Comparing IBS with Data (pp,PbPb)

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IBS calculation method

- Calculate IBS growth times at 3.5 Z TeV varying 3 parameters (MAD-X, Mathematica packages John Jowett):
  - RF Voltage [1 MV-16 MV]
  - Longitudinal Emittance [0.5 eVs – 2.5 eVs]
  - Normalized Transverse Emittance (assuming round beams $\sigma_x = \sigma_y$) [2.0 μm rad – 17.0 μm rad]
- Creating an interpolation function on this 3-dimensional grid for :
  - Bunch length
  - Momentum spread
  - Longitudinal growth time
  - Transverse growth time

Note:

IBS calculation is done with the algorithm implemented in MAD-X

Fill 1400 (pp, during physics) [1]

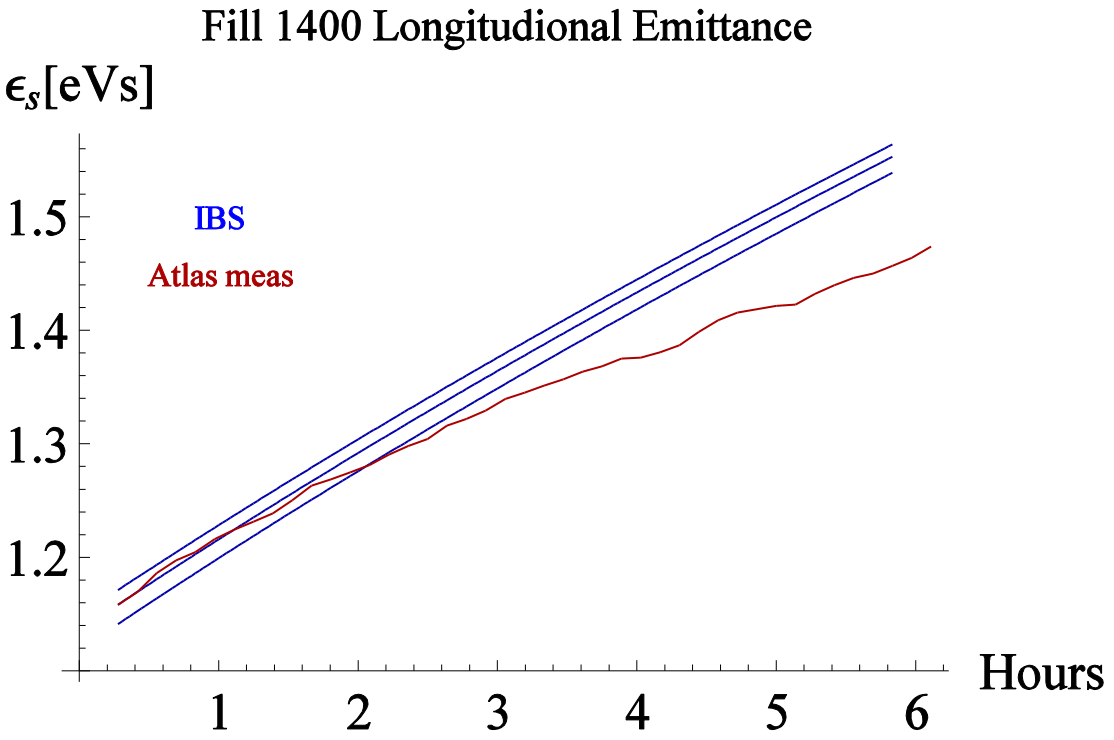
- Data sources : Atlas Luminous Region (Timber)/RF Voltage (Timber)
- Applied moving average to raw data
- Created interpolating function for this averaged data
- Use the initial value as input for the IBS interpolating function
- Output growth times τ of the IBS interpolation used in :

$$\varepsilon(t) = \varepsilon(0)\exp[\frac{t}{\tau}]$$

ONLY initial values of emittances used in the IBS simulated curves (Blue curves)!!!

Red curve:

Calculated longitudinal emittance from atlas luminous region data using the interpolating function created for this data.



Fill 1400 (pp, during physics) [2]

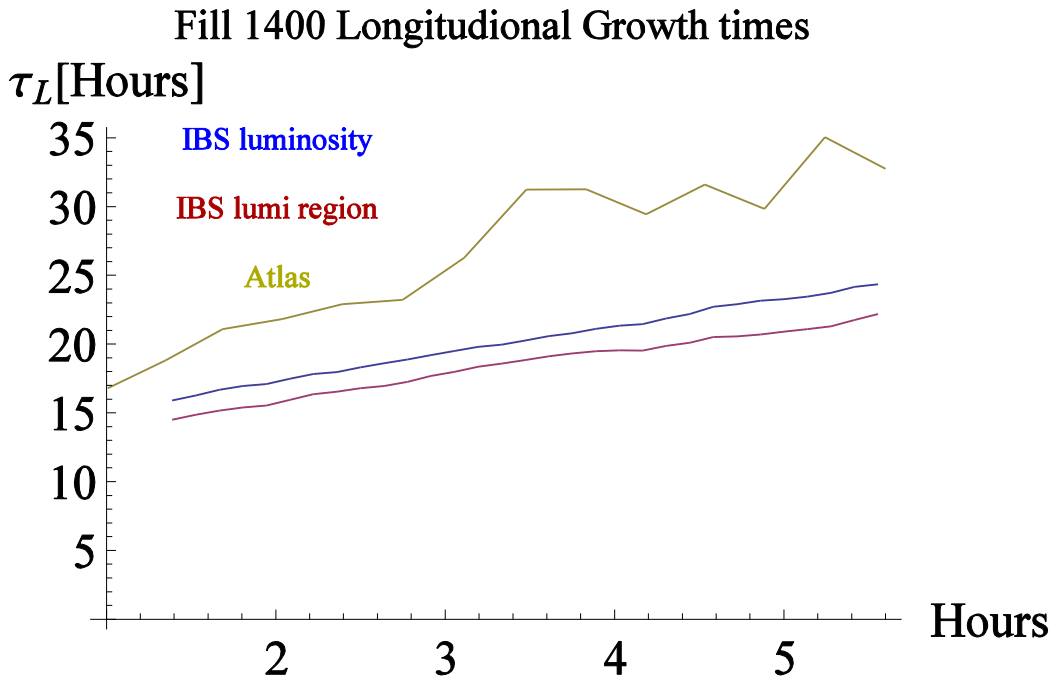
- Data sources : Atlas Luminous Region (Timber/LPC webpage)/RF Voltage (Timber)/Atlas Luminosity(LPC)
- Creating input for the IBS interpolating function:
  - Longitudinal :
    - Bunch length from Atlas Luminous Region (Timber)
    - Using RF Voltage and MAD-X calculate momentum spread
    - Calculate longitudinal emittance using:

$$\varepsilon = 4\pi \frac{\sigma_s}{c} \sigma_E E_0$$

  - Transverse:
    - Calculated from Atlas luminous region (LPC) using

$$\varepsilon_i = 2\frac{\sigma_i^{\,2}}{\beta^*}, i = x, y$$

    - The factor 2 comes from definition of luminous regions
- At each data point the IBS growth time is calculated
  - IBS with emittances calculated from Atlas luminosity data (LPC)
  - IBS with emittances calculated from Atlas luminous region data (LPC/Timber)
- Calculated growth times from Atlas longitudinal luminous region data (Timber) after taking moving average.



$$\varepsilon = \gamma_{coll} \frac{I_1 I_2 k_C f}{4\pi\beta^* L k_{b1} k_{b2}}$$

$k_{b1,2}$ = number of bunches in Beam 1,2

k_C = number of colliding bunches in Atlas

L = luminosity

f = revolution frequency

I_i = intensities B1,2

Fill 1400 (pp, during physics) [3]

•Data sources : Atlas Luminous Region (LPC webpage)/RF Voltage (Timber)

•Use the initial value as input for the IBS interpolating function

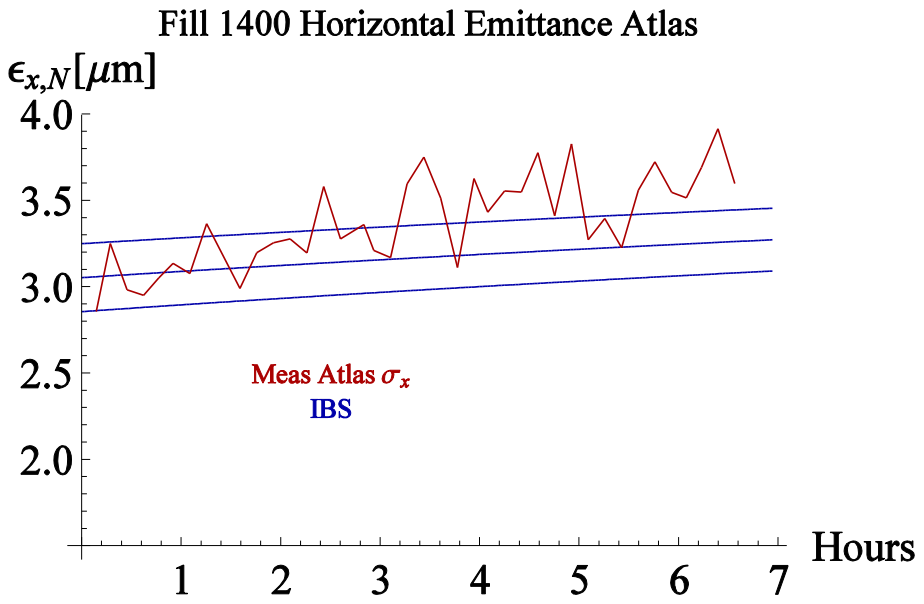
• Output growth times τ of the IBS interpolation used in

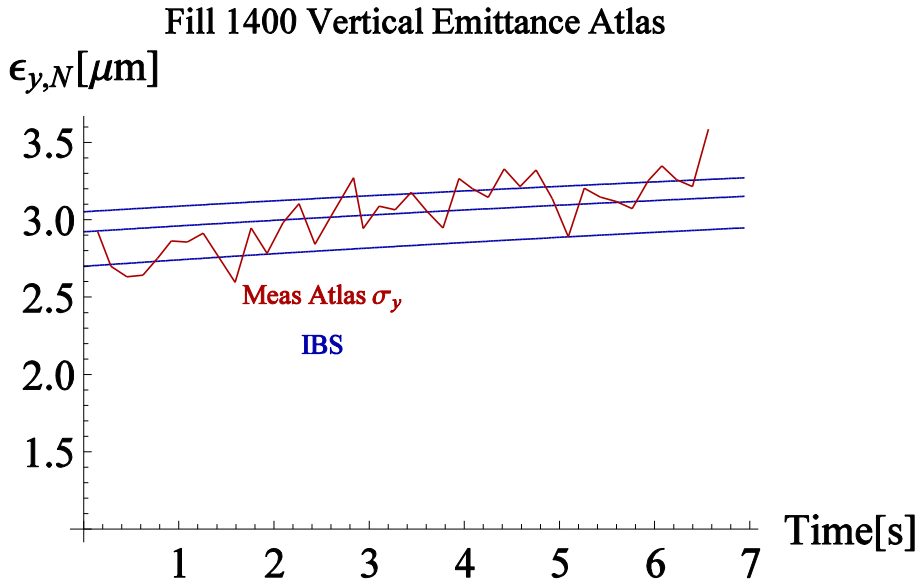
$$\varepsilon(t) = \varepsilon(0).\exp[\frac{t}{\tau}]$$

ONLY initial values of emittances used in the IBS simulated curves (Blue curves)!!!

Red curve:

Calculated transverse emittances from atlas luminous region data (LPC) using the interpolating function created for this data.





Fill 1400 (pp, during physics) [4]

- Data sources : Atlas Luminous Region (Timber/LPC webpage)/RF Voltage (Timber)/Atlas Luminosity(LPC)
- Creating input for the IBS interpolating function:
  - Longitudinal :
    - Bunch length from Atlas Luminous Region (Timber)
    - Using RF Voltage and MAD-X calculate momentum spread
    - Calculate longitudinal emittance using:

$$\varepsilon = 4\pi \frac{\sigma_s}{c} \sigma_E E_0$$

  - Transverse:
    - Calculated from Atlas luminous region (LPC) using

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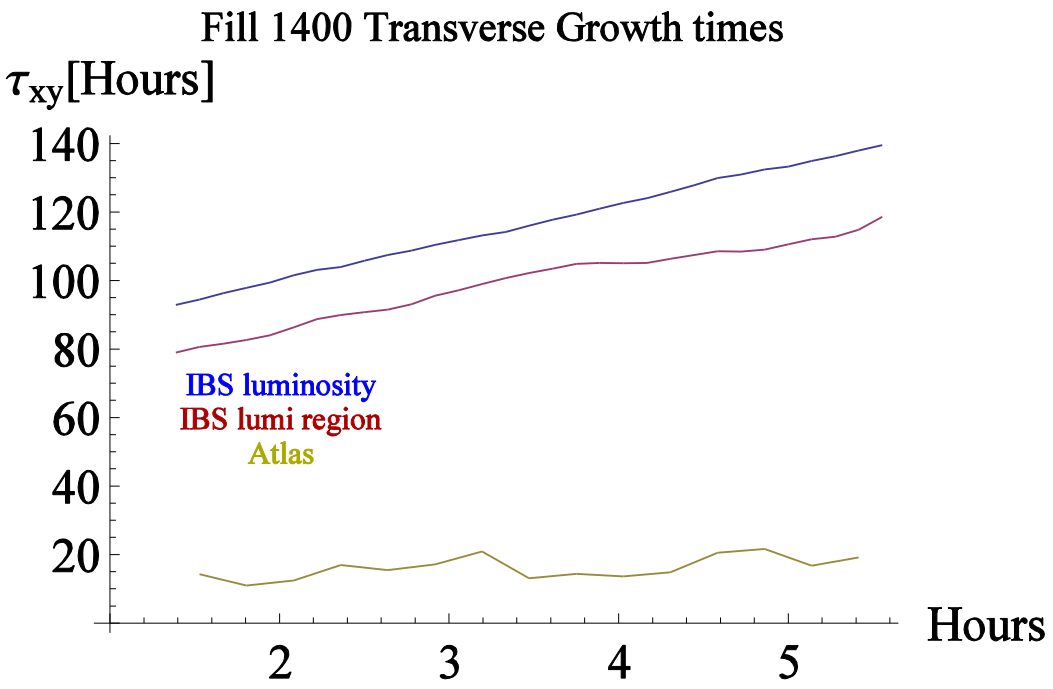


Fill 1440 (pp, during physics) [1]

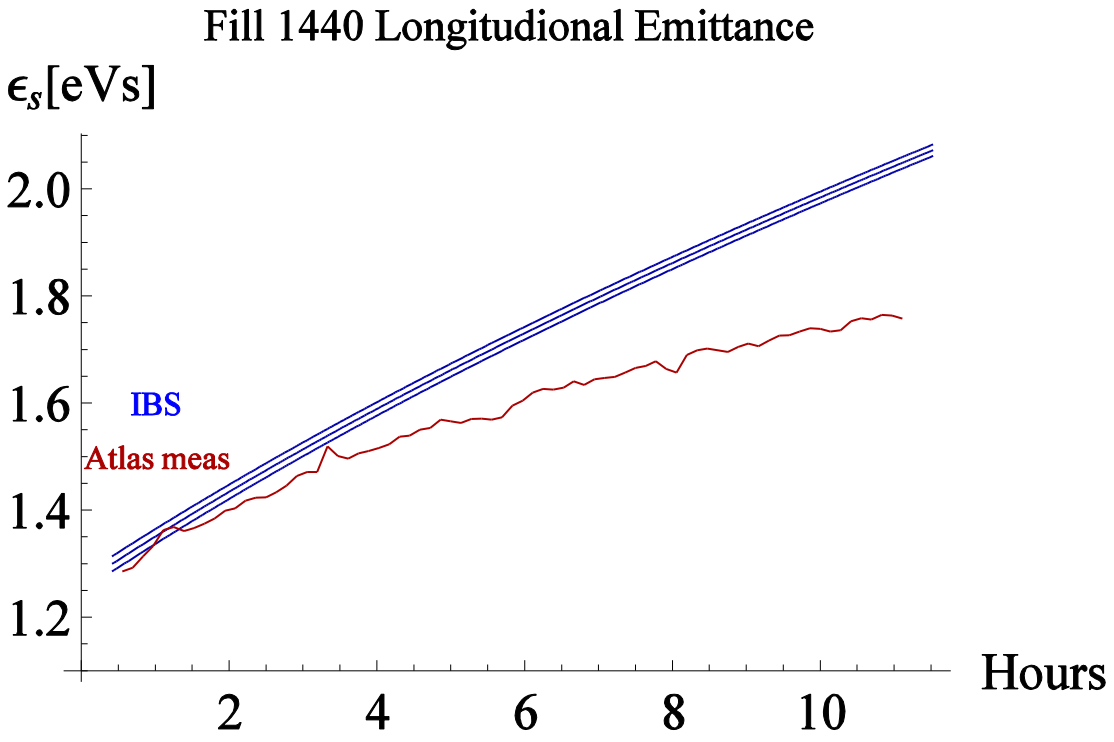
- Data sources : Atlas Luminous Region (Timber)/RF Voltage (Timber)
- Applied moving average to raw data
- Created interpolating function for this averaged data
- Use the initial value (3 different) as input for the IBS interpolating function
- Output growth times τ of the IBS interpolation used in :

$$\varepsilon(t) = \varepsilon(0).\exp[\frac{t}{\tau}]$$

ONLY initial values of emittances used in the IBS simulated curves (Blue curves)!!!

Red curve:

Calculated longitudinal emittance from atlas luminous region data using the interpolating function created for this data.



Fill 1440 (pp, during physics) [2]

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- Creating input for the IBS interpolating function:
  - Longitudinal :
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    - Using RF Voltage and MAD-X calculate momentum spread
    - Calculate longitudinal emittance using:

$$\varepsilon = 4\pi \frac{\sigma_s}{c} \sigma_E E_0$$

  - Transverse:
    - Calculated from Atlas luminous region (LPC) using

$$\varepsilon_i = 2\frac{\sigma_i^{\,2}}{\beta^*}, i = x, y$$

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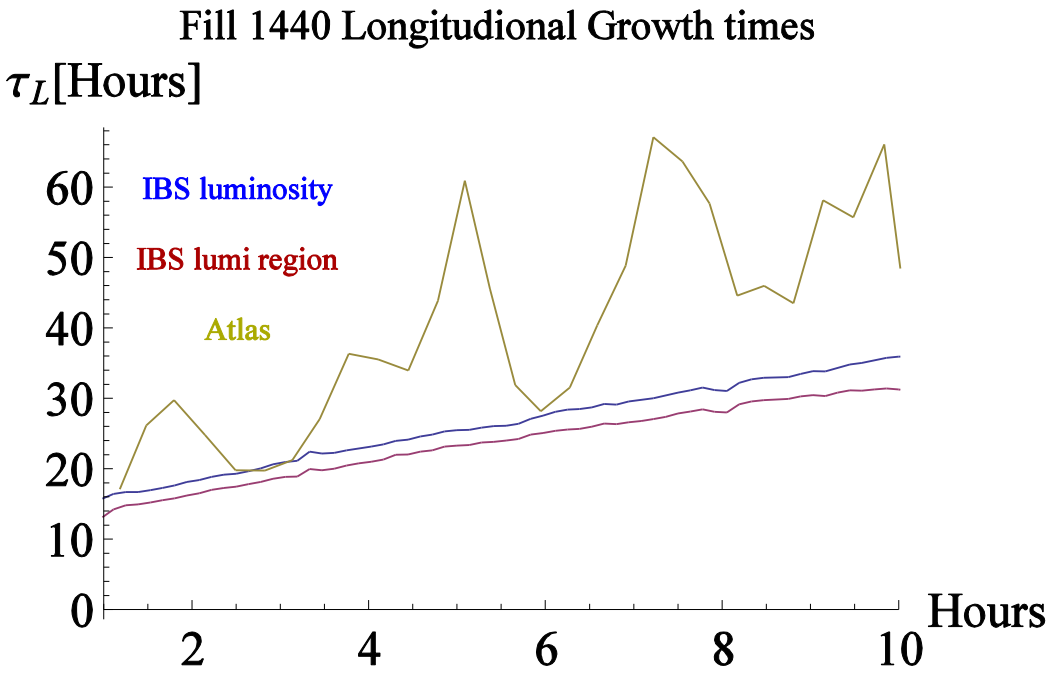


Fill 1440 (pp, during physics) [3]

•Data sources : Atlas Luminous Region (LPC webpage)/RF Voltage (Timber)

•Use the initial value as input for the IBS interpolating function

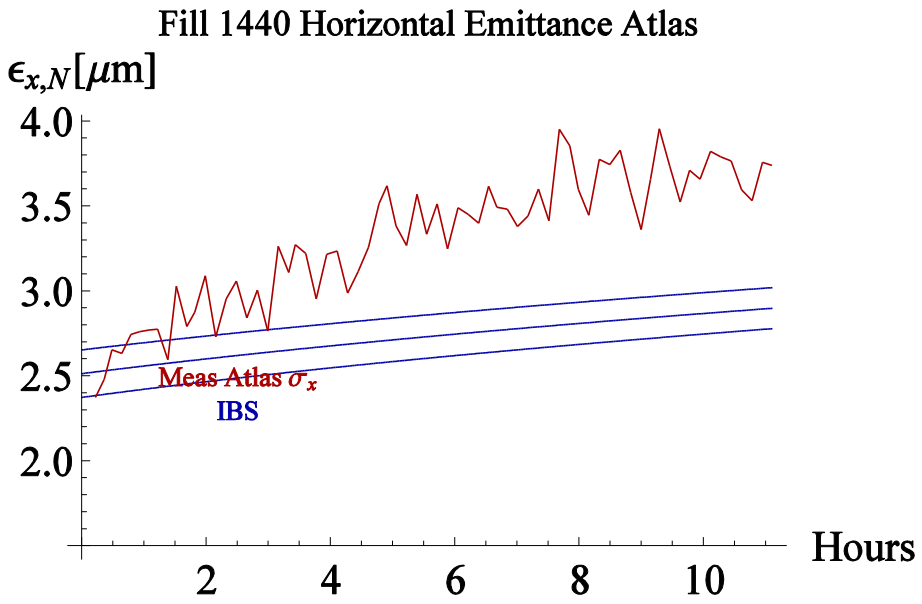
• Output growth times τ of the IBS interpolation used in

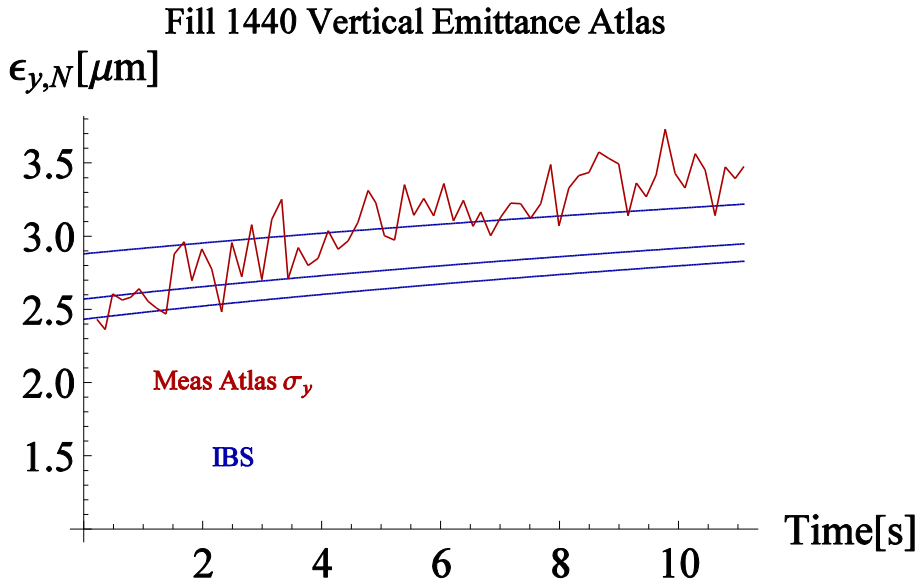
$$\varepsilon(t) = \varepsilon(0).Exp[\frac{t}{\tau}]$$

ONLY initial values of emittances used in the IBS simulated curves (Blue curves)!!!

Red curve:

Calculated transverse emittances from atlas luminous region data (LPC) using the interpolating function created for this data.





Fill 1440 (pp, during physics) [4]

- Data sources : Atlas Luminous Region (Timber/LPC webpage)/RF Voltage (Timber)/Atlas Luminosity(LPC)
- Creating input for the IBS interpolating function:
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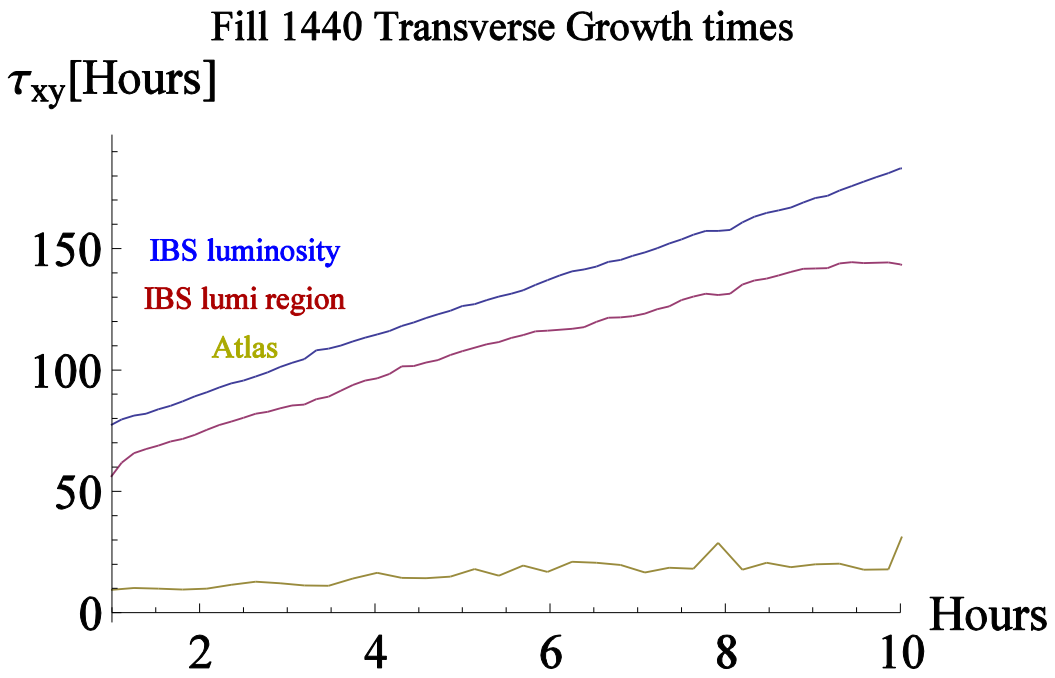
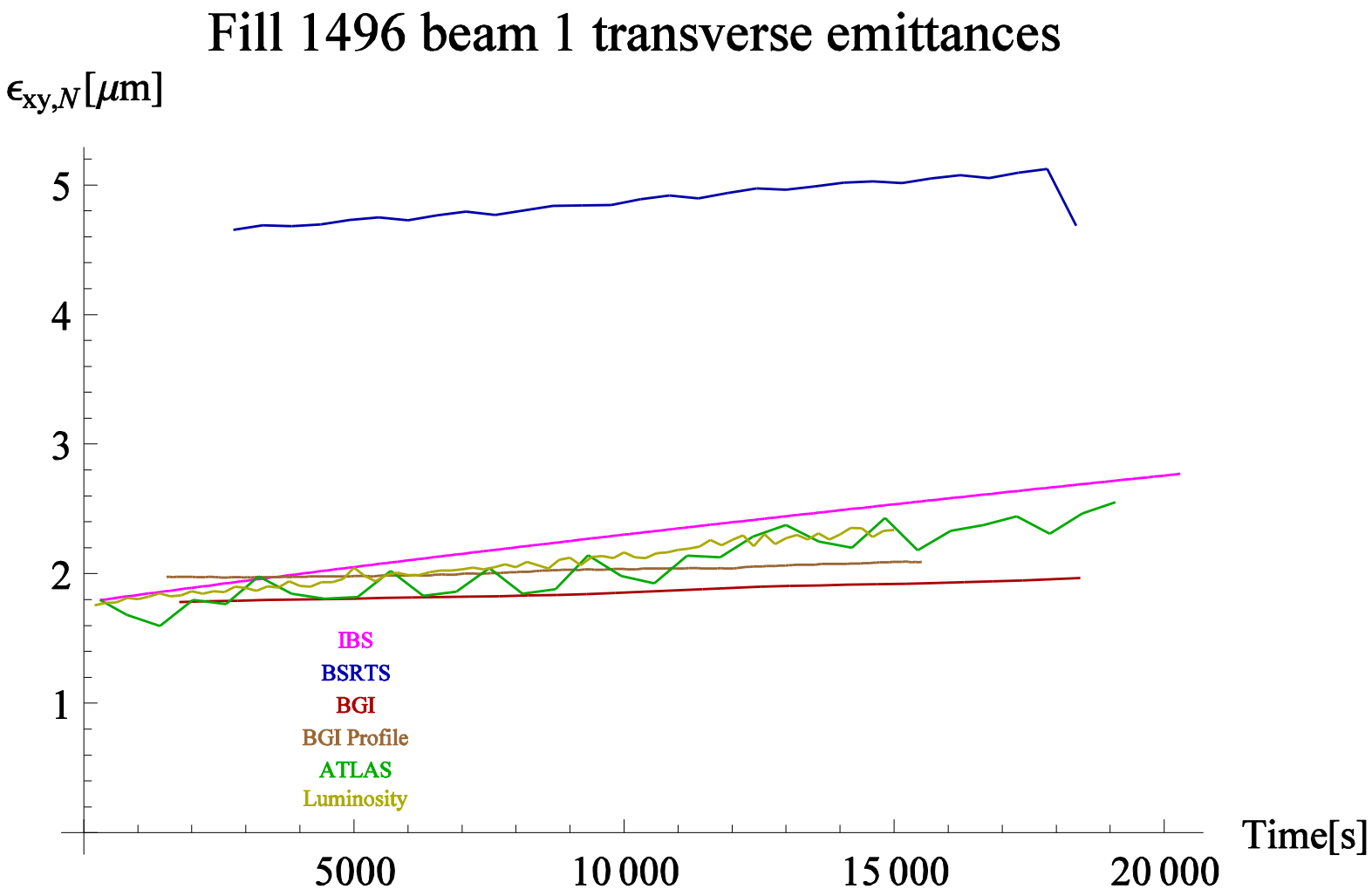


Fill 1496 (PbPB, during physics) [1]



Transverse emittance calculated from the measurement of different devices.

The IBS curve is generated as before, using the ATLAS initial data as input.

Fill 1496 (PbPb, during physics) [2]

• Data sources : Timber (BSRTS, BGI,BGI profile , BCTDC)/Atlas luminous regions (LPC website)

• BSRTS (cycles through the bunches) :

  • Taking moving average of the raw data and creating an interpolating function for the horizontal and vertical beam sigma's (for averaging over the bunches)

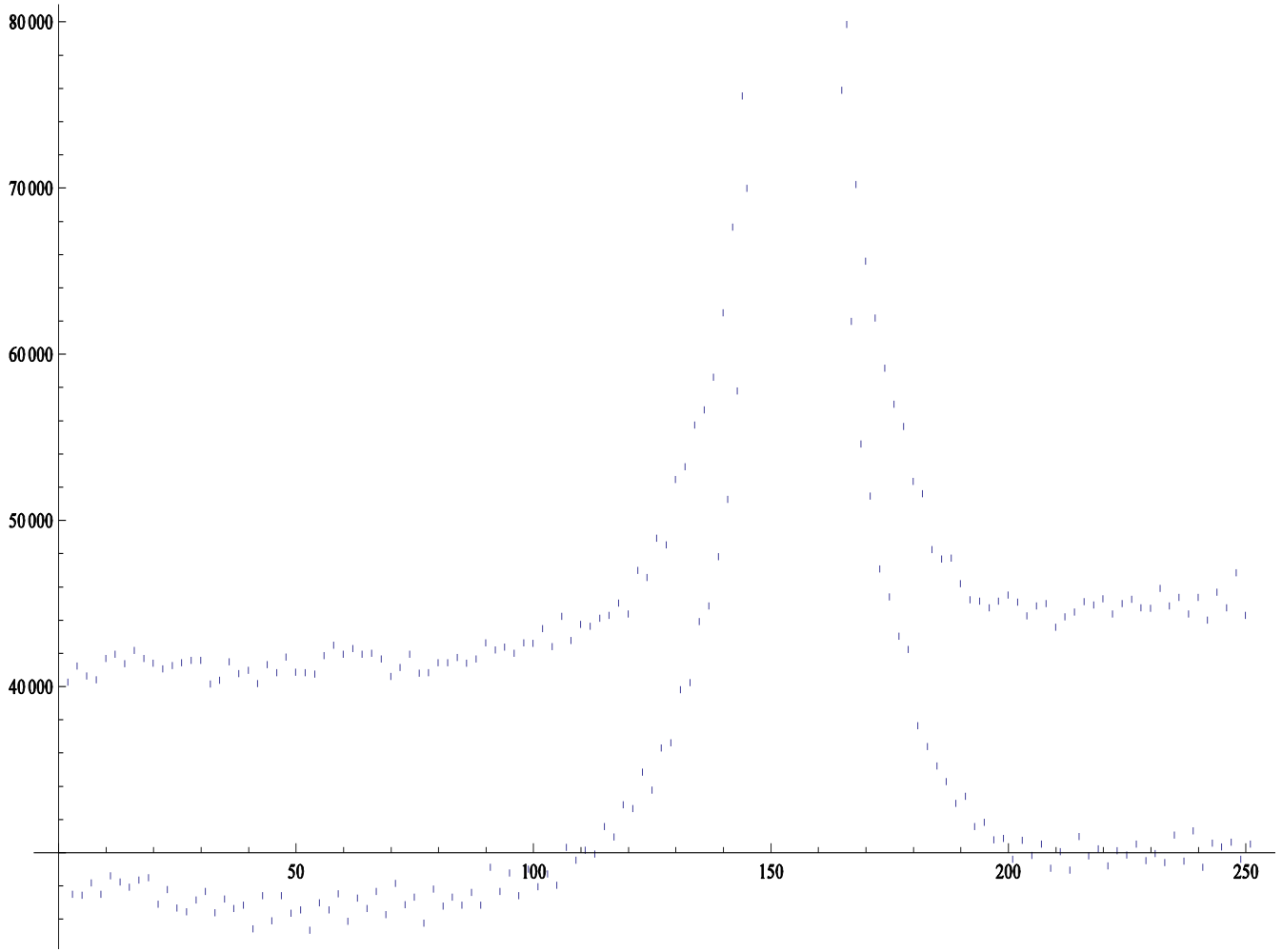
  • Using $\varepsilon_i = \frac{\sigma_i^2}{\beta}, i = x, y$ with β the optical beta function at the BRSTS (horizontal and vertical location in the LHC, using John Jowett's mathematica packages for using MAD-X in mathematica to calculate the optical function)

  • Combining horizontal and vertical (and normalizing) : $\varepsilon_{xy} = \gamma_{coll}\sqrt{\varepsilon_x \varepsilon_y}$

• BGI : same procedure as for BSRTS

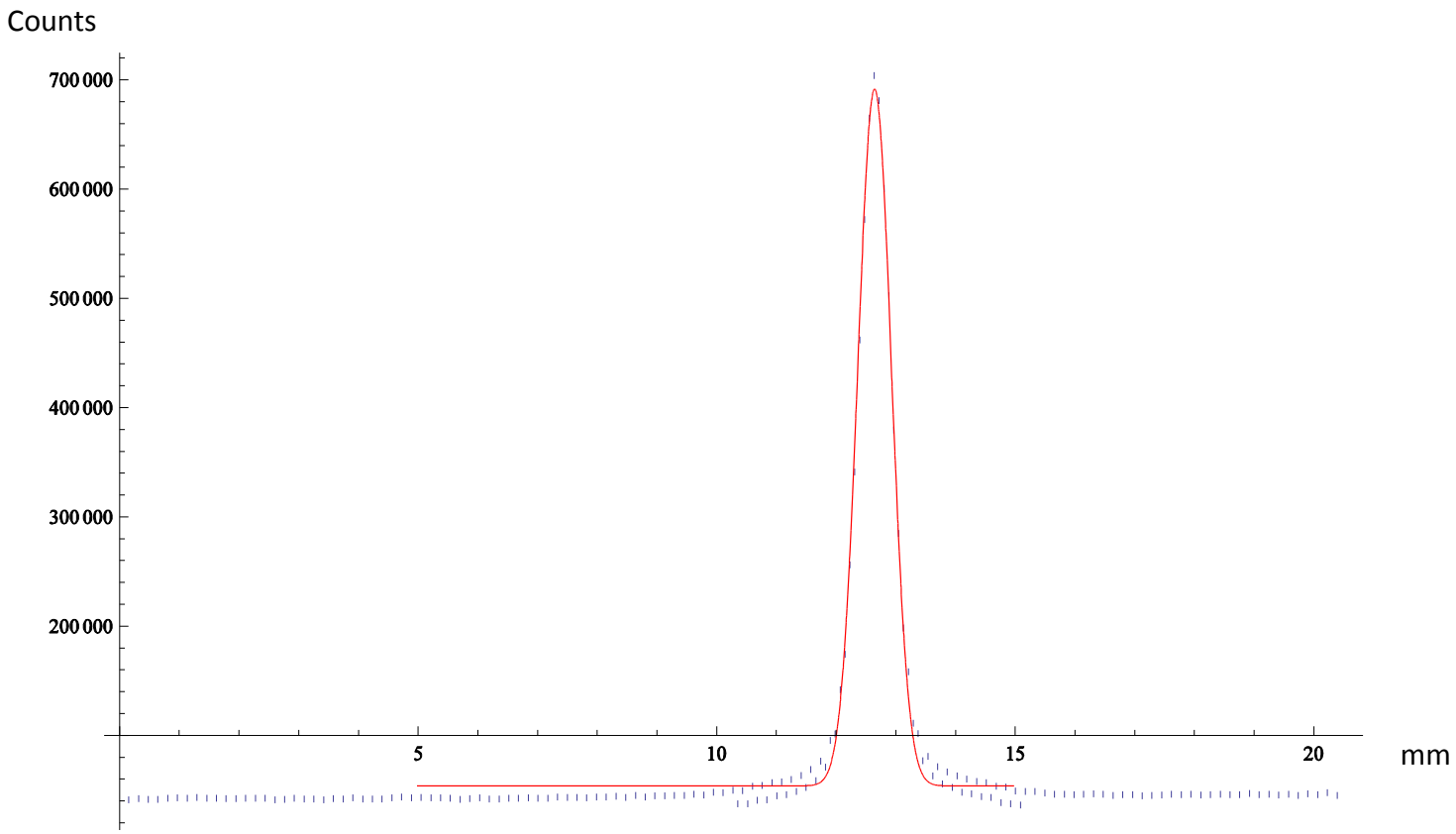
Fill 1496 (PbPb, during physics) [3]

- BGI profile:
  - Raw data looks like plot below
  - Selecting the right data points
  - Calibrating the selected data (0.0816 mm/pixel, Mariusz Gracjan Sapinski)



Fill 1496 (PbPB, during physics) [4]

- BGI profile:
  - Fitting with a Gaussian
  - Using the sigma's from the Gaussian's as beam sigma's
  - Apply the same procedure as for BGI and BSRTS to these beam sigma's



Fill 1496 (PbPB, during physics) [5]

- ATLAS Luminosity :
  - Raw BCTDC data for the intensity and the Atlas luminous region luminosity data
  - Take a moving average to smoothen the data
  - Create interpolating functions (sampling rates for luminosity and intensity differ and we want to do our calculation at a specific time for all the data)
  - Calculate normalized emittance using

$$\varepsilon = \gamma_{coll} \frac{I_1 I_2 k_C f}{4\pi\beta^* L k_{b1} k_{b2}}$$

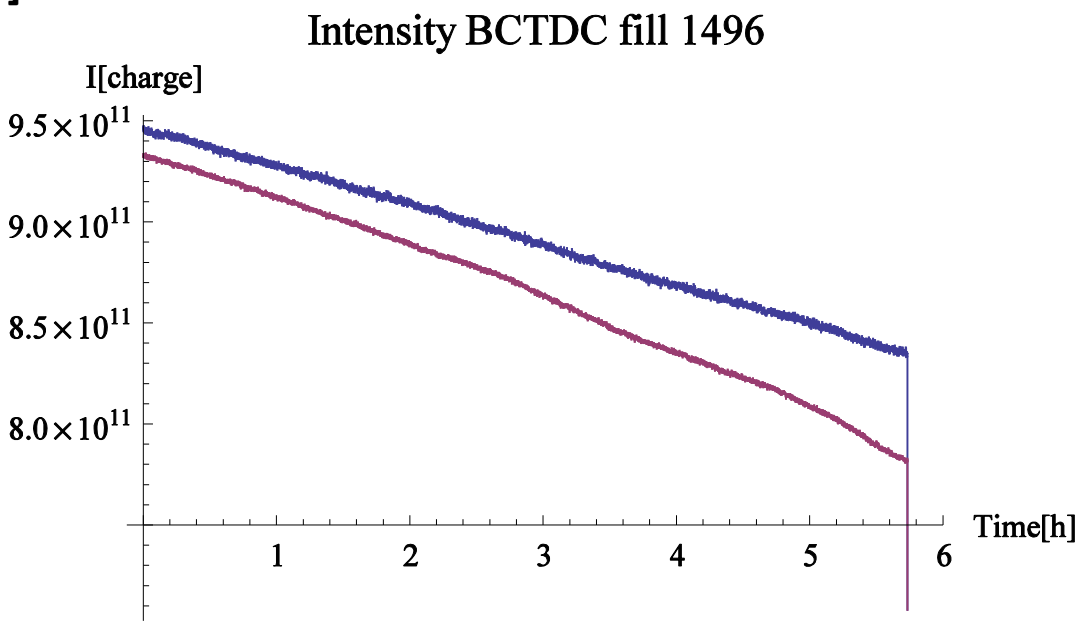
$k_{b1,2} =$ number of bunches in Beam 1,2

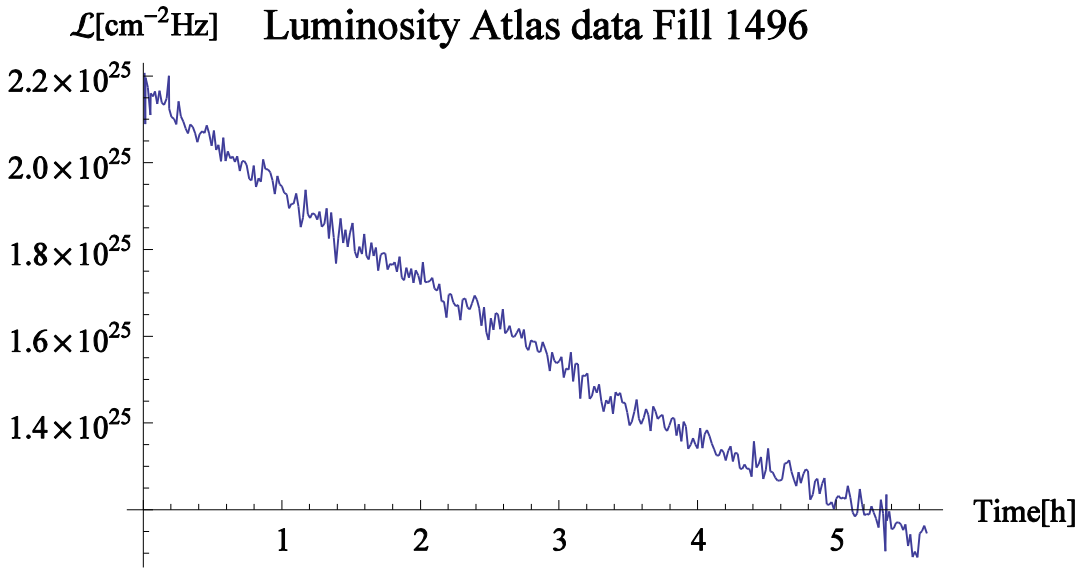
$k_C =$ number of colliding bunches in Atlas

$L =$ luminosity

$f =$ revolution frequency

$I_i =$ intensities B1,2





Fill 1496/1504 (PbPb, during physics) [6]

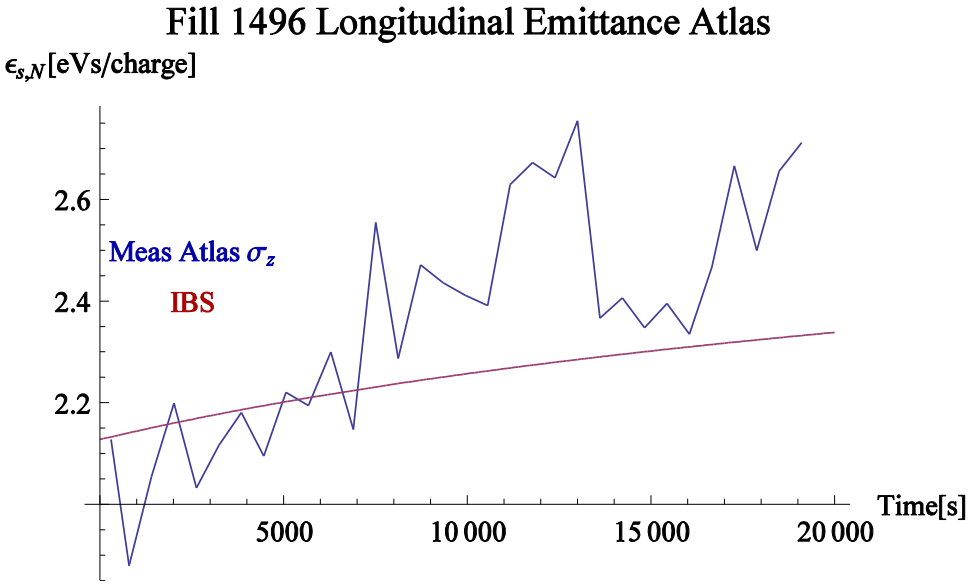
- Data sources : Atlas Luminous Region (Timber)/RF Voltage (Timber)
- Applied moving average to raw data
- Created interpolating function for this averaged data
- Use the initial value as input for the IBS interpolating function
- Output growth times τ of the IBS interpolation used in :

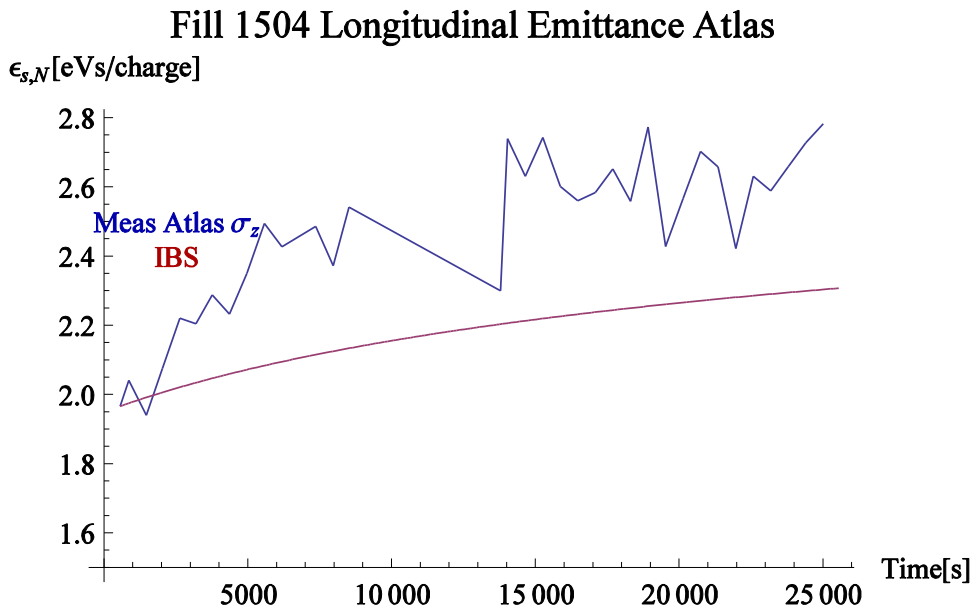
$$\varepsilon(t) = \varepsilon(0)\exp[\frac{t}{\tau}]$$

ONLY initial values of emittances used in the IBS simulated curves (Blue curve)!!!

Red curve:

Calculated longitudinal emittance from atlas luminous region data using the interpolating function created for this data.





Fill 1496 (pp, during physics) [8]

•Data sources : Atlas Luminous Region (LPC webpage)/RF Voltage (Timber)

•Use the initial value as input for the IBS interpolating function

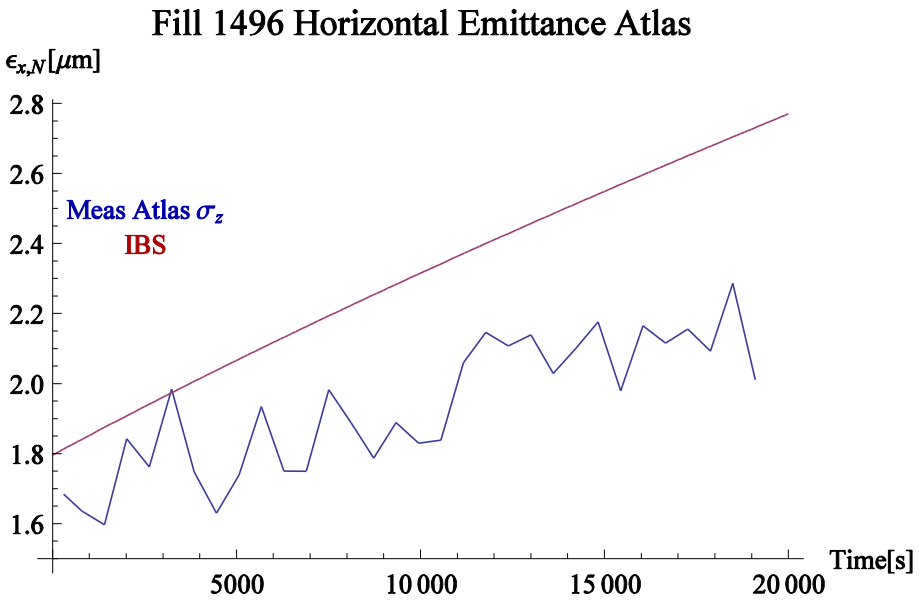
• Output growth times τ of the IBS interpolation used in

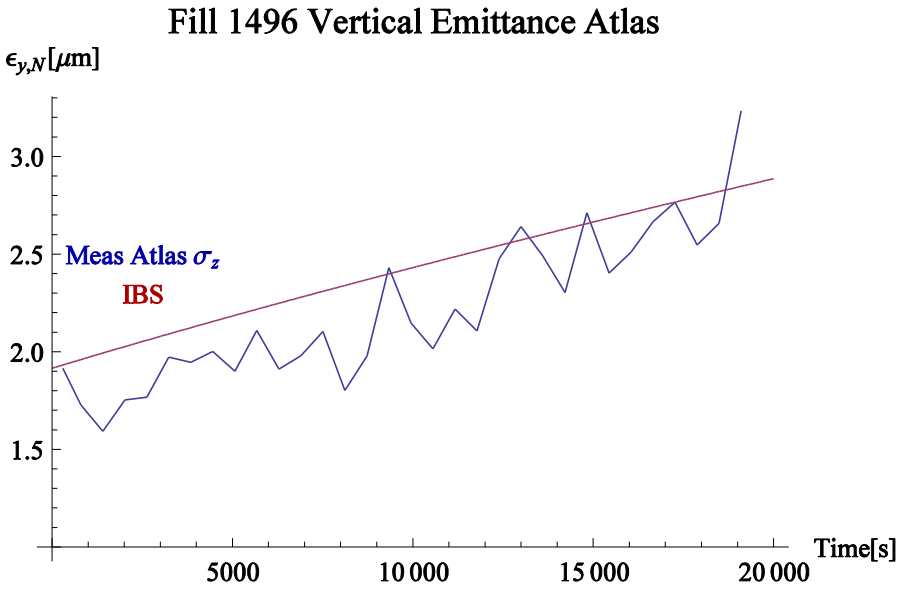
$$\varepsilon(t) = \varepsilon(0)\exp[\frac{t}{\tau}]$$

ONLY initial values of emittances used in the IBS simulated curves (Blue curve)!!!

Red curve:

Calculated transverse emittances from atlas luminous region data (LPC) using the interpolating function created for this data.





Fill 1496 (pp, during physics) [9]

•Data sources : Atlas Luminous Region (LPC webpage)/RF Voltage (Timber)

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• Output growth times τ of the IBS interpolation used in

$$\varepsilon(t) = \varepsilon(0)\exp[\frac{t}{\tau}]$$

ONLY initial values of emittances used in the IBS simulated curves (Blue curve)!!!

Red curve:

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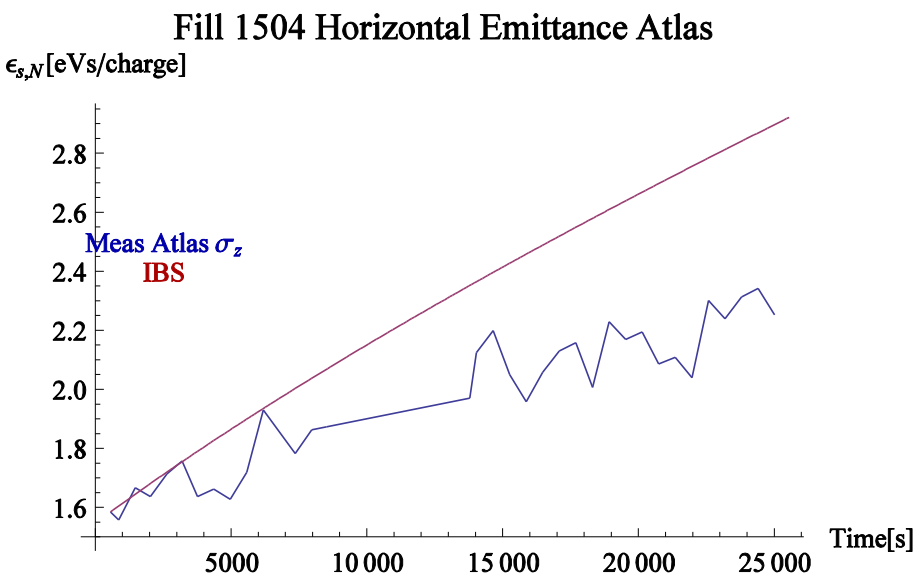

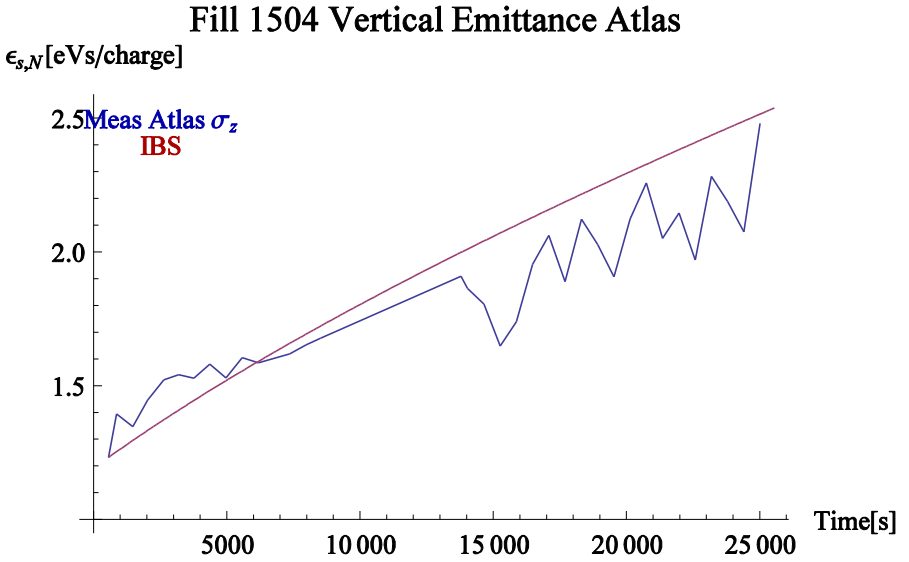

Conclusions and outlook

- The different measuring devices seem to be converging (except BSRTS, but preliminary recalibration algorithm has been received since)
- Longitudinal emittance: at the beginning of collisions the growth times seem to agree with IBS, but clearly other effects need to be taken into account
- Transverse emittance: strong deviation from what IBS predicts for protons and ions
- Particle tracking simulations are under way to compare with MAD-X algorithm and include other effects (collisions, radiation damping, synchrotron motion,…)