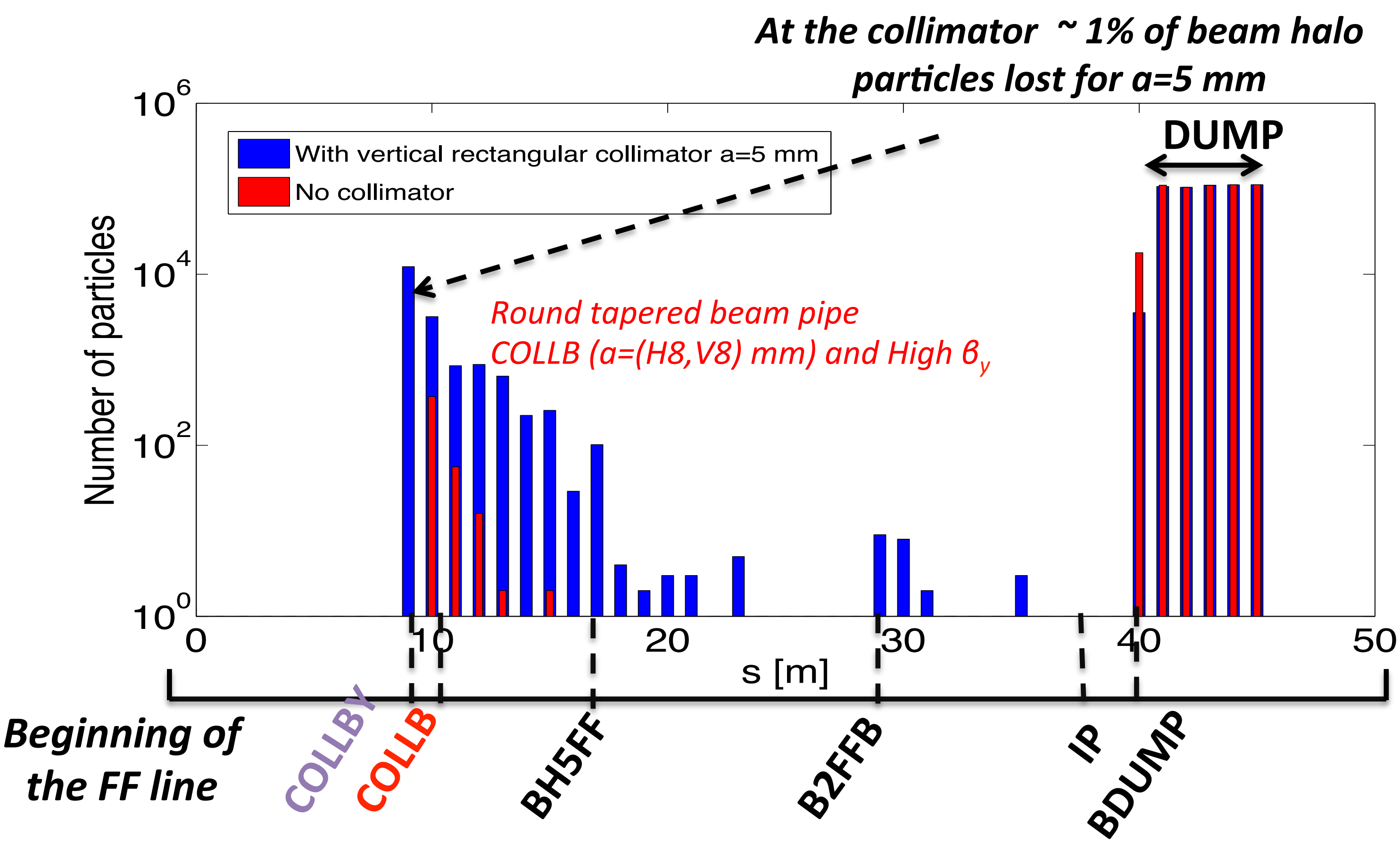
Good alignment is required

Beam halo collimation

BDSIM vertical collimation system efficiency study:

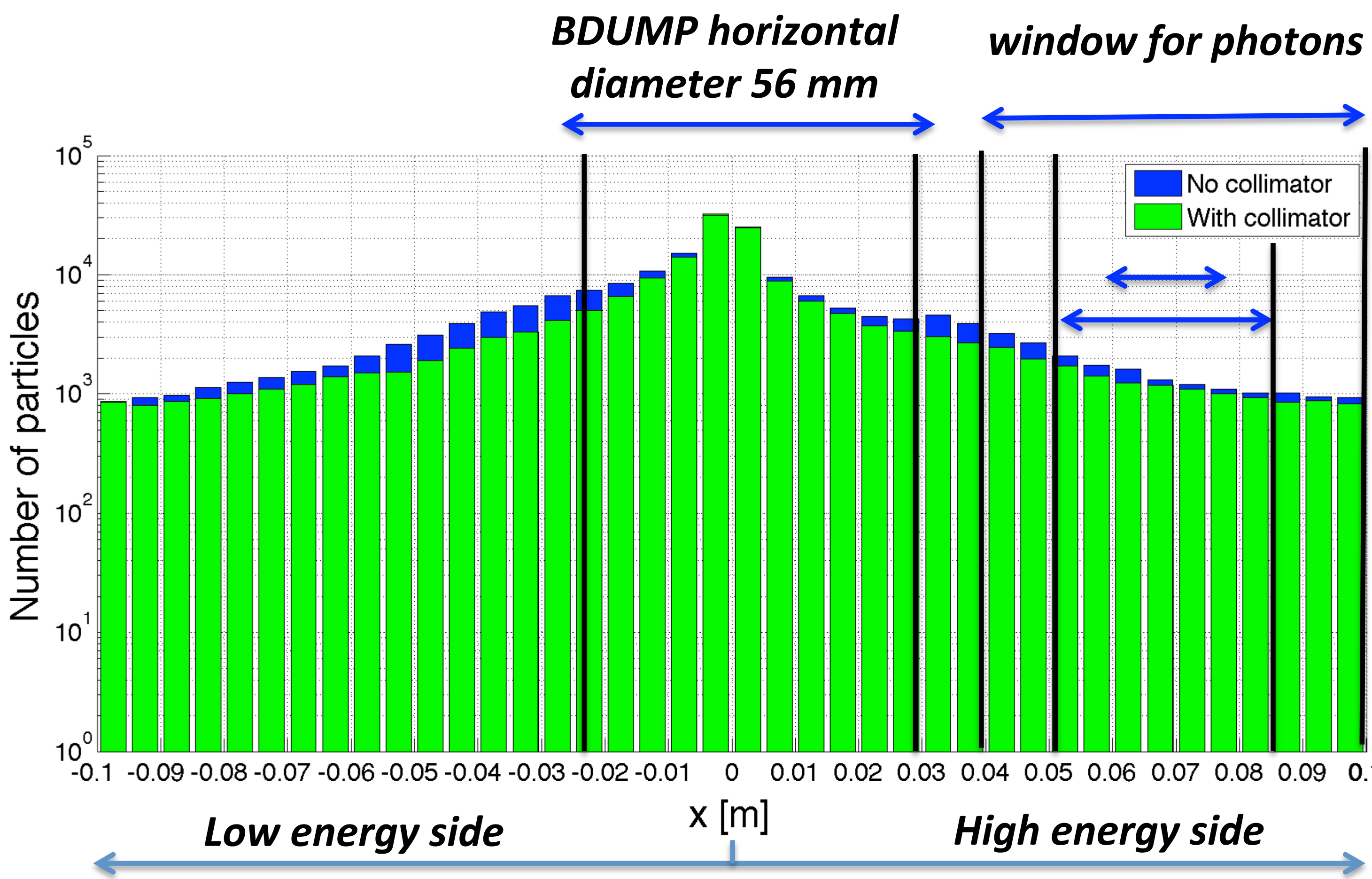
From the preliminary simulations performed with BDSIM the vertical collimation system with a half aperture of **5 mm (10^6 particles and 10x1 optics):**

- **Reduction of losses at the last bending magnet about 77%**
- No additional background photons will reach the IPBSM monitor



Window sampler: reduction of number of photons in the IPBSM

Secondaries in the horizontal plane: photons



Reduction of photons that can reach the IPBSM is about 40%

Window sampler: reduction of number of photons in the IPBSM

Secondaries in the vertical plane: photons