Effect of e-lens on circulating beams

D. Mirarchi,

H. Garcia Morales, M. Fitterer, A. Mereghetti, G. Stancari, S. Redaelli, J. Wagner

On behalf of the LHC Collimation team

Outline

I. Needs and working principle

II. Simulation tools

III. Simulation studies

IV. Conclusions

Outline

I. **Needs and working principle**

II. Simulation tools

III. Simulation studies

IV. Conclusions

Introduction

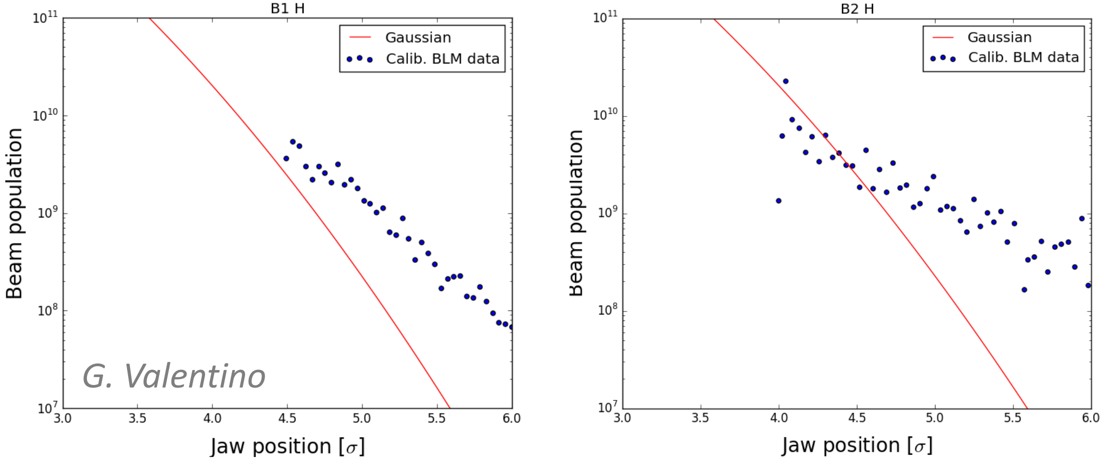
- **Present collimation system** designed to handle up to **360 MJ**, **HL-LHC** design **~700 MJ**
- **How much** of this energy is **in the tails**?

Halo population probed by means of **collimator scans**

BLM signal calibrated using BCT signal

~5% of the beams in the tails (>3.5 σ) while 0.22% if Gaussian

Scaling to HL-LHC parameters: ~33.6 MJ in the tails!



Fast failure scenarios:

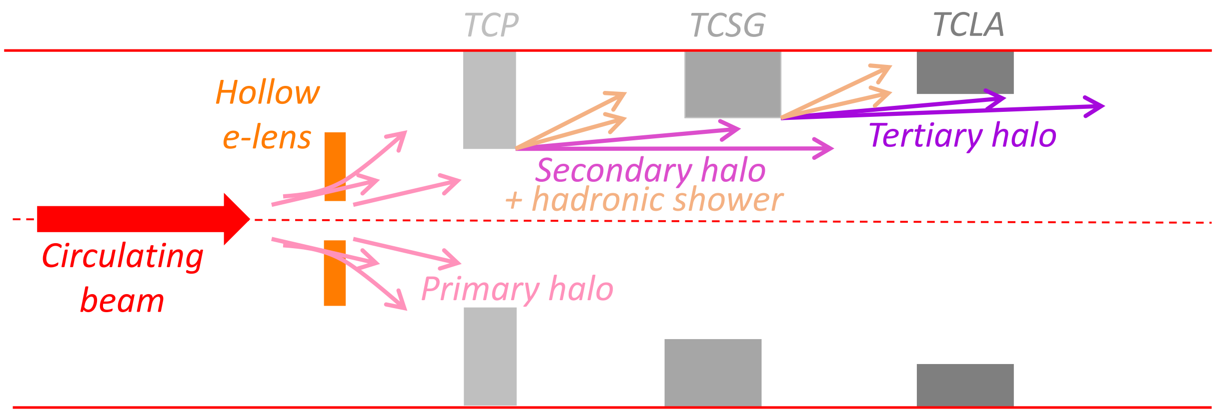
Orbit jitter
Crab cavity phase slip

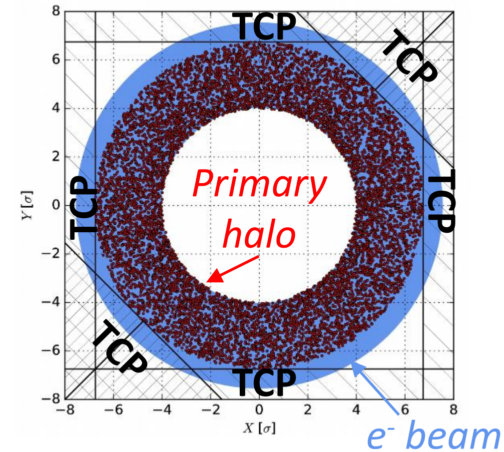
Possible consequences:

Magnet quench
Permanent damage to TCPs

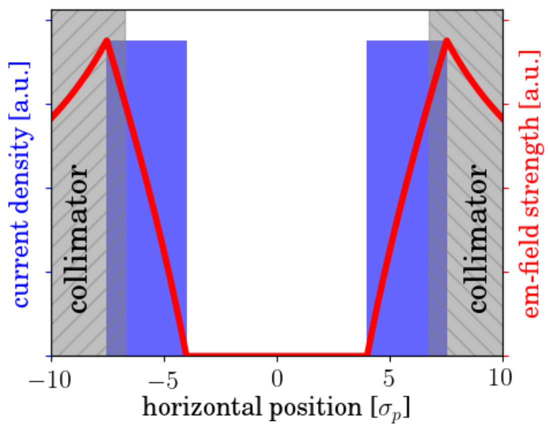
Hollow e-lens assisted collimation

Working principle: **hollow electron beam** surrounds the p beam as **additional hierarchy layer**

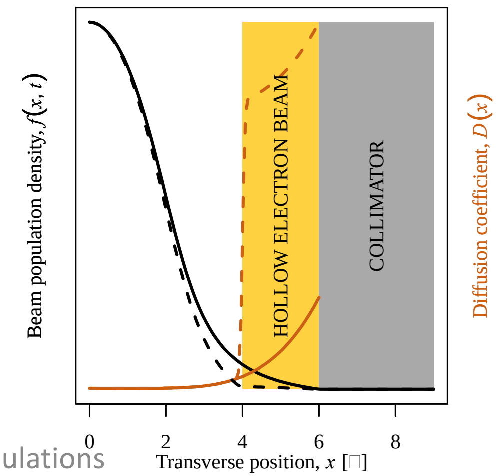




em-field acting only on halo particles



Increased diffusion speed and depleted halo population



Simulation challenges

Very demanding collimation simulations with electron lens:

Standard cleaning simulations:		**Plus e-lens:**
✓ Interaction radiation with matter	→	✓ Interaction radiation with matter
✓ Symplectic tracking for 200 turns	→	✓ Symplectic tracking for **>1e6 turns**
✓ Small dependence on initial distribution	→	✓ **Sensitive to initial distribution**
✓ Negligible effect of non-linearity	→	✓ **Coupling with $\delta p/p$, Q' and MO**

Outline

I. Needs and working principle

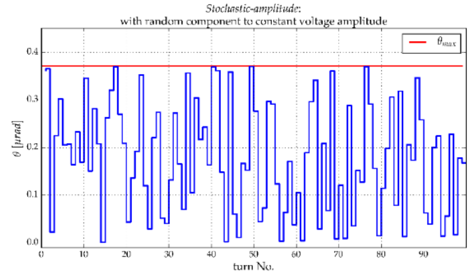
II. Simulation tools

III. Simulation studies

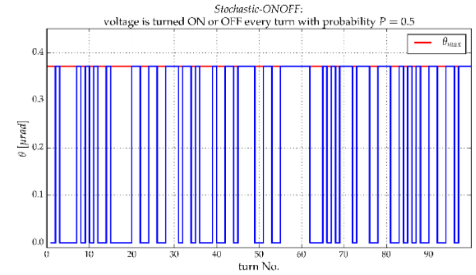
IV. Conclusions

Simulation tools

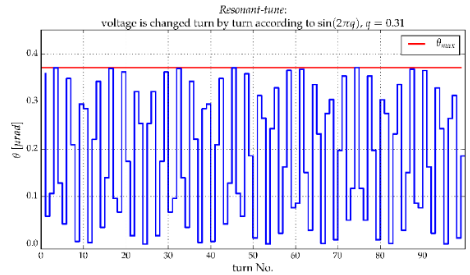
- **Electron lens** model implemented in **SixTrack and several working mode** available:
  1. **continuous (DC)**
  2. **Stochastic:**
     - Stochastic-amplitude:



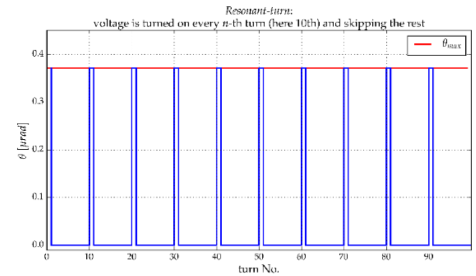
     - Stochastic-ONOFF:



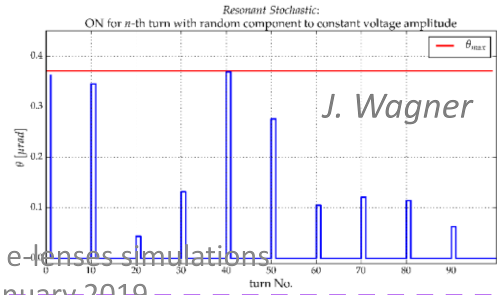
  3. **Resonant:**
     - Resonant-tune:



     - Resonant-turn:

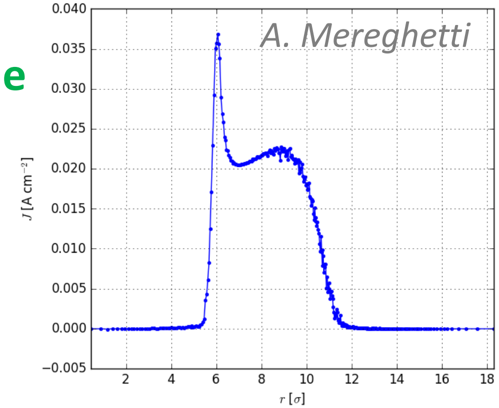


  4. **Stochastic-amplitude + Resonant-turn**

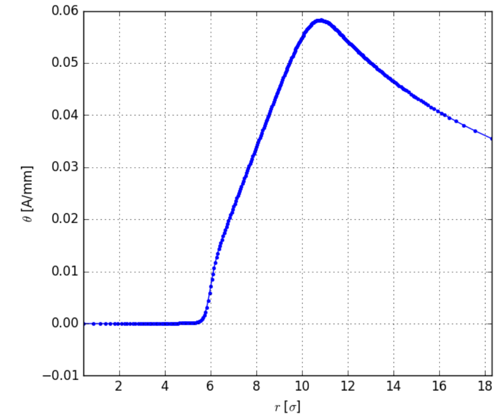


Recent development

- Only uniform e^- beams could be used, **two new functionalities** are now available:
  1. **Gaussian profile**
  2. **Measured radial profile**



kick



- Continuous simulations during **energy ramp** using either **fixed or matched radius**
- Simulations with **ions beams** circulating in the machine
- Can run on **BOINC**: crucial for long term tracking (>1e6 turns)
- **On-going:**
  - Implementation of **bends** using Chebyshev polynomials
  - **Measured 2D e^- beam profile**

Outline

I. Needs and working principle

II. Simulation tools

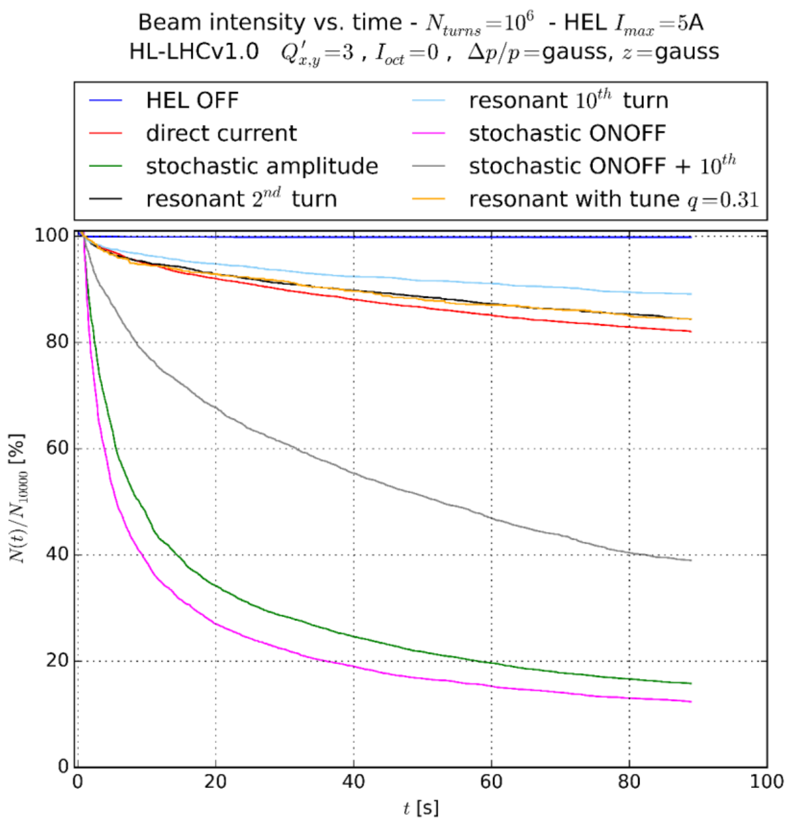
III. Simulation studies

IV. Conclusions

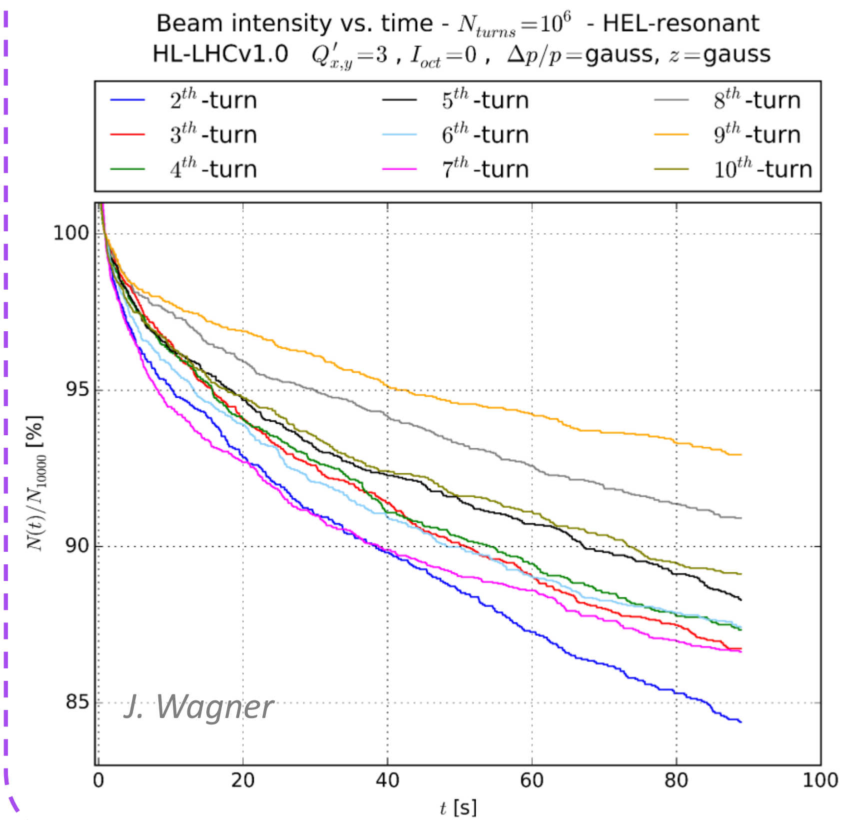
First performance assessment

Main goal: reasonable halo depletion rate without affecting the beam core

Different working mode



Scan in resonant excitation



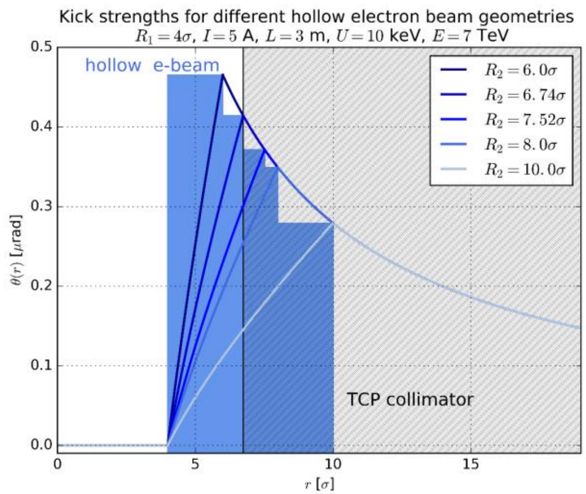
Detailed studies to be repeated for latest HL-LHC scenarios

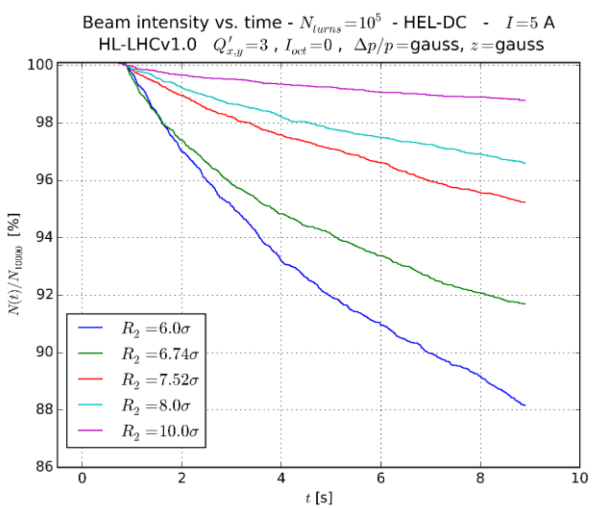
Support to the cathode design

Kick strengths

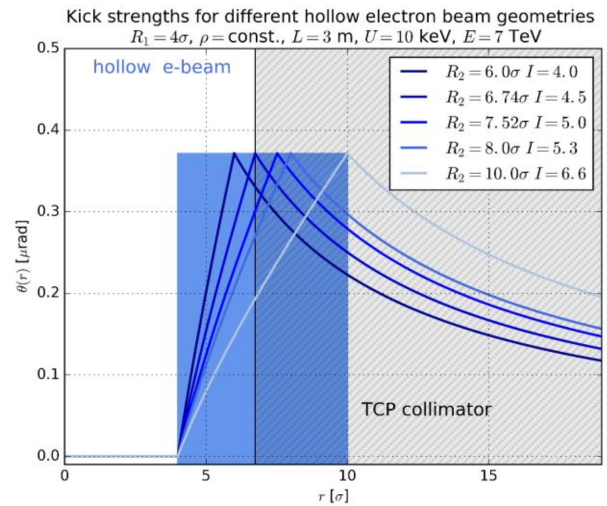
Depletion rate

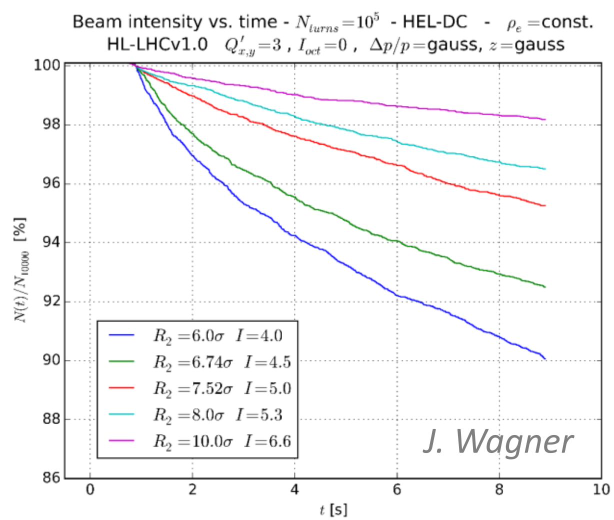
Constant current





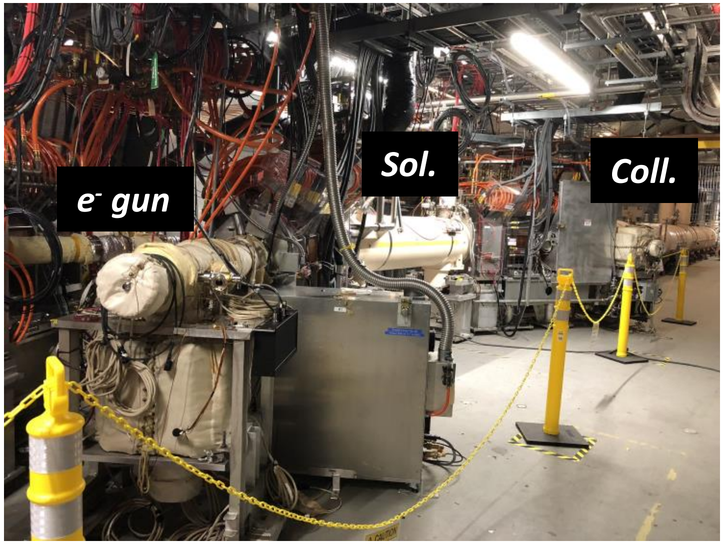
Constant current density

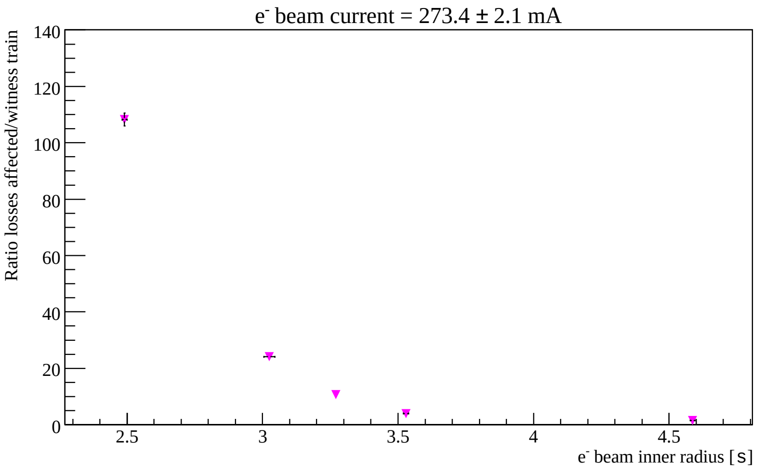


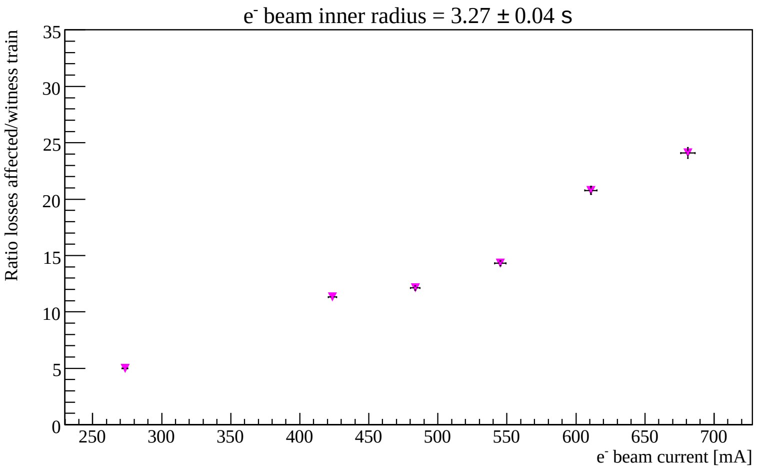


On-going studies

- **Experimental tests** recently performed **at BNL:**
  - ✓ e^- beam radius scan
  - ✓ e^- beam current scan
  - ✓ Chromaticity scan
  - ✓ Octupole scan
  - ✓ Resonant excitation







Unique opportunity to explore different operational scenarios and benchmark simulation code!

Outline

I. Needs and working principle

II. Simulation tools

III. Simulation studies

IV. Conclusions

Conclusions

- **Solid collimation upgrade baseline for the HL-LHC**

  → Recent assessment of **large tail populations might require active halo control**

  → **HEL identified as most promising solution**

- **Simulation tools available, updated and suitable for long term tracking**

- **Simulation studies** on both beam **halo and core** to provide **optimal working** point for HL-LHC and support to **cathode design**

- **Encouraging results obtained in experimental tests** recently performed at BNL, also useful for a **thorough code benchmarking**

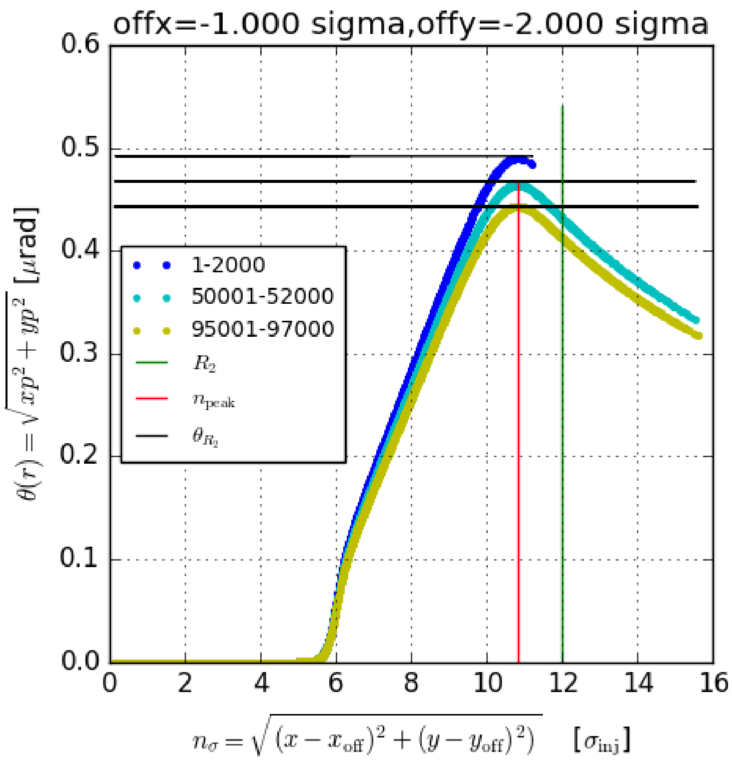
Outline

Thank you for your attention!

BACKUP

Simulations during energy ramp

Constant radius



Matched radius