MAMA at FLASH

Momentum and momentum spread analysis at FLASH:

The Accelerator and the magnetic spectrometer

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HELMHOLTZ ASSOCIATION

DESY

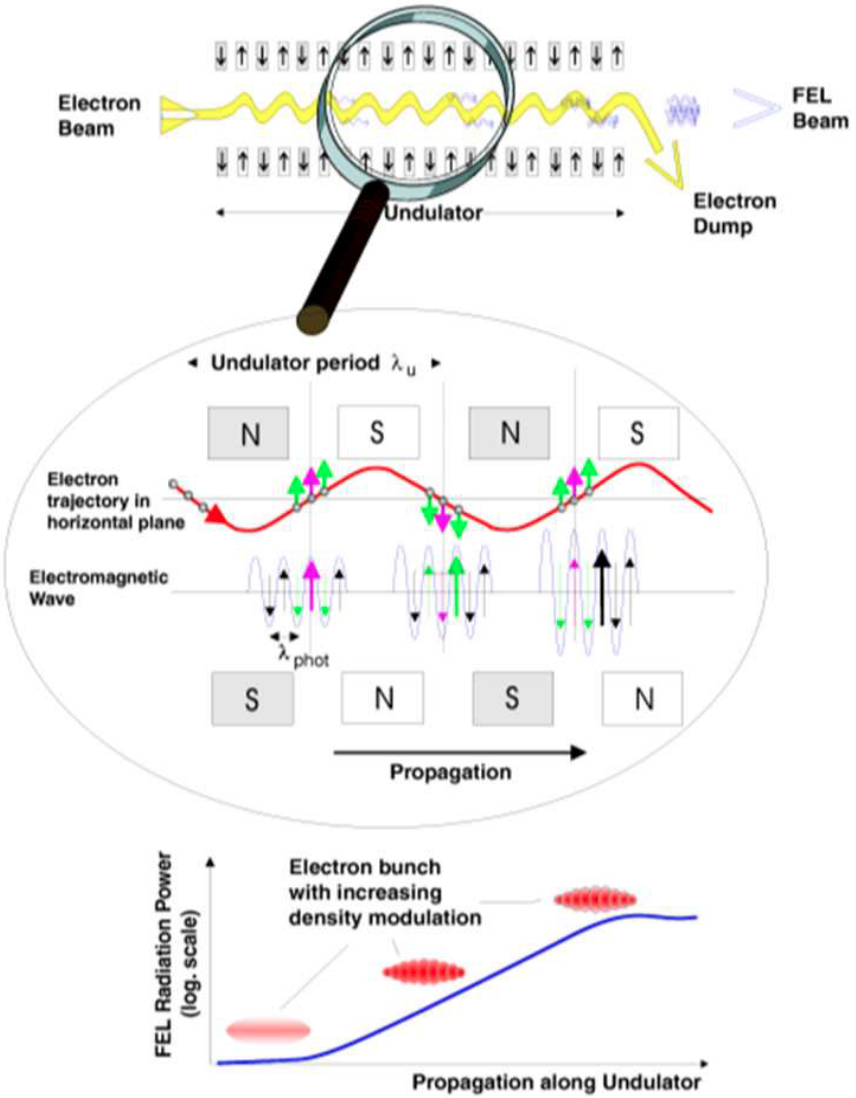
Motivation: SASE Beam Requirements

SASE: Self Amplified Spontaneous Emission

The beam undergoes a process called micro-bunching, due to the energy transfer from electrons to electromagnetic wave.

The power of the electromagnetic wave grows exponentially with z until saturation

L_g: exponential characteristic growth length.



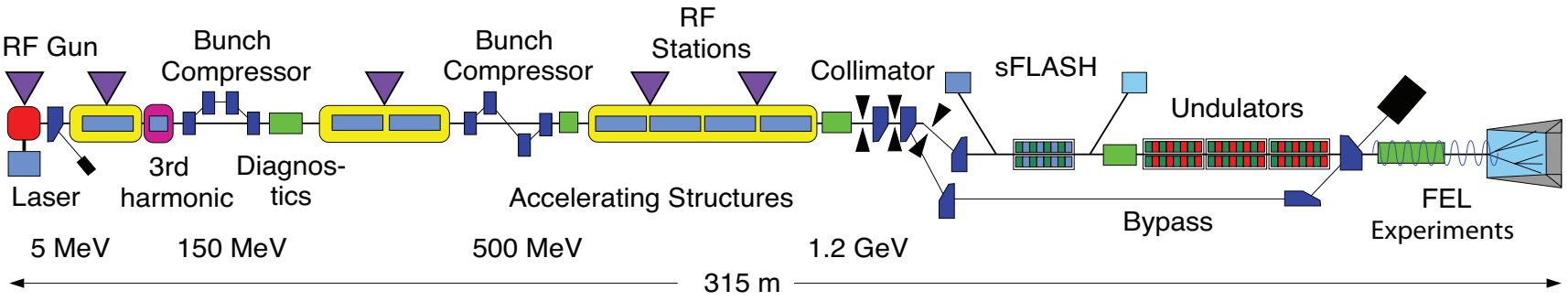
Motivation: SASE Beam Requirements

To decrease L_g means to reduce the undulator length

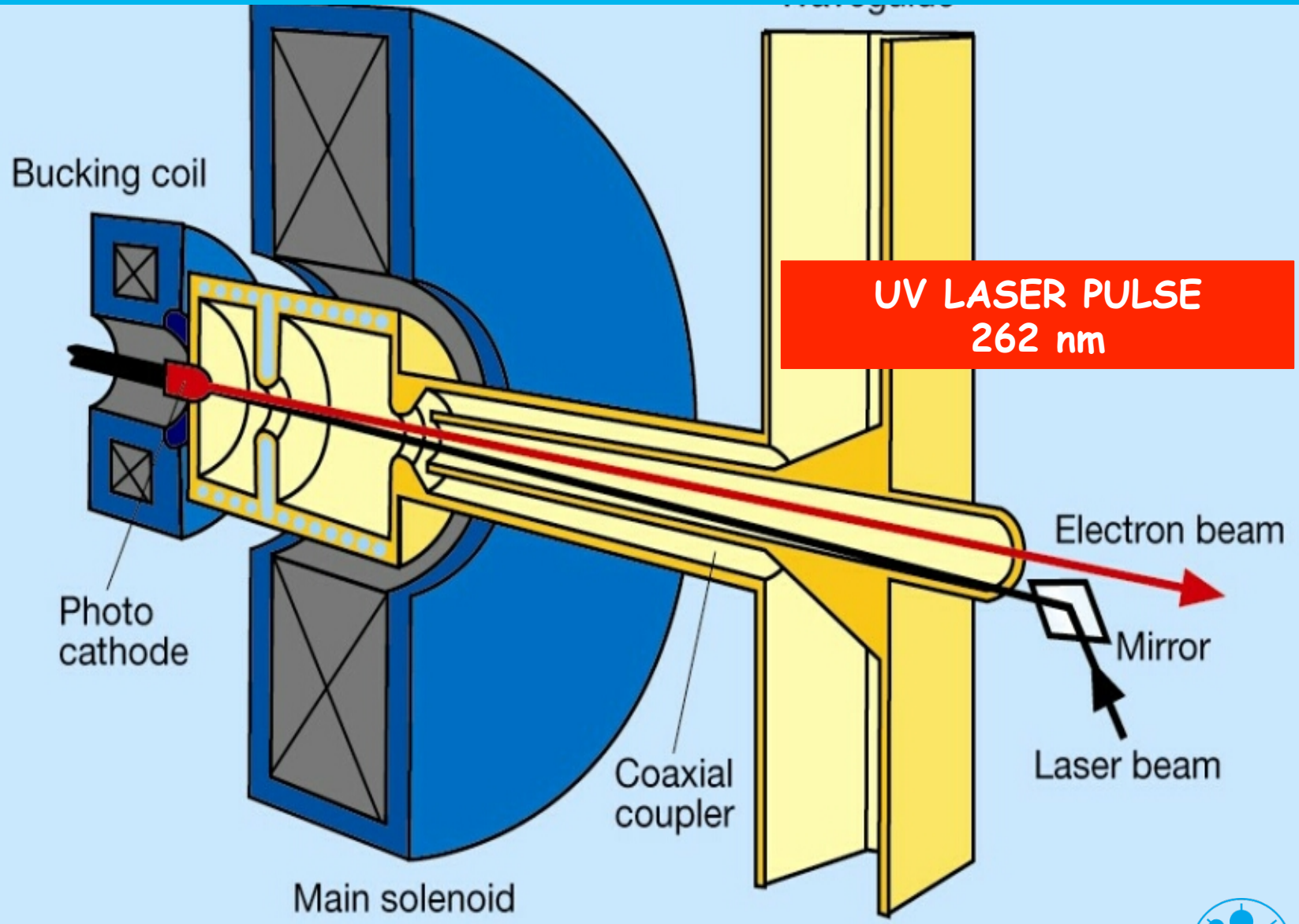
It is necessary to obtain:

- **Small Transverse Emittance:** Good overlap of electron-photon all over the undulator length
- **High Peak Current:** High radiation power within a small length
- **Small Energy Spread:** As many particles as possible within the lasing bandwidth and to allow good compression

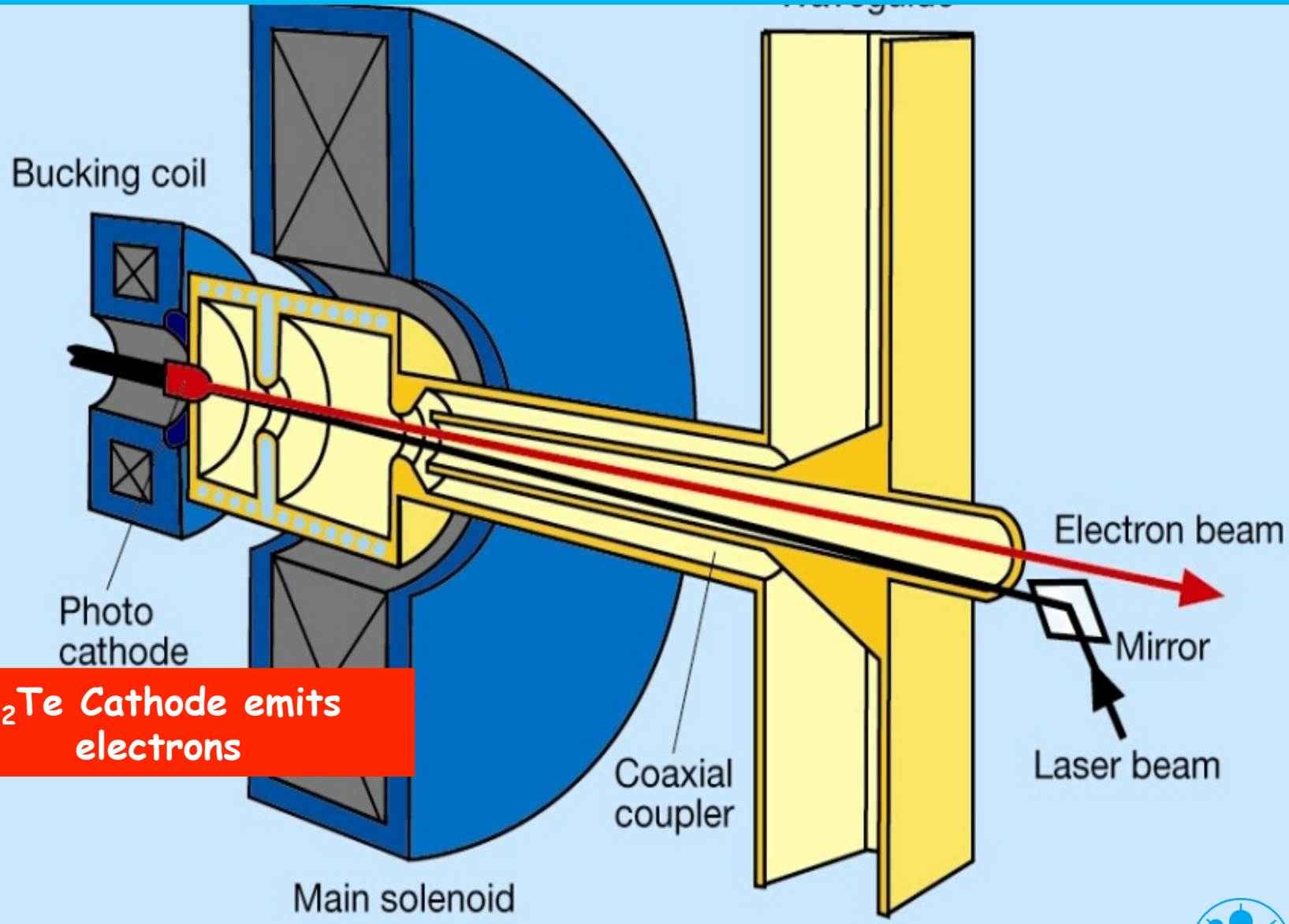
FLASH Accelerator



FLASH Complex

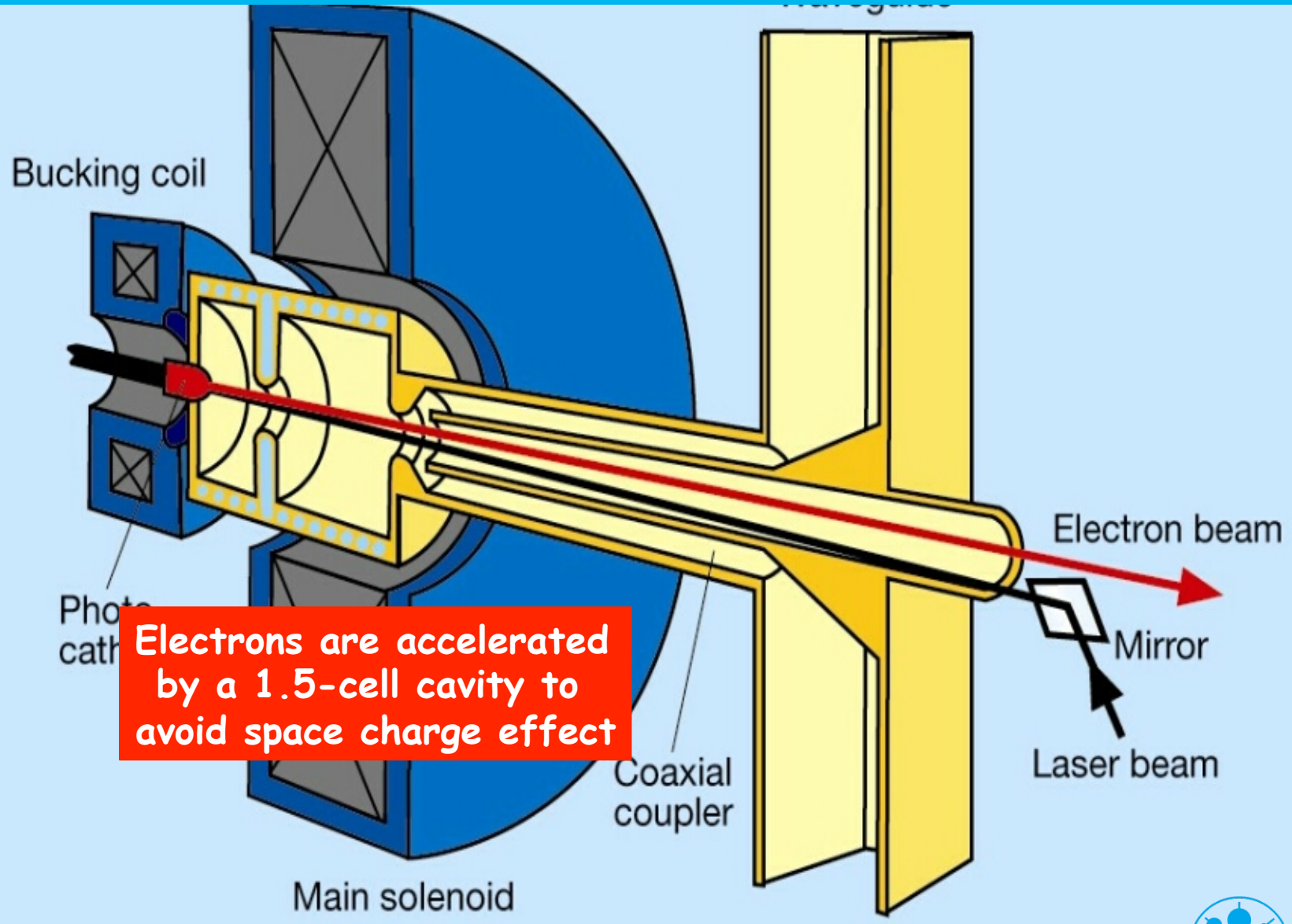


FLASH Complex

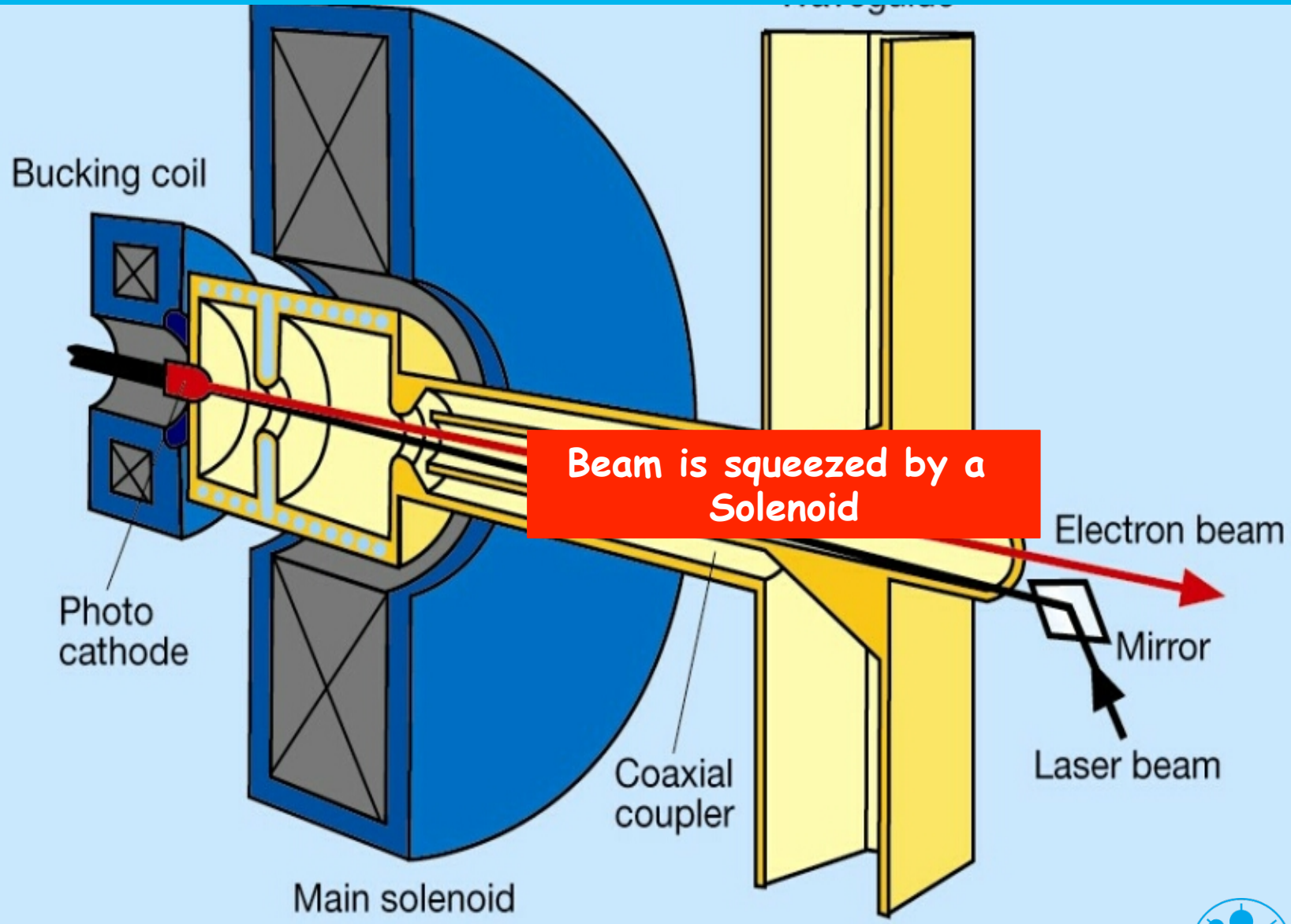


Cs_2Te Cathode emits electrons

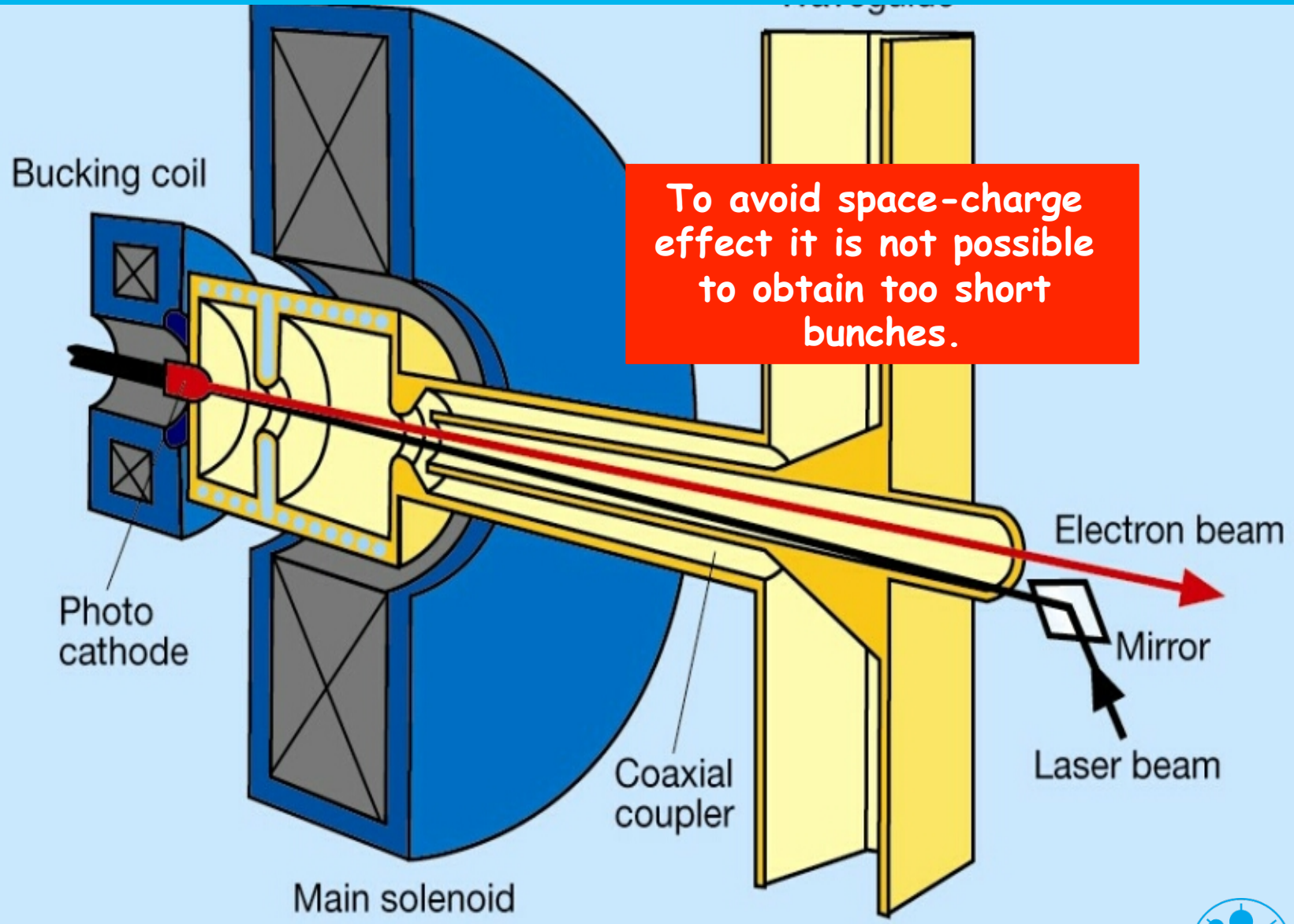
FLASH Complex



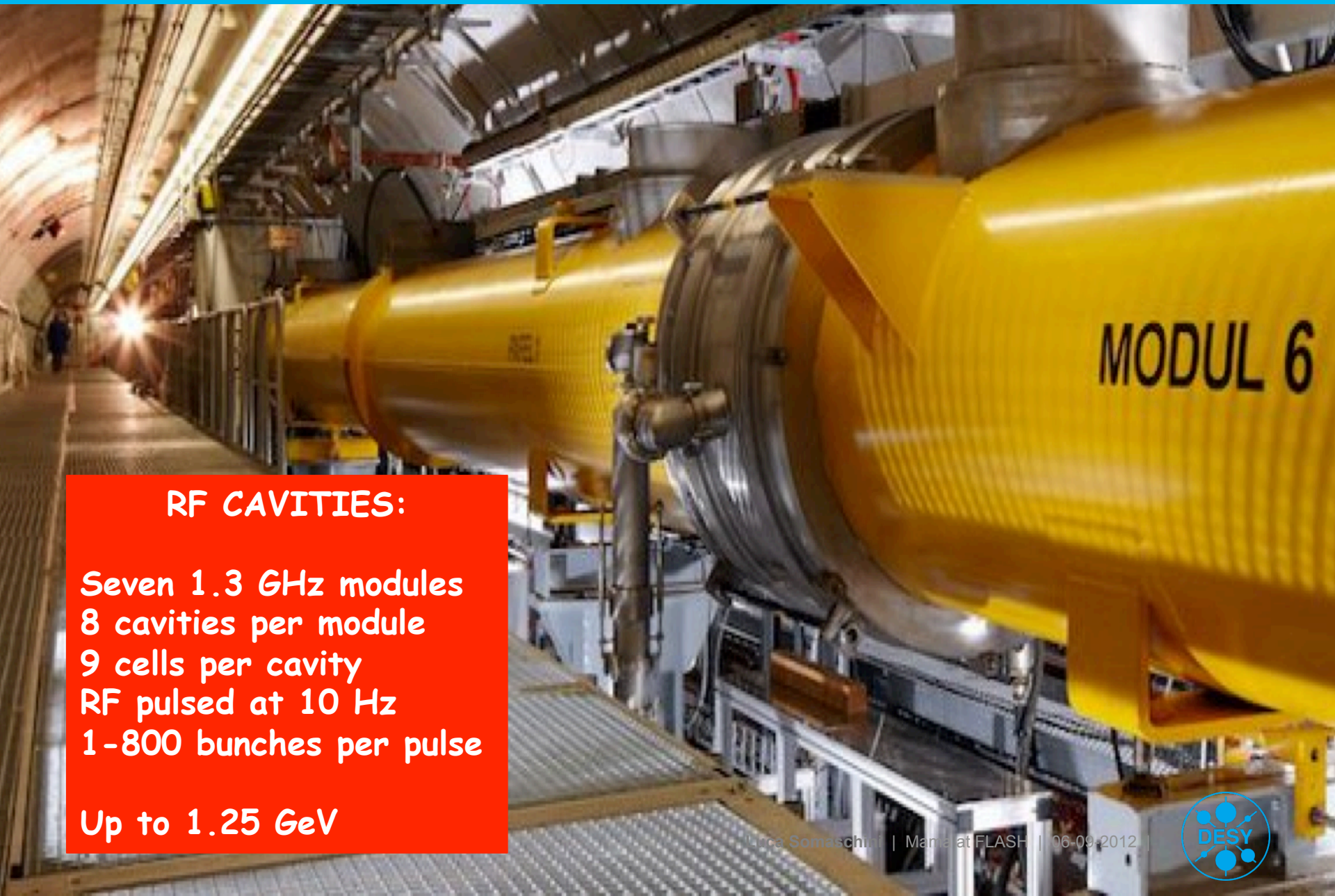
FLASH Complex



FLASH Complex



FLASH Accelerator



RF CAVITIES:

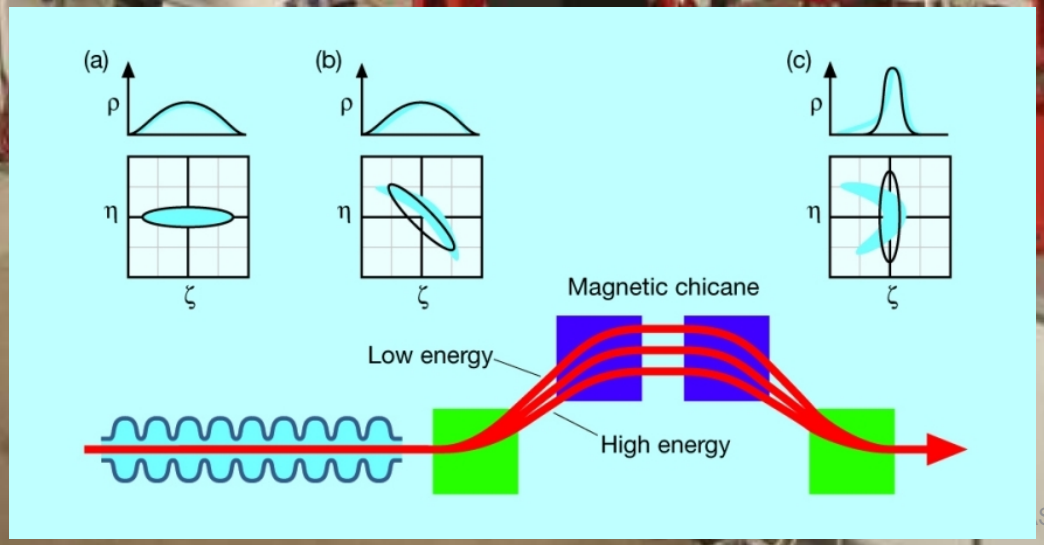
Seven 1.3 GHz modules
8 cavities per module
9 cells per cavity
RF pulsed at 10 Hz
1-800 bunches per pulse

Up to 1.25 GeV

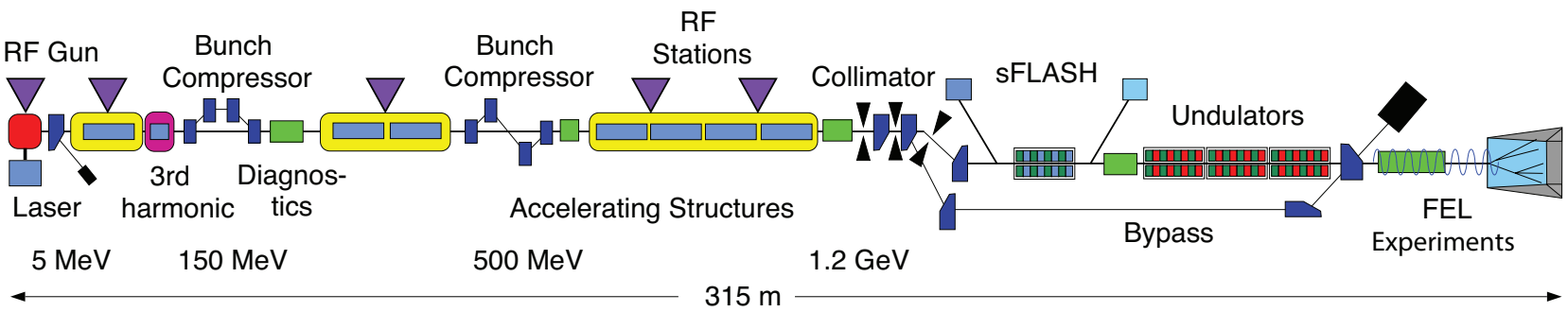
FLASH Accelerator

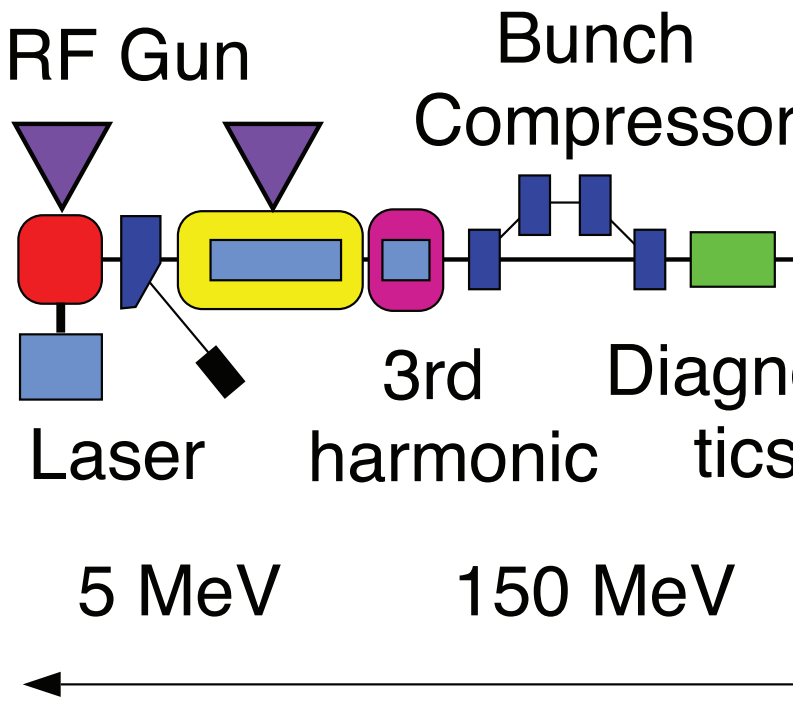
FLASH Accelerator

BUNCH COMPRESSORS
Reduce the bunch length
Increase the peak current

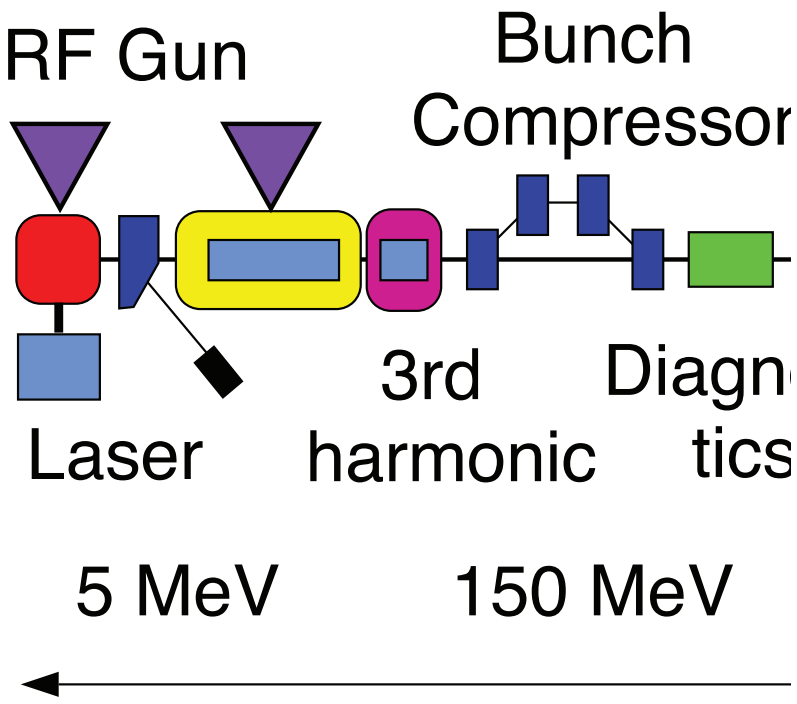


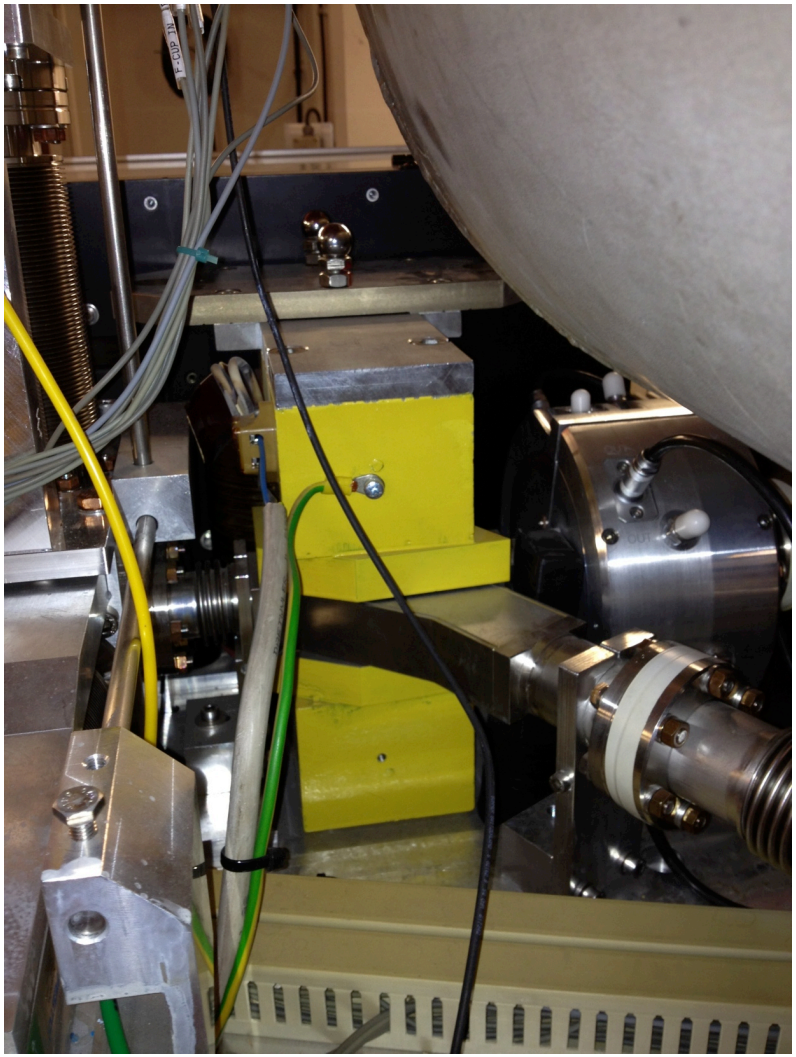
FLASH Complex





FLASH Complex

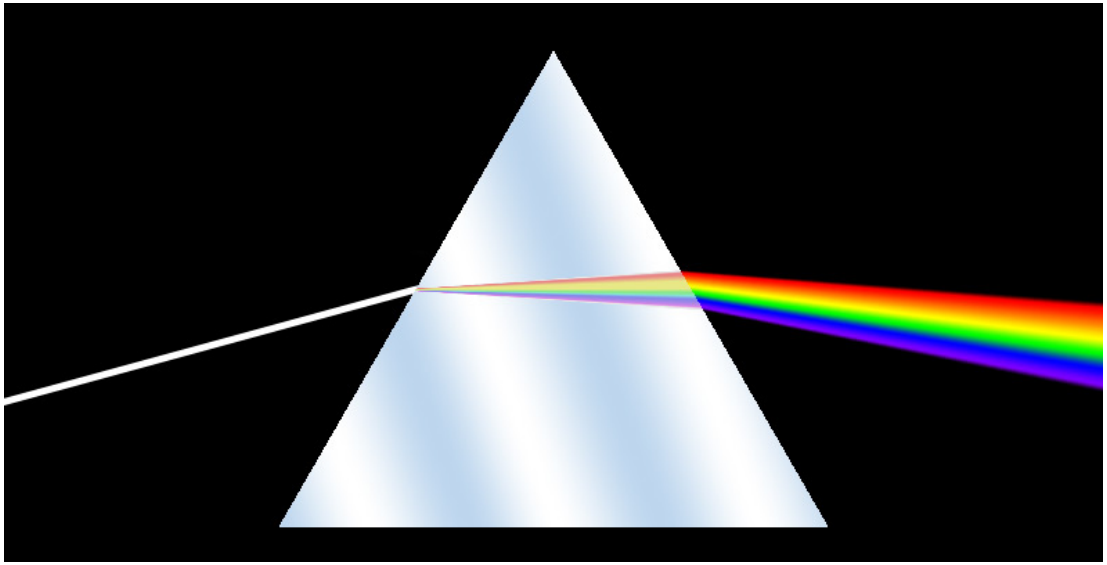




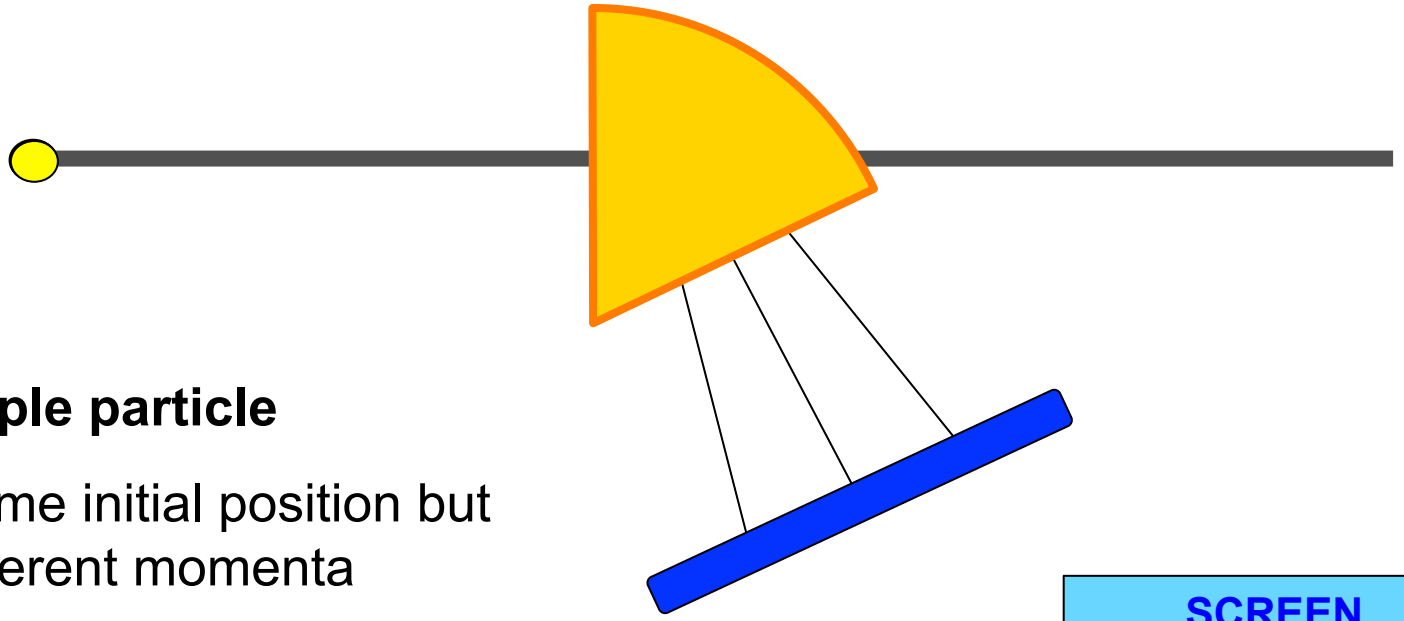
The spectrometer

Longitudinal phase space is scanned by means of a spectrometer to determine:

- Mean Momentum
- Momentum Spread



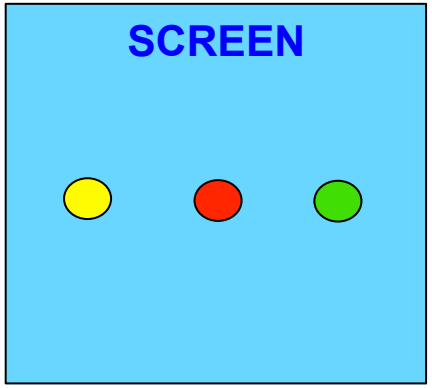
The spectrometer



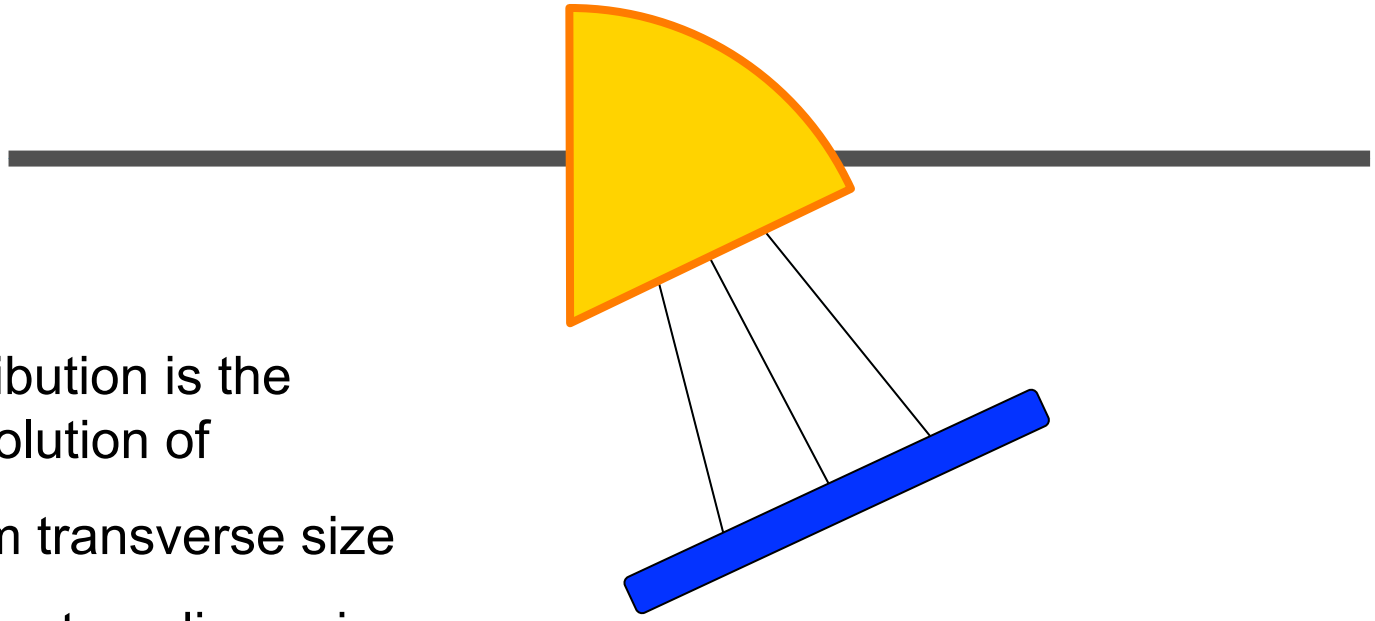
Multiple particle

- Same initial position but different momenta
- Different position depending on the momentum

$$R = \frac{p}{qB}$$



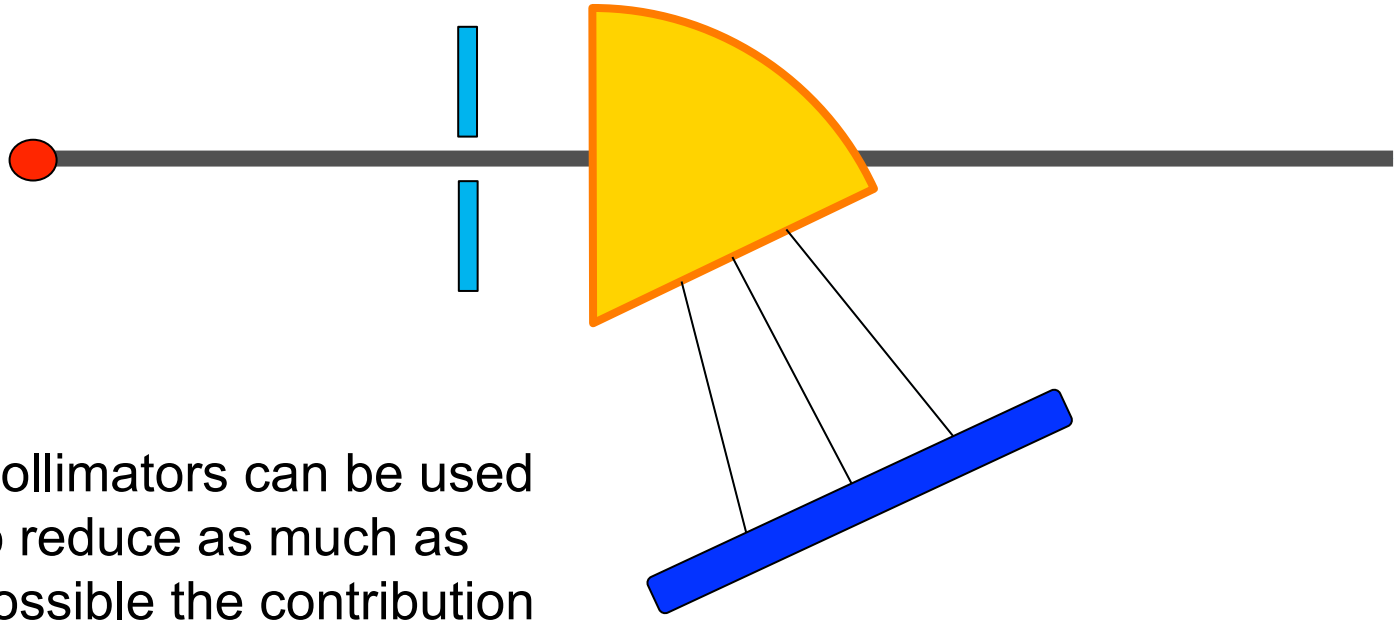
The spectrometer



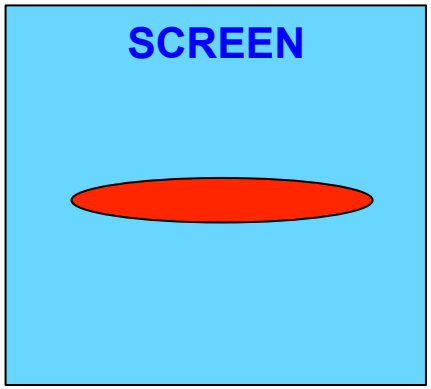
- Distribution is the convolution of
- Beam transverse size
- Momentum dispersion

$$f(x) = g\left(x_0, x_o'\right) * h(\delta)$$

The spectrometer



- Collimators can be used to reduce as much as possible the contribution of the beam width

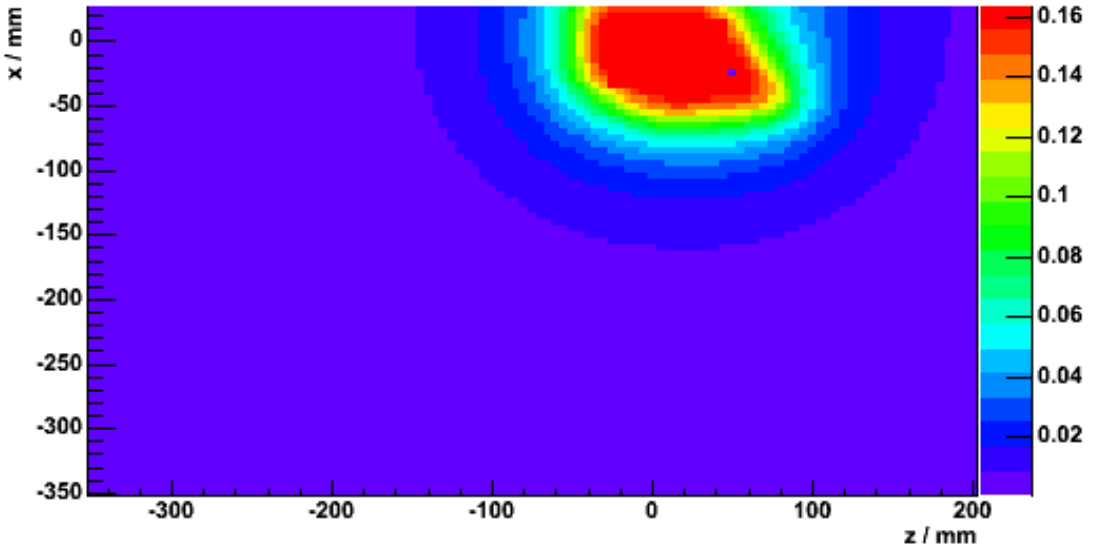


Dipole

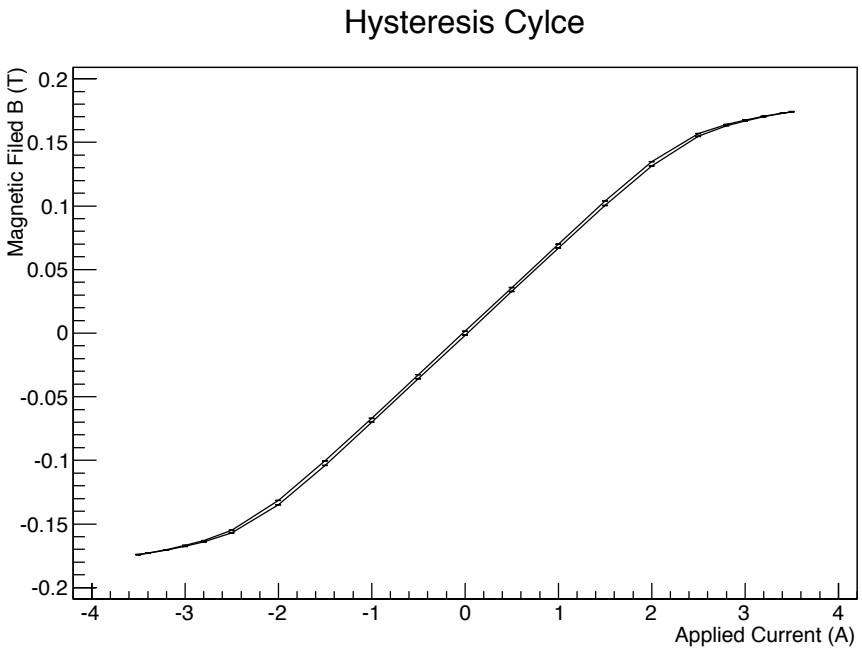
A good knowledge of the moments requires a good knowledge of the dipole filed:

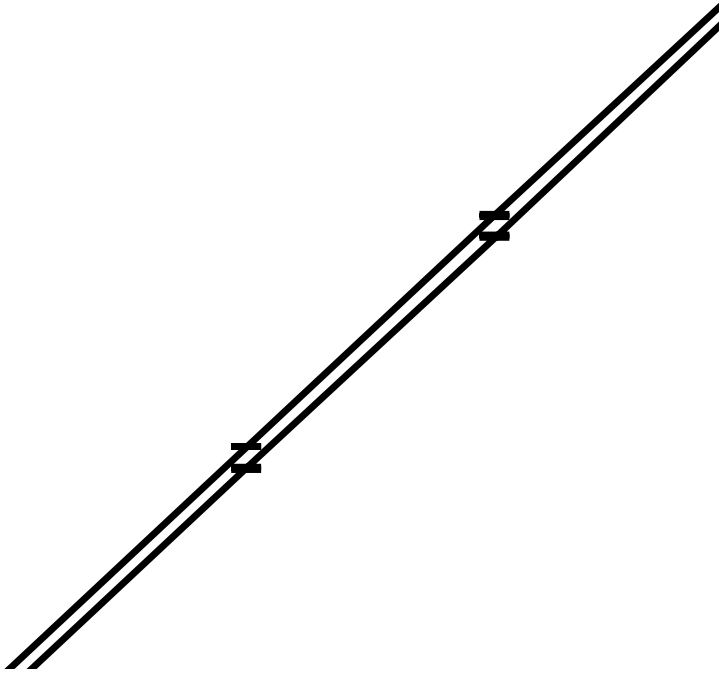
$$p_0 = \frac{e}{\alpha}\left|B_{dipole}(I)\right| l_{eff} \qquad l_{eff} = \frac{\int_{-\infty}^{+\infty} B(l)\,dl}{B_{\max}}$$

- Non flat field
- Edge Effects



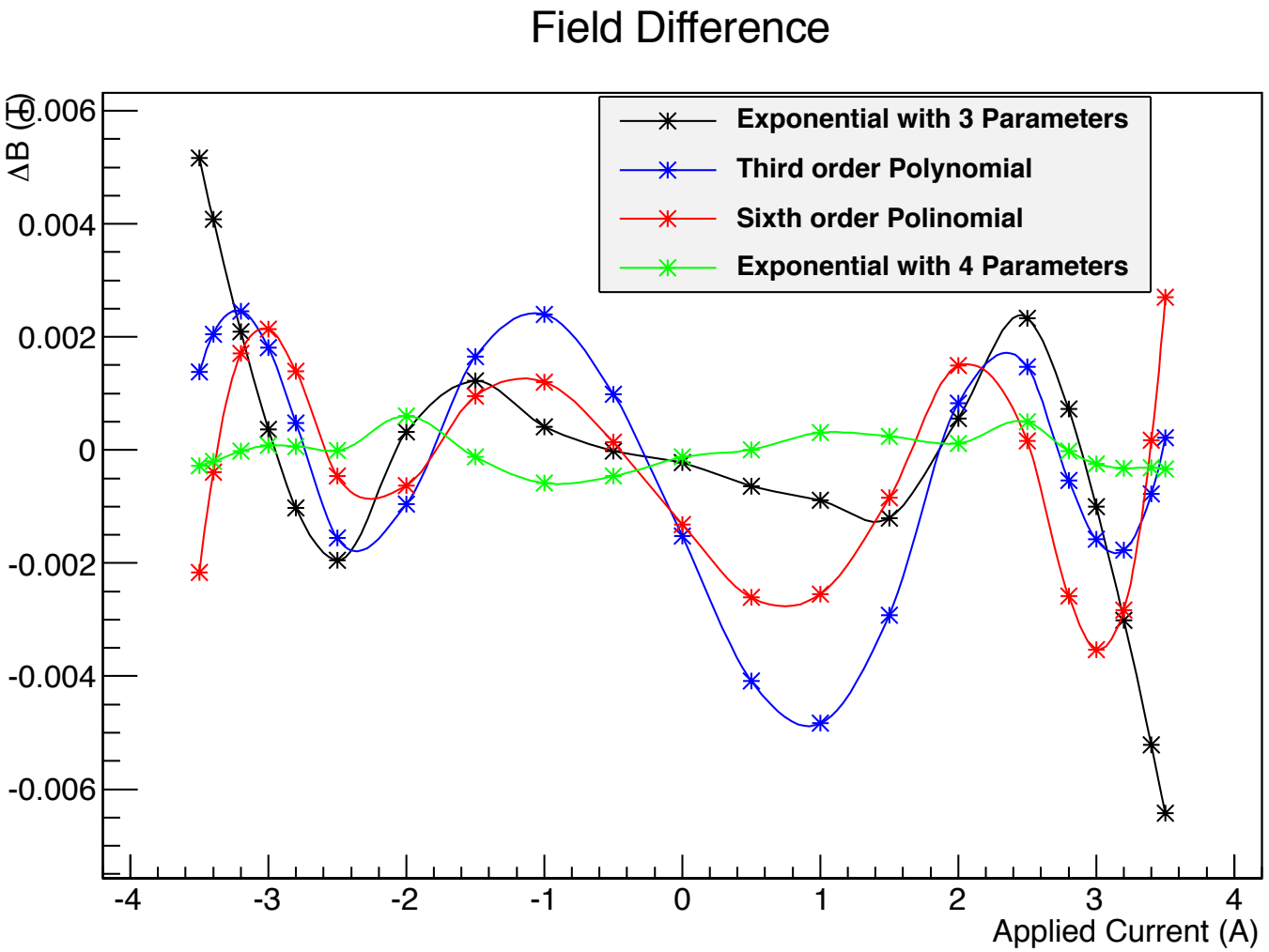
Dipole: Hysteresis Cycle





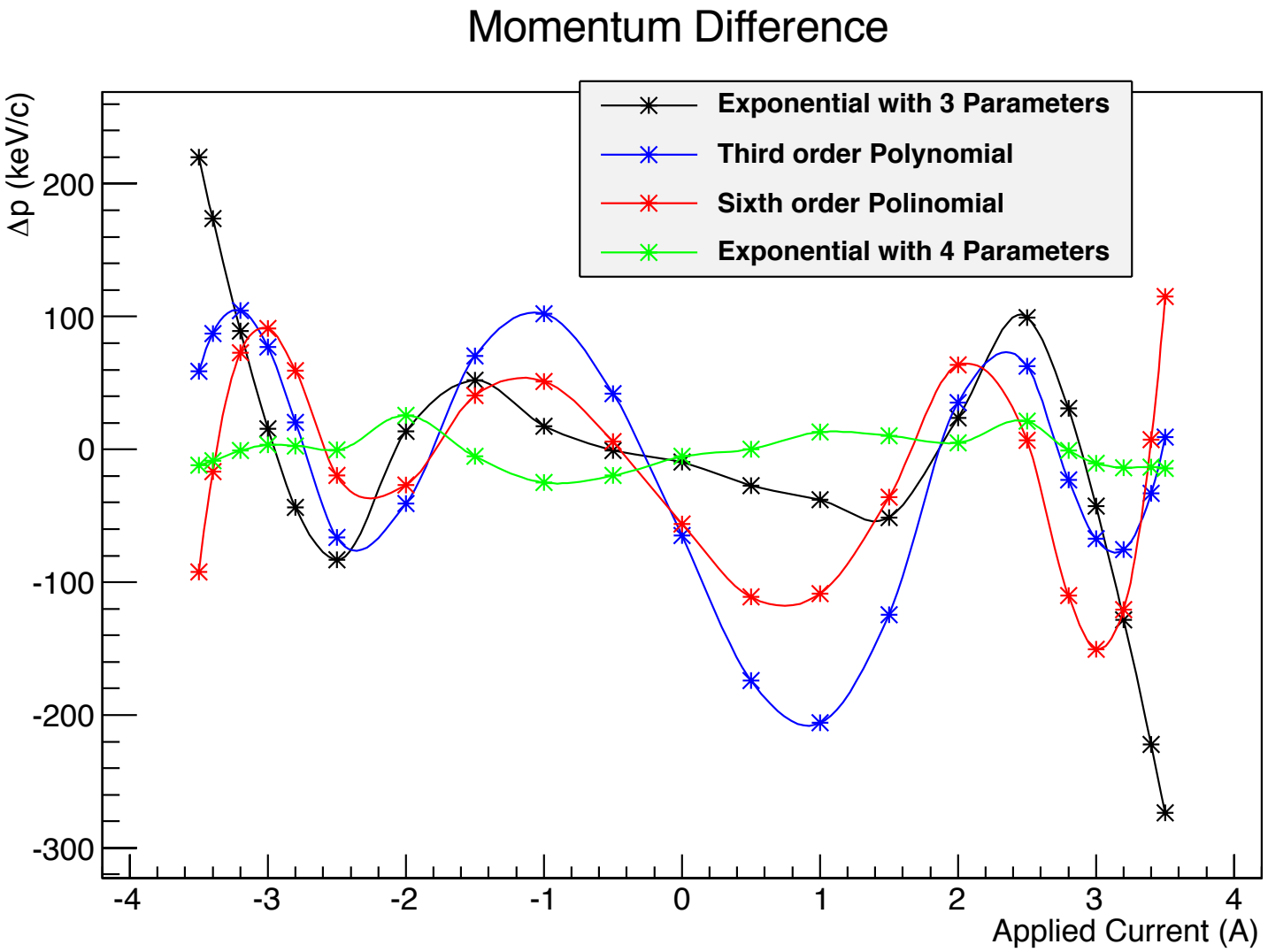
- Important to move ALWAYS on the falling cycle edges.
- Small area but significant momentum difference
- Need to know the B field for each current

Dipole: Hysteresis Cycle

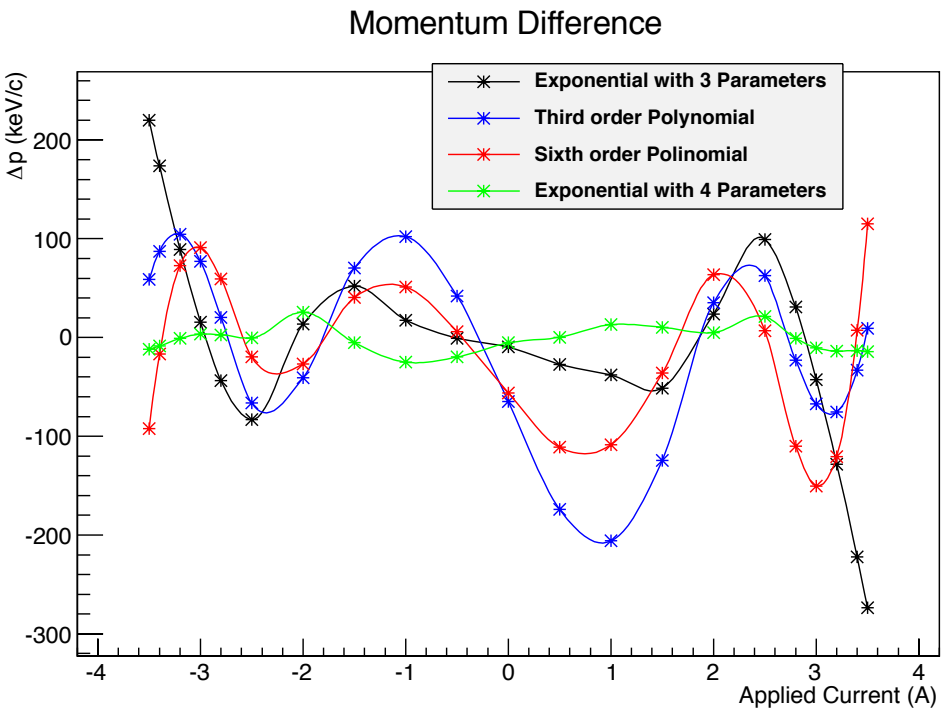


Difference between measure and fitted value. NO interpolation

Dipole: Hysteresis Cycle

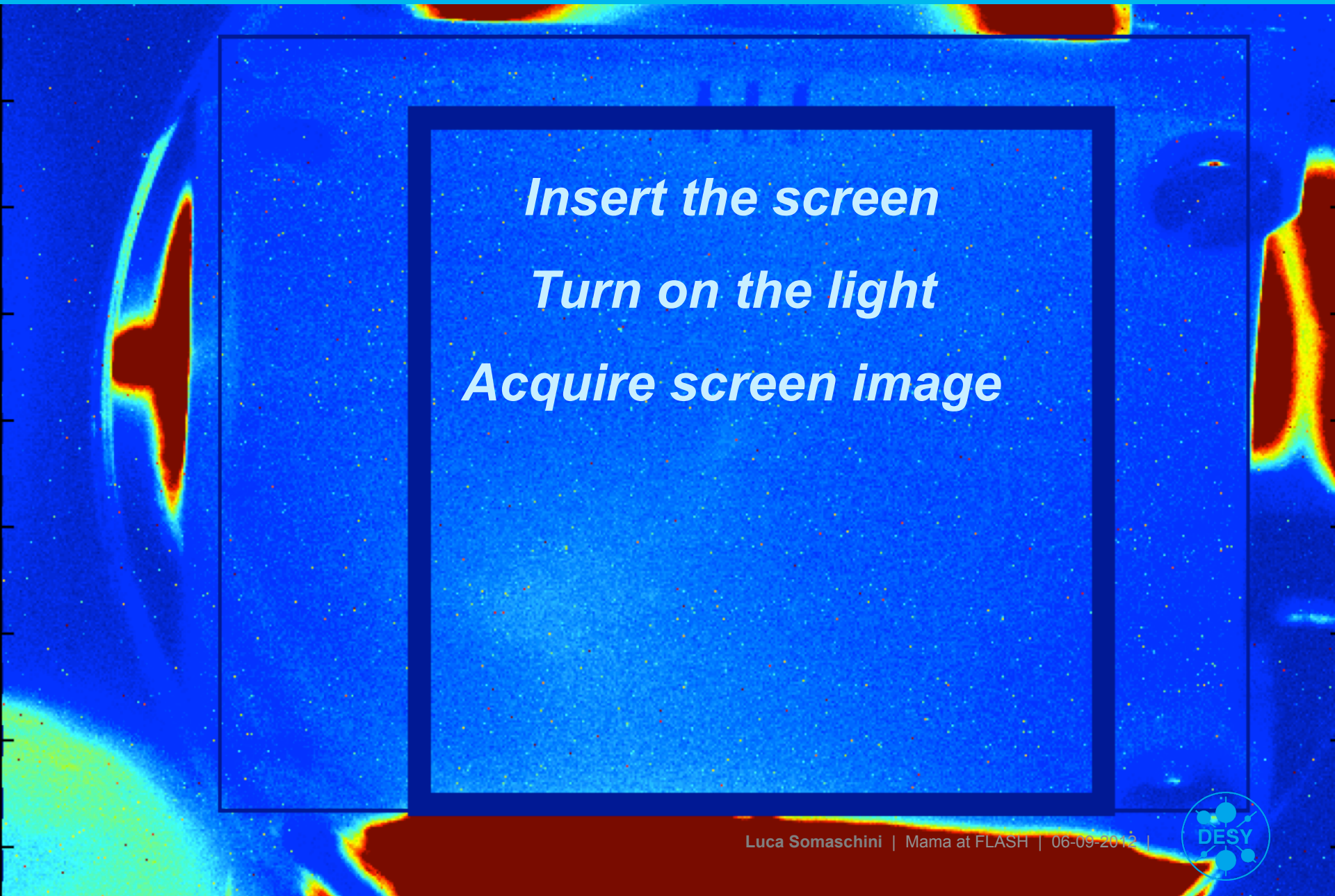


Dipole: Hysteresis Cycle

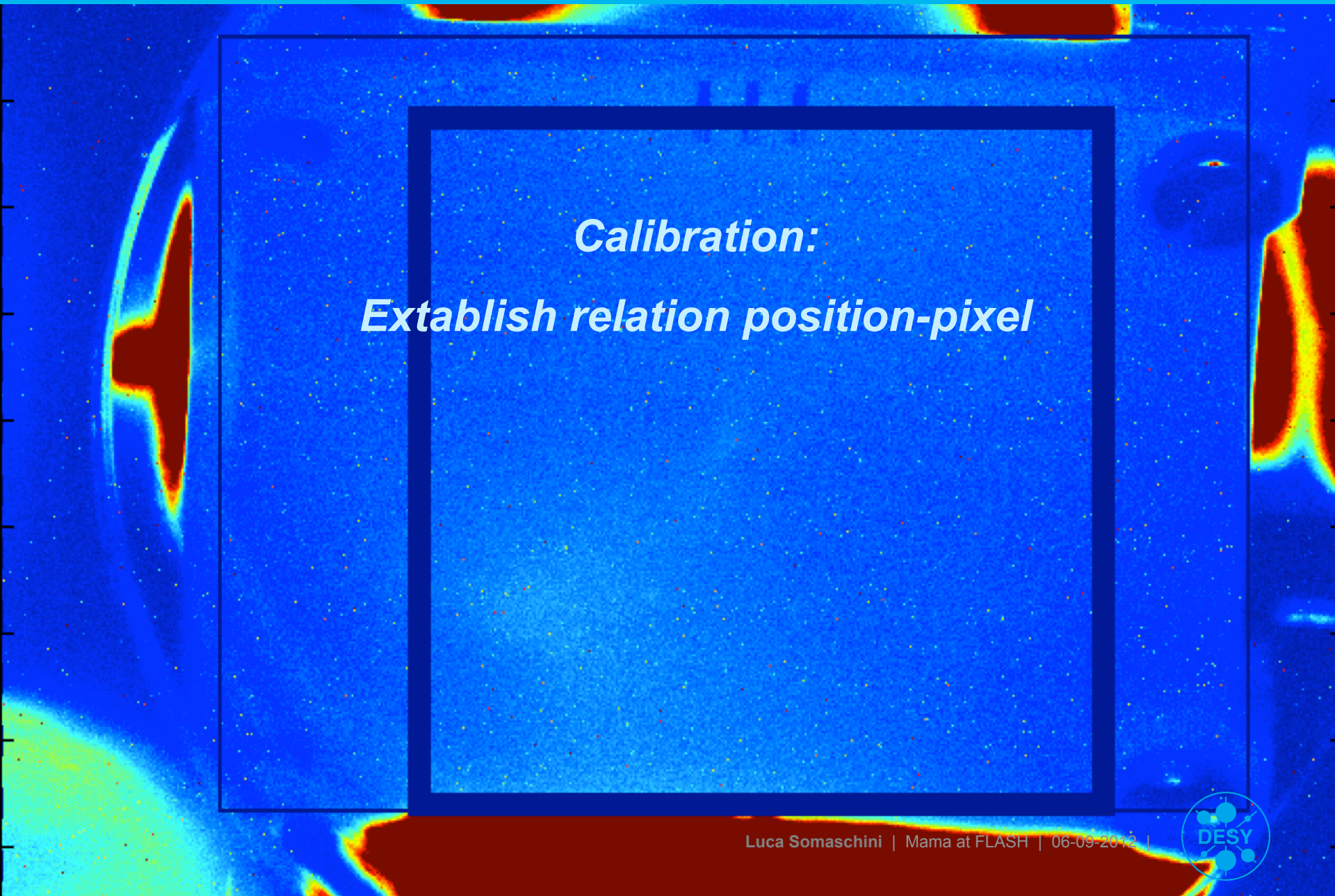


- Small field differences translate into great momentum differences
- Typically exponential with three parameters is used
- Exponential with 4 parameter provides best fitting

MAMA Software



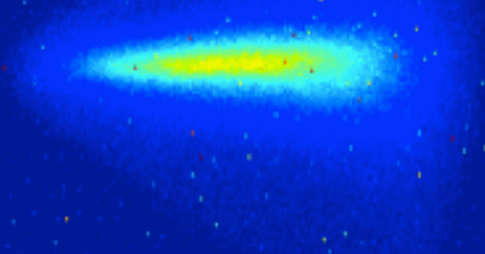
MAMA Software



The spectrometer

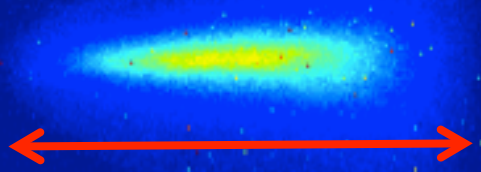
Beam Acquisition

Image of the beam on the screen



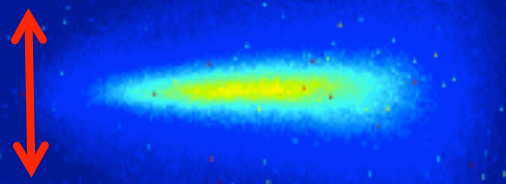
Beam Acquisition

The Dispersion takes places only in one direction



Beam Acquisition

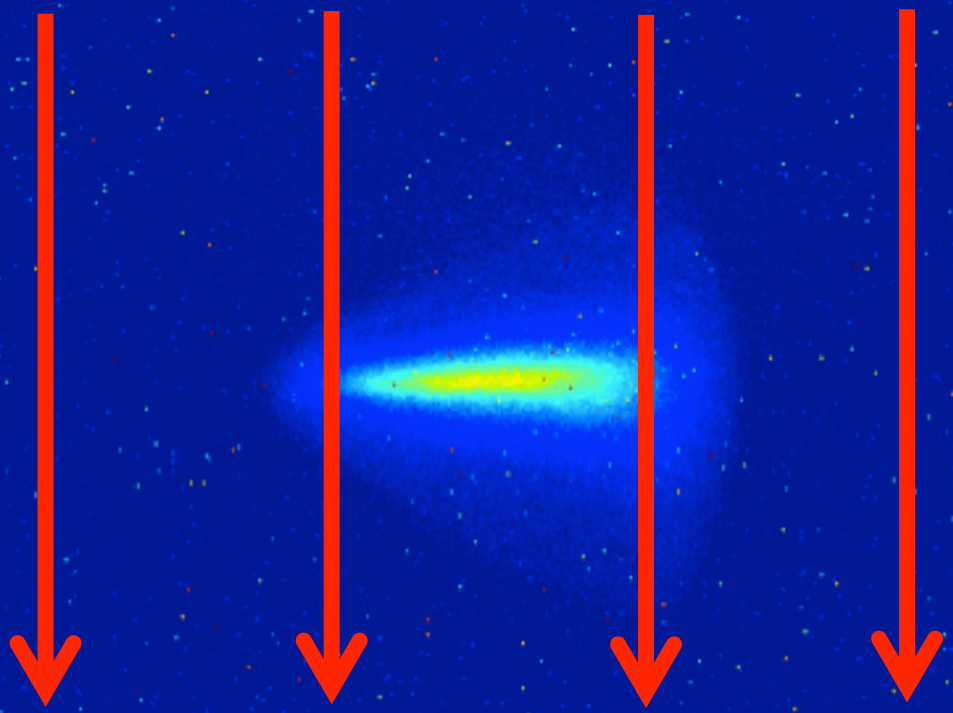
Transverse spread is only due to beam size
It has to be as small as possible



The spectrometer

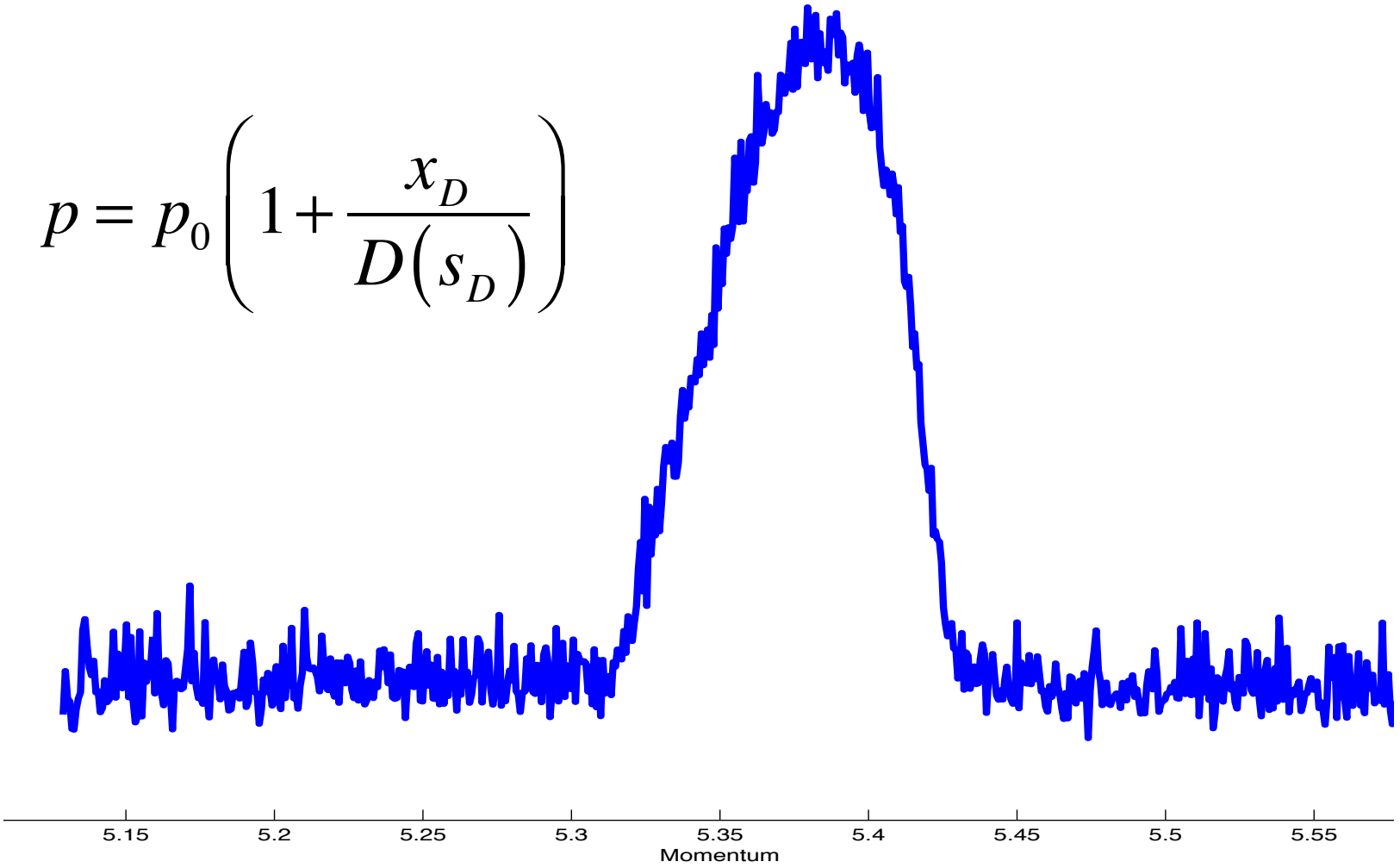
Beam Acquisition

Sum over trasverse direction



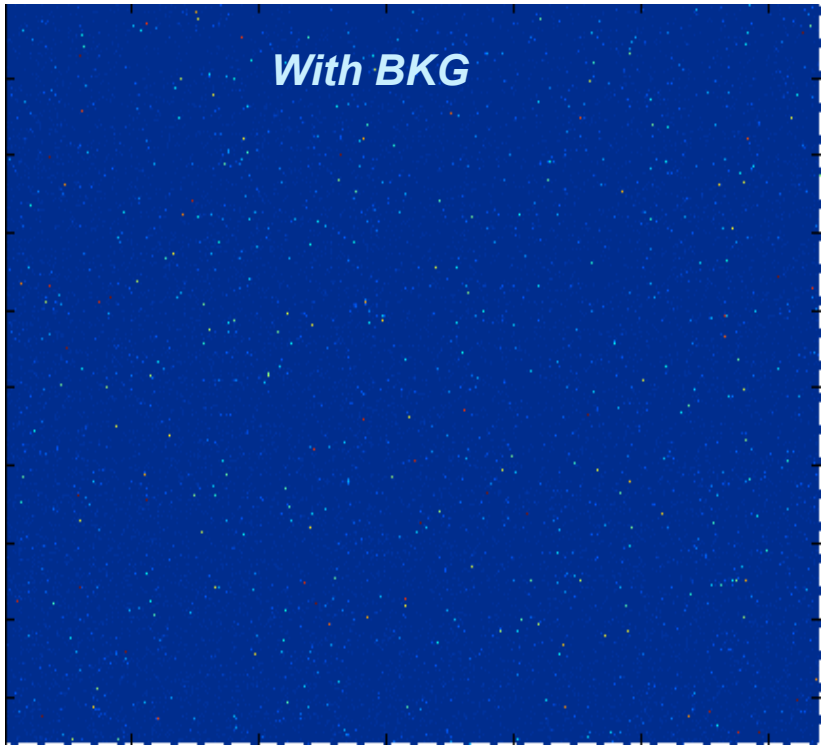
The spectrometer

$$p = p_0\left(1+\frac{x_D}{D(s_D)}\right)$$



MAMA Software

Possibility to define background reduction



MAMA Software

Development of an analysis code:

- Inspired by MAMA code for PITZ (by Lipka)
- Matlab Based

Project is meant to be expanded and improved….it's not a complete project:

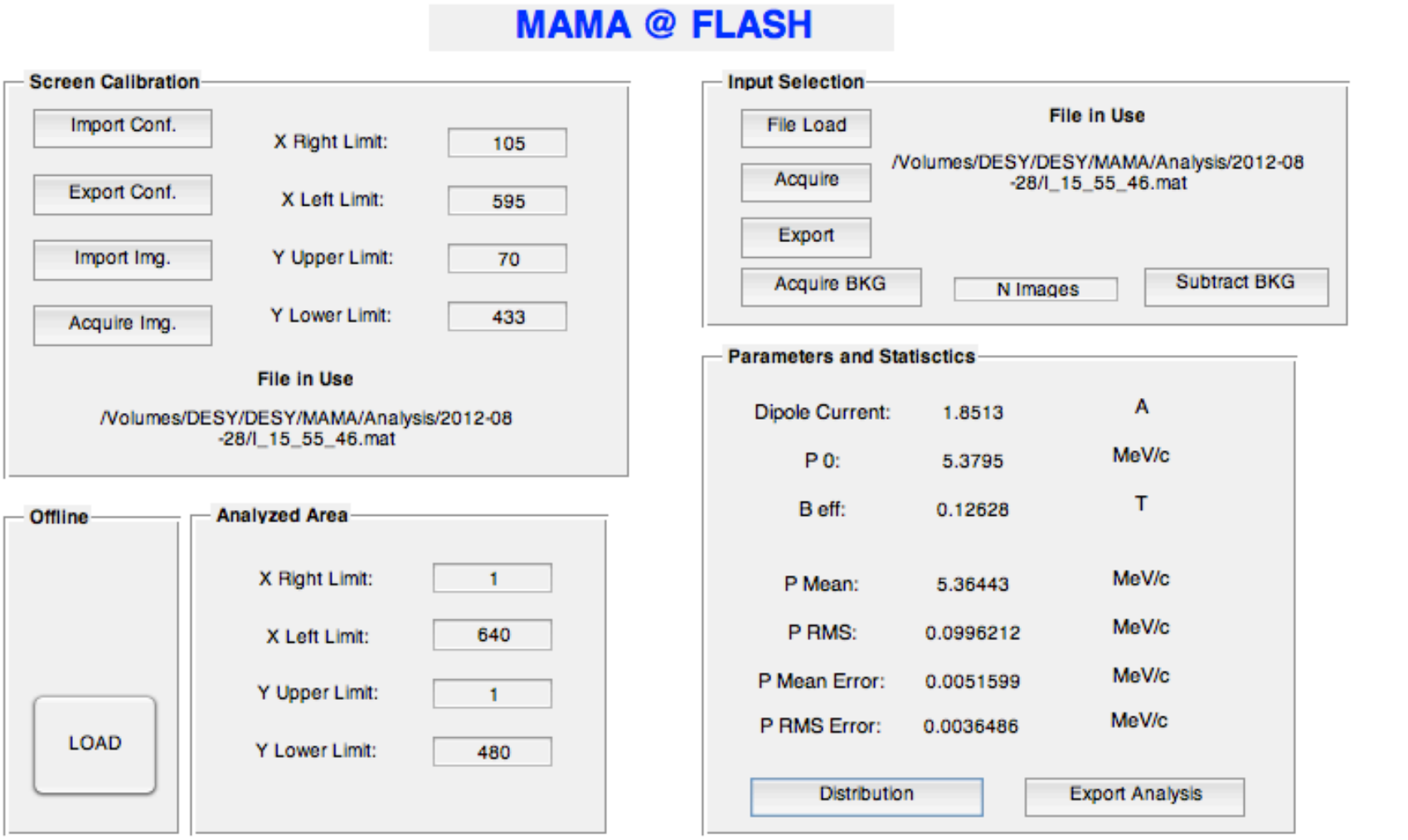
- The code must be simple and easy to be modified
- Separate features and functions on separate files

MAMA Software

Four files with separate functions:

- MAMA_GUI.fig: Graphic information
- MAMA_GUI.m: Callback definition
- MAMA_main.m: Test file
- Data.m: Class with:
  - Parameters
  - Acquired data
  - Analysis functions

MAMA Software



MAMA Software

Further Improvements:

- Embedded control on the machine:
  - Control of the screen
  - Control on the dipole current and hysteresis cycle
  - Control on the beam status
- Embedded logbook printout
- Current Scan function for non-fitting beams
  - Multiple pictures for a single analysis
  - To generate momentum distribution as a function of the dipole current


Thank you!!!
Thanks to DESY and to MPY group


Thanks to ALL the
summer students….

The spectrometer

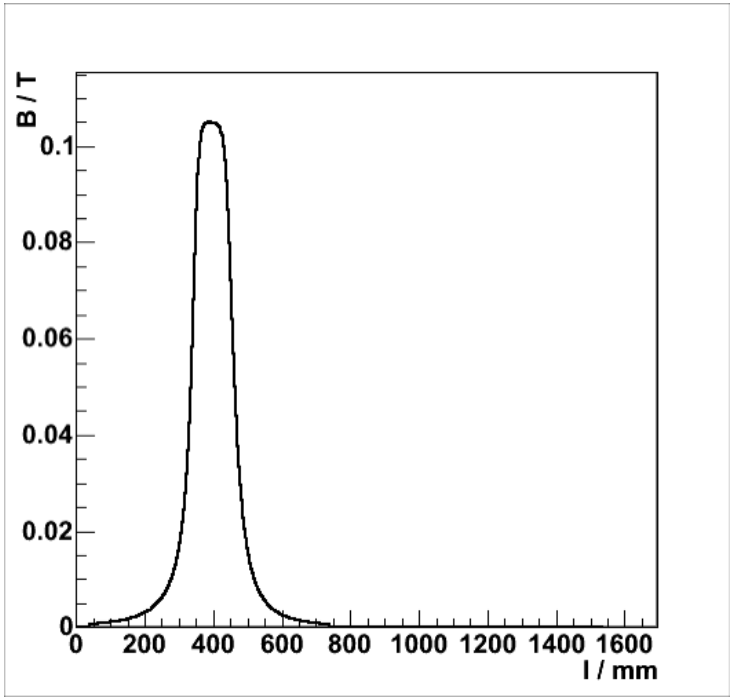
The central particle is called reference particle

Every other measure is expressed referring to the reference particle frame

Momentum of the reference particle:

$$p_0 = \frac{e}{\alpha}\left|B_{dipole}(I)\right| l_{eff}$$

$$l_{eff} = \frac{\int_{-\infty}^{+\infty} B(l)\,dl}{B_{\max}}$$



Dipole: Hysteresis Cycle

Search of the best fitting function:

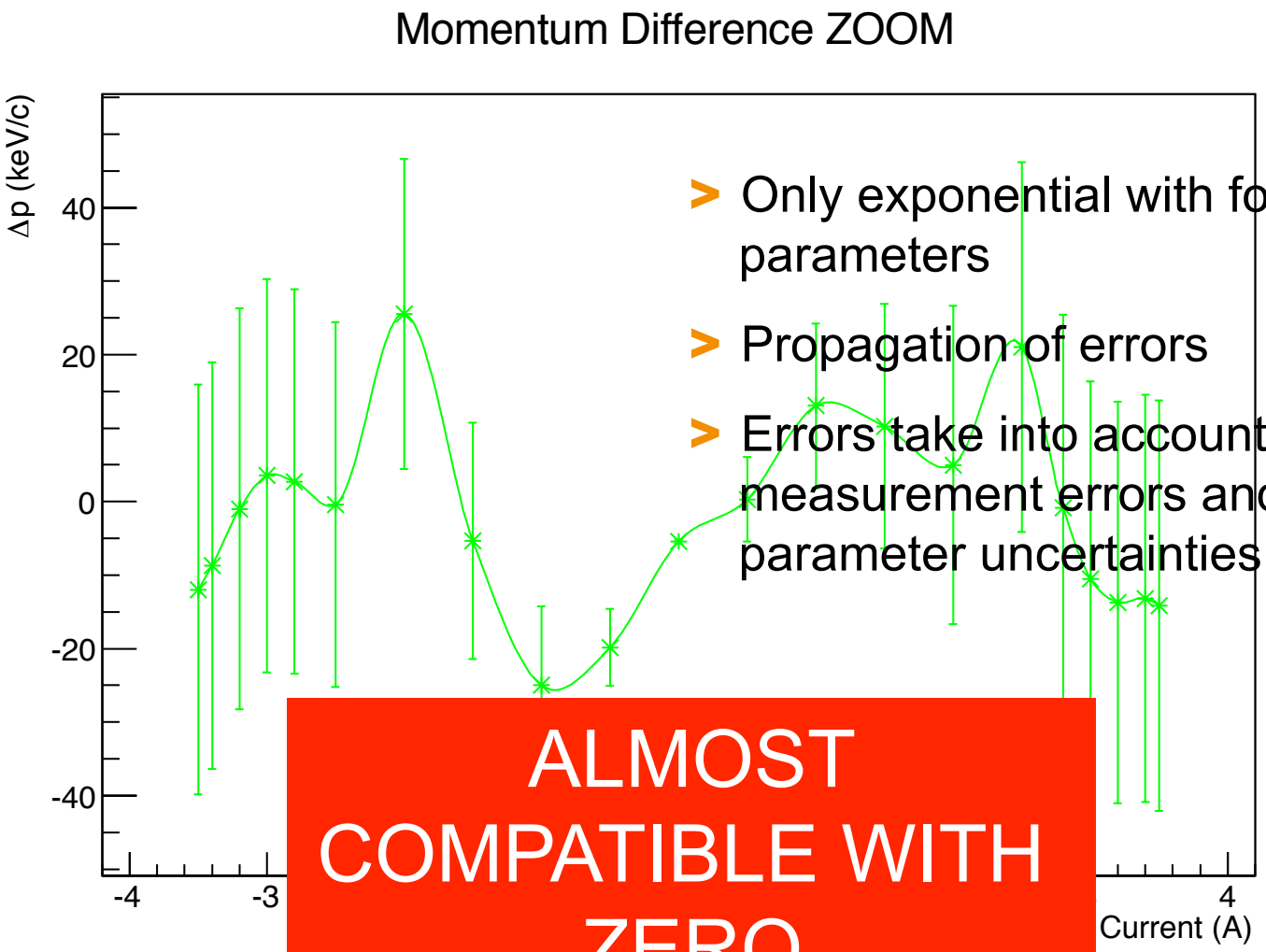
$$B(I) = a + bI + cI^2 + dI^3$$

$$B(I) = a + bI + cI^2 + dI^3 + eI^4 + fI^5 + gI^6$$

$$B(I) = \frac{a(I-b)}{1 + e^{-\frac{c}{(I-b)^2}}}$$

$$B(I) = \frac{a(I-b)}{d + e^{-\frac{c}{(I-b)^2}}}$$

Dipole: Hysteresis Cycle



- Only exponential with four parameters
- Propagation of errors
- Errors take into account measurement errors and fitting parameter uncertainties

ALMOST COMPATIBLE WITH ZERO

The spectrometer

The main statistical functions we can compute are:

- Mean Momentum:

$$\bar{p} = \frac{\sum_i p_i h_i}{\sum_i h_i}$$

- Momentum Spread:

$$p_{RMS} = \sqrt{\frac{\sum_i \left(\bar{p} - p_i\right)^2 h_i}{\sum_i h_i}}$$

The spectrometer

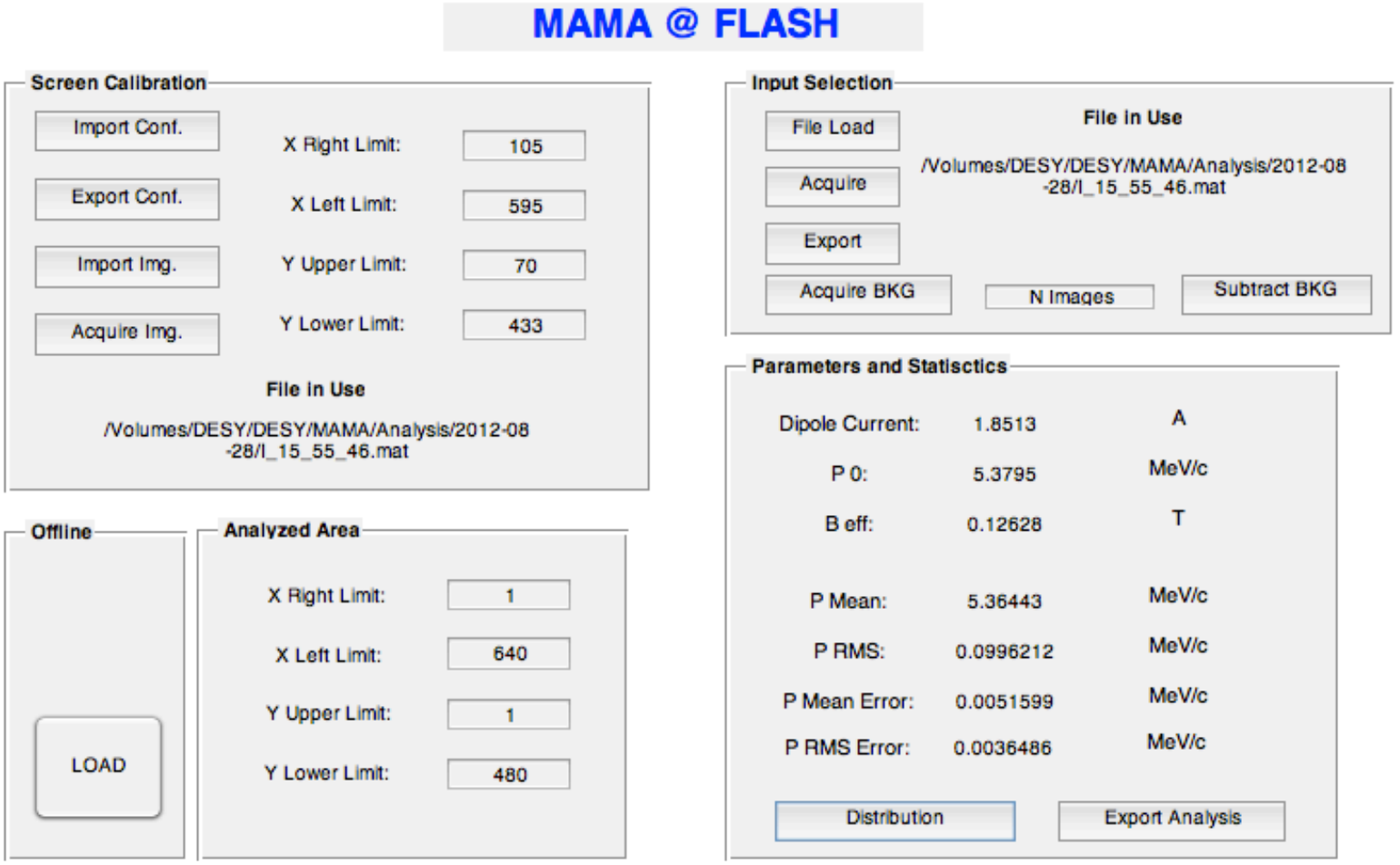
It is also possible to compute associate errors:

$$\sigma_{\bar{p}} = p_{RMS} \frac{\sqrt{\sum_i h_i^2}}{\sum_i h_i}$$

$$\sigma_{p_{RMS}} = \frac{\sigma_{\bar{p}}}{\sqrt{2}}$$

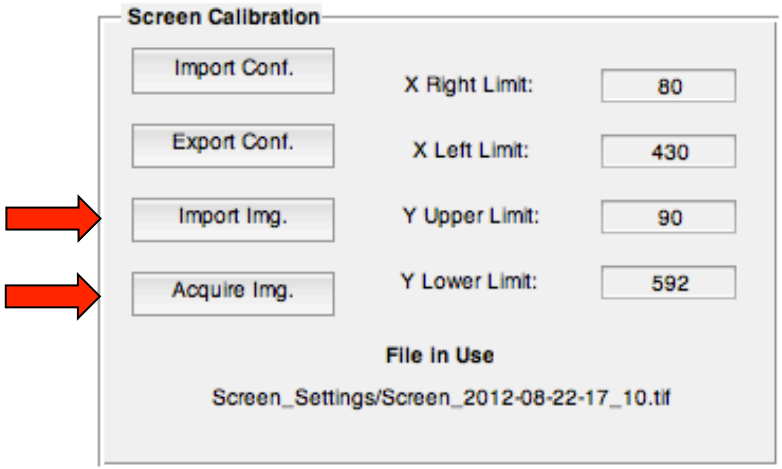
MAMA Software

Graphic Interface



MAMA Software

1 Step: Screen Acquisition and calibration



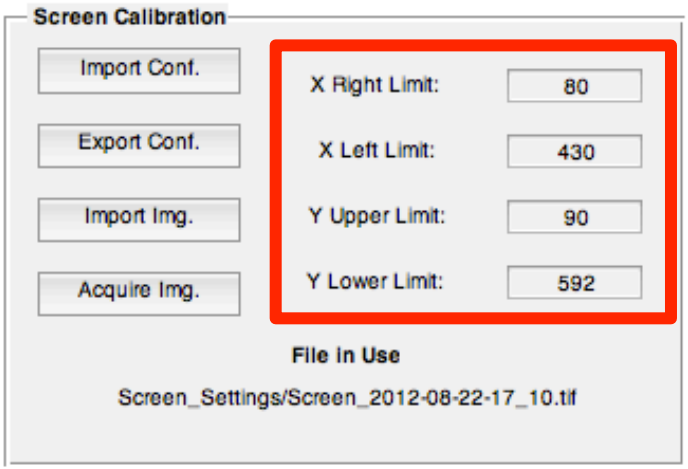
- Go to GUN mode
- Move in the screen
- Turn on the light
- Acquire a Screen image
- Turn off the light

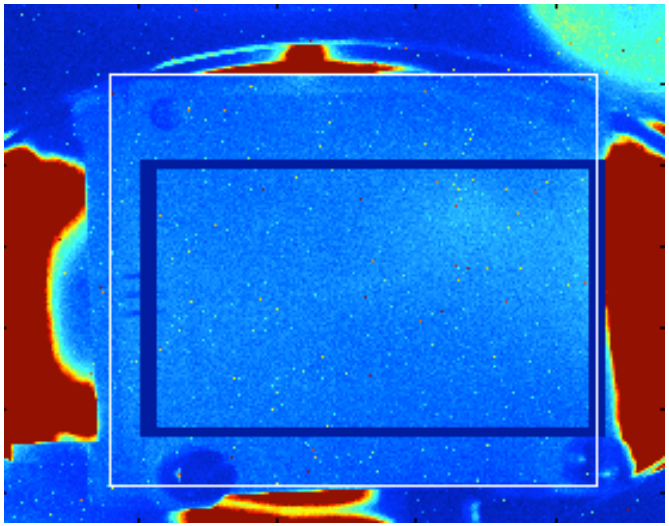
Or

- Import a old screen image

MAMA Software

1 Step: Screen Acquisition and calibration

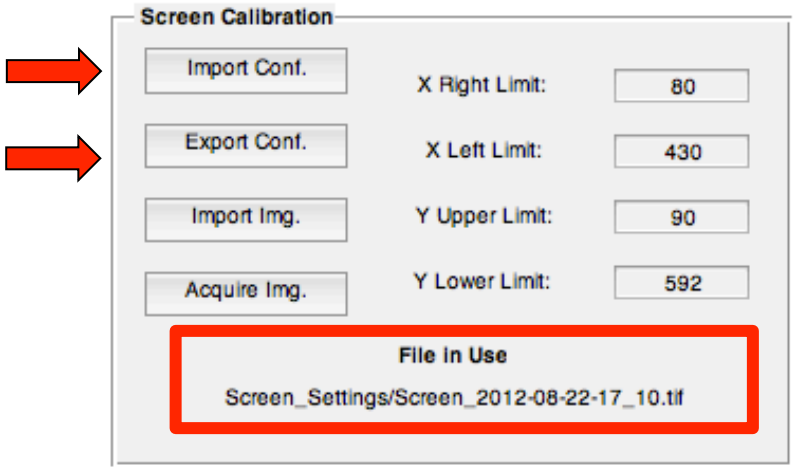


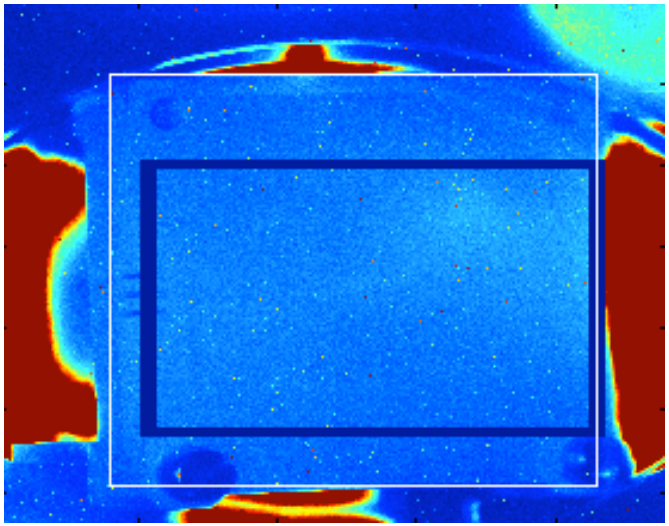


- Calibration:
- Find a relation between screen size and pixels
- Set the screen border pixels

MAMA Software

1 Step: Screen Acquisition and calibration

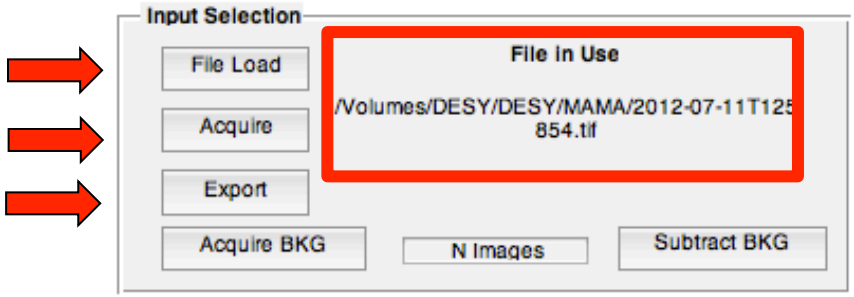


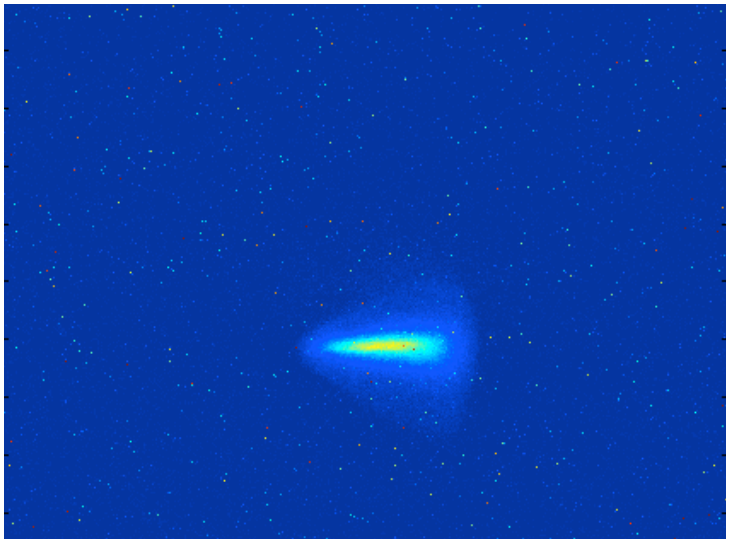


- Export configuration:
  - Screen Image
  - Calibration Parameters
- Import configuration
  - Screen Image
  - Calibration Parameters
- File Path
  - Screen image in use
  - “ONLINE”: acquired non save image

MAMA Software

2 Step: Image Acquisition

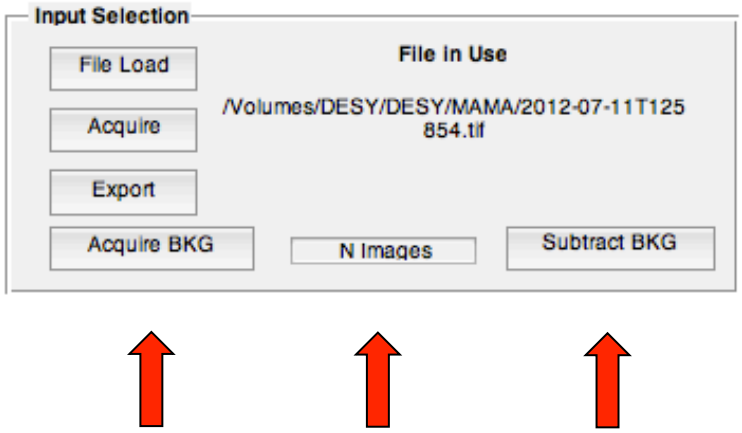




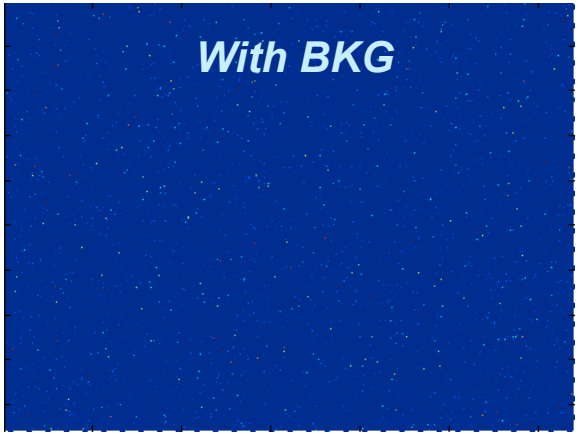
- Set dipole current
- Acquire an image from the screen
- Load an image from file
- Export the acquired image
- Read the image in use:
  - File path
  - “ONLINE”: acquired non saved image

MAMA Software

3 Step: Background Reduction

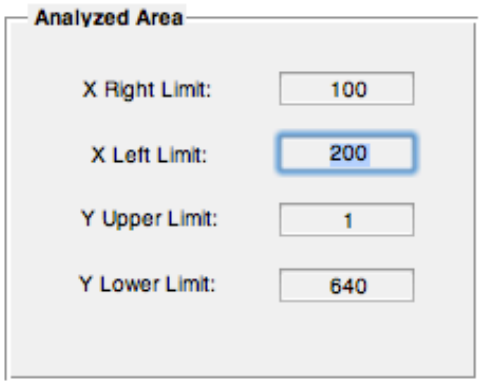


- Set number of samples
- Acquire background
- Turn ON and OFF the BKG reduction
- Pictures and results are refreshed at every change



MAMA Software

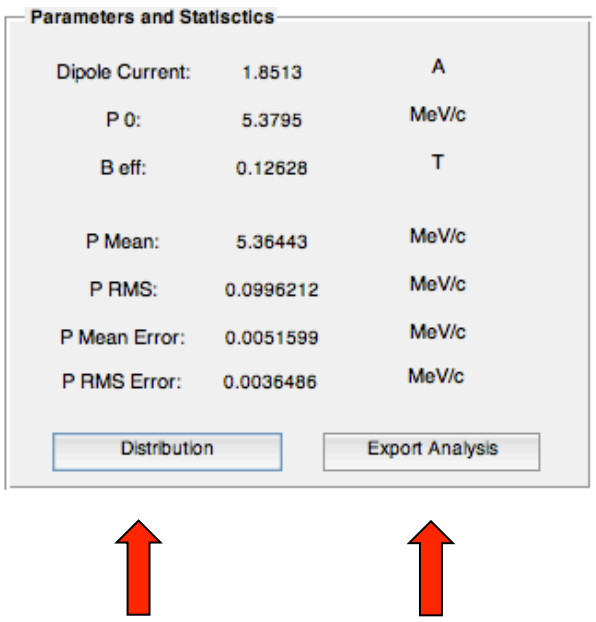
Step 4: Analysed area



- Resize the analysed area to reduce noise
- Pictures and results are refreshed every time a change is made

MAMA Software

Step 5: Results and Storing



- Read the results
  - Momentum and momentum spread
  - Associated errors
  - Dipole parameters
- Zoomed distribution view
- Export entire class properties:
  - Pictures (matrixes and paths)
  - Dipole parameters
  - Screen and parameters
  - Statists results

MAMA Software

Offline analysis

- Possibility to reload saved data and perform new analysis