

# **Optics status and plans**

**Demin Zhou**

Acknowledgements:

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13th HE-LHC design meeting, CERN, May. 11, 2017

# Outline

- Scaling HL-LHC
  - HLLHCV1.0 [pre-squeeze, non-ATS]
- Tests of using 60deg arc cells
  - Injection optics for HL-LHC (HLLHCV1.0, opt\_inj.madx)
- Discussion and plans

# 1. Scaling HL-LHC

## ► HLLHCV1.0 [pre-squeeze, non-ATS]

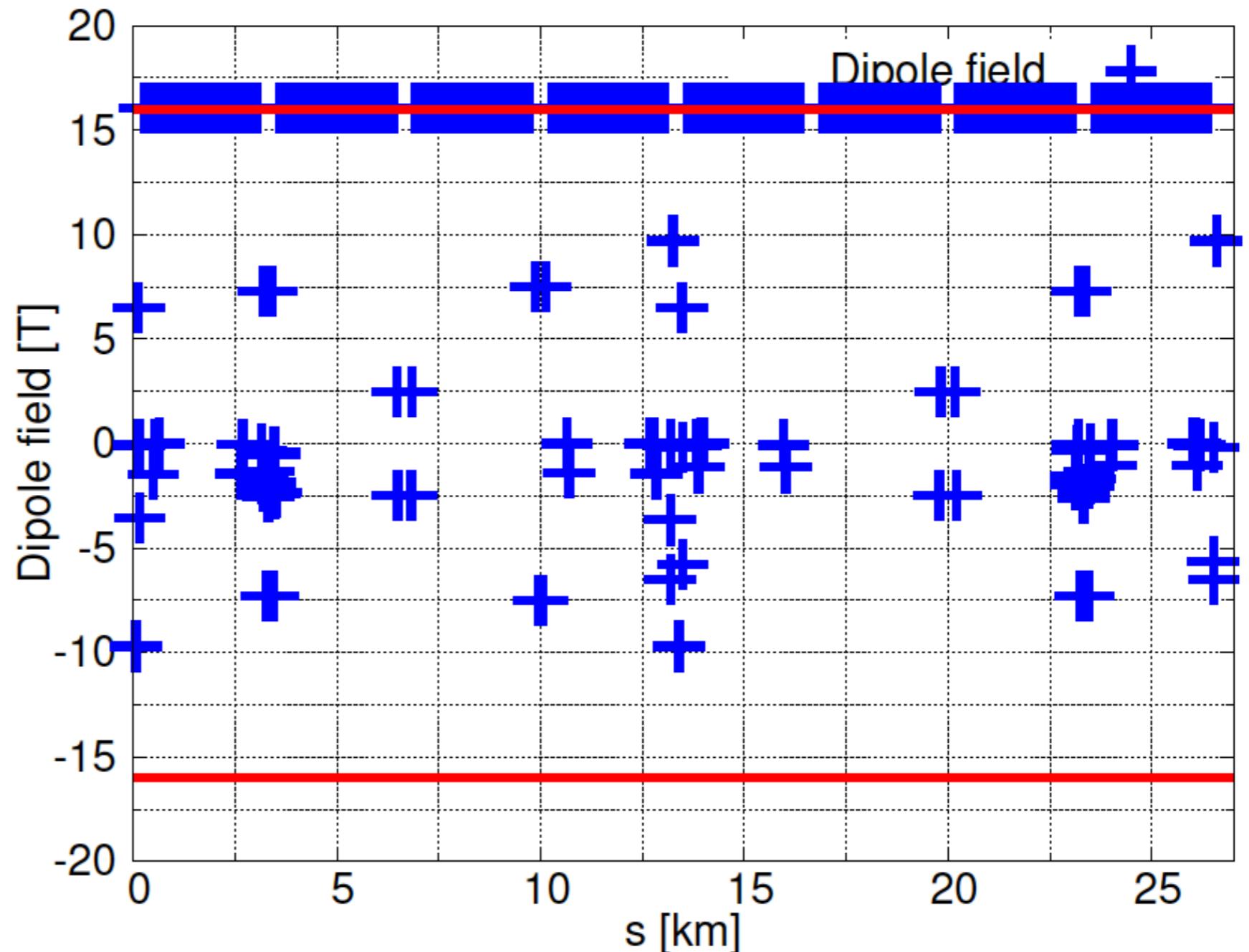
- $E=13.5 \text{ TeV}$ ,  $\beta^*=44\text{cm}$  @IP#1&5
- Dipole:  $L=14.3\text{m}$

$K_n$ : MAD convention

$$K_n L = \frac{B^{(n)} L}{B \rho}$$

FCC specification:

$B_{\max} \approx 16\text{T}$



# 1. Scaling HL-LHC

## ► HLLHCV1.0 [pre-squeeze, non-ATS]

- $E=13.5 \text{ TeV}$ ,  $\beta^*=44\text{cm}$  @IP#1&5
- Quadrupole:  $L=3.1\text{m}$  in arcs [Typical]

$K_n$ : MAD convention

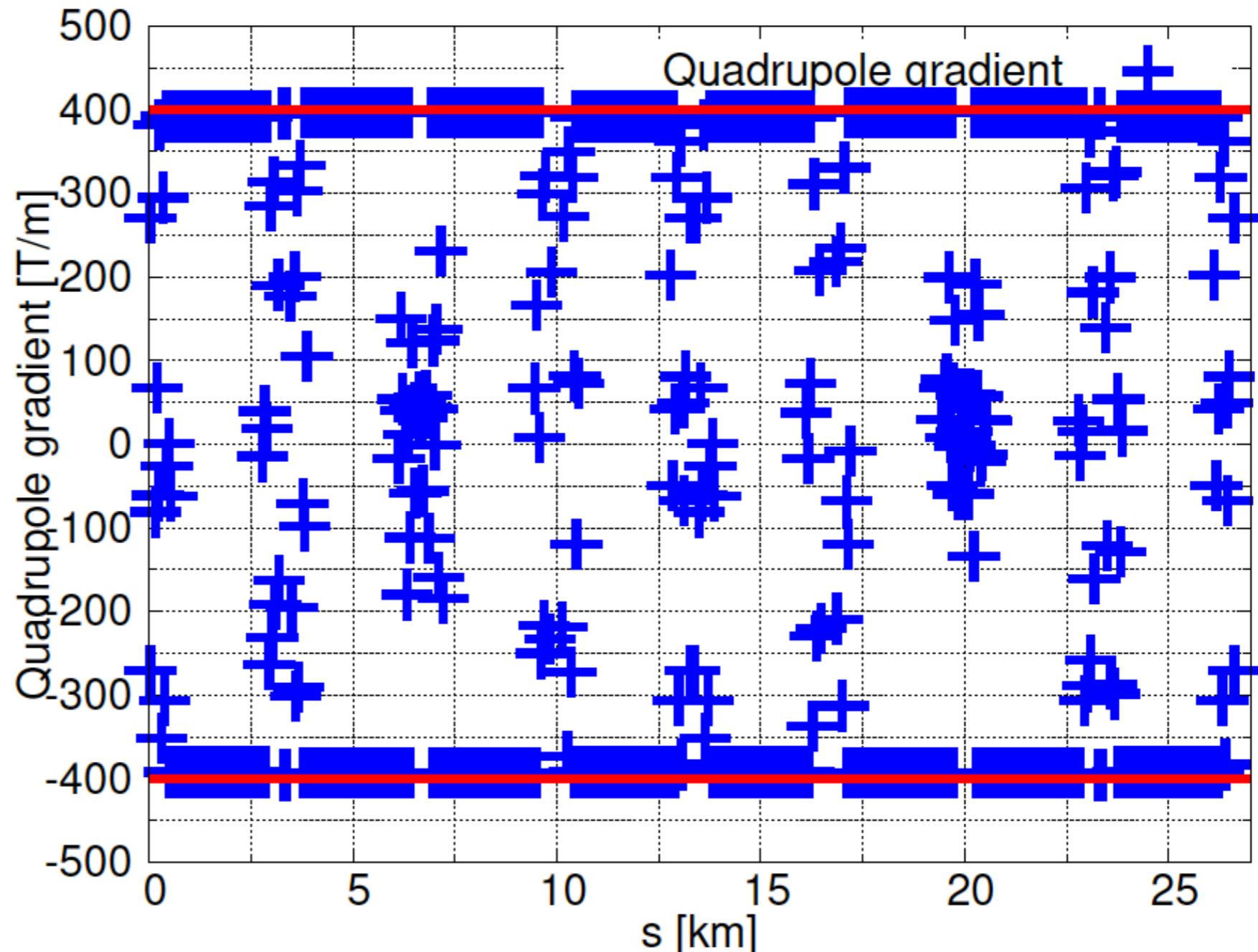
$$K_n L = \frac{B^{(n)} L}{B \rho}$$

FCC specification:

$B^{(1)}_{\max} \approx 400 \text{T/m}$ <sup>[1]</sup>

with aperture

$\phi=50\text{mm}$



<sup>[1]</sup>A. Chance, FCC-hh magnet-beam dynamics coordination meeting, Mar. 17, 2017

# 1. Scaling HL-LHC

## ► HLLHCV1.0 [pre-squeeze, non-ATS]

- E=13.5 TeV,  $\beta^*=44\text{cm}$  @IP#1&5
- Sextupole: L=0.369m in arcs [Typical]

$K_n$ : MAD convention

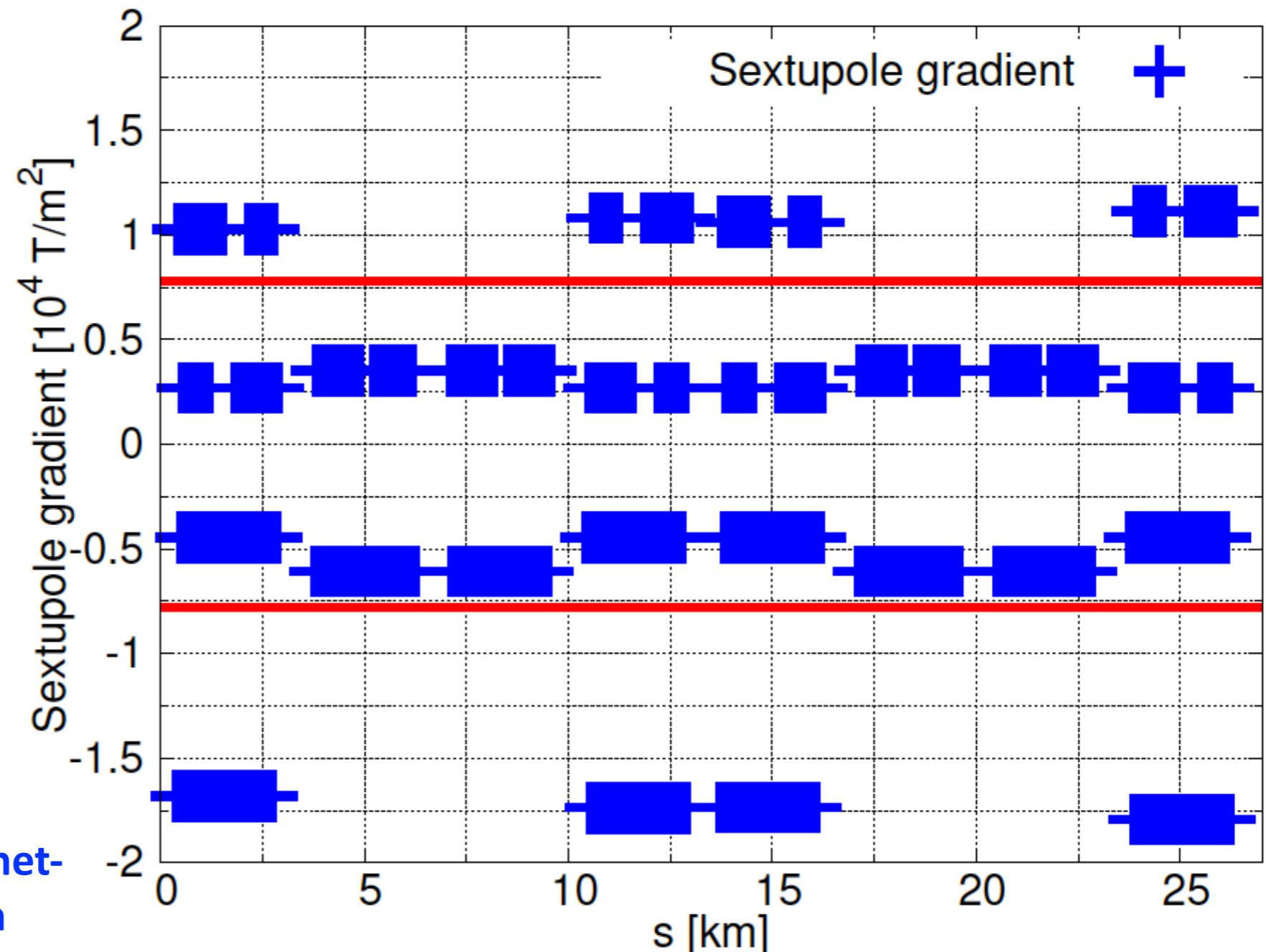
$$K_n L = \frac{B^{(n)} L}{B \rho}$$

FCC specification:

$B^{(2)}_{\max} \approx 7800\text{T/m}^2$ <sup>[2]</sup>

with aperture

$\phi=50\text{mm}$



<sup>[2]</sup>D. Schoerling, FCC-hh magnet-beam dynamics coordination meeting, Apr. 28, 2017

# 1. Scaling HL-LHC

## ➤ Quick conclusions for scaling of HL-LHC to HE-LHC (13.5TeV) with assumed FCC technologies

- [1] Almost no margins for main dipoles and quadrupoles
- [2] Sextupoles too strong in arcs
- [3] Challenges for magnets in IRs (see Leon's talk in this meeting)

## ➤ Possible solutions

- For [1]:
  - \* Option 1: Use longer dipoles and quadrupoles in arcs but reduce number of cells. How about 90deg 20 arc cells?
  - \* Option 2: 60deg 18 arc cells (Yuri, Frank, Massimo, etc.). This sets challenges to injection at 450GeV (see Frank's talk in last meeting). => Higher injection energy preferred

# 1. Scaling HL-LHC

## ➤ Possible solutions (cont'd)

- For [2]:
  - \* Option 1: Use longer sextupoles in arcs
  - \* Option 2: 60deg 18 arc cells
- For [3]:
  - \* Longer triplets necessary
  - \* Challenges not coupled with those in arcs (?). Could be studied independently (?)

## 2. Tests of using 60deg arc cells

### ➤ Conditions

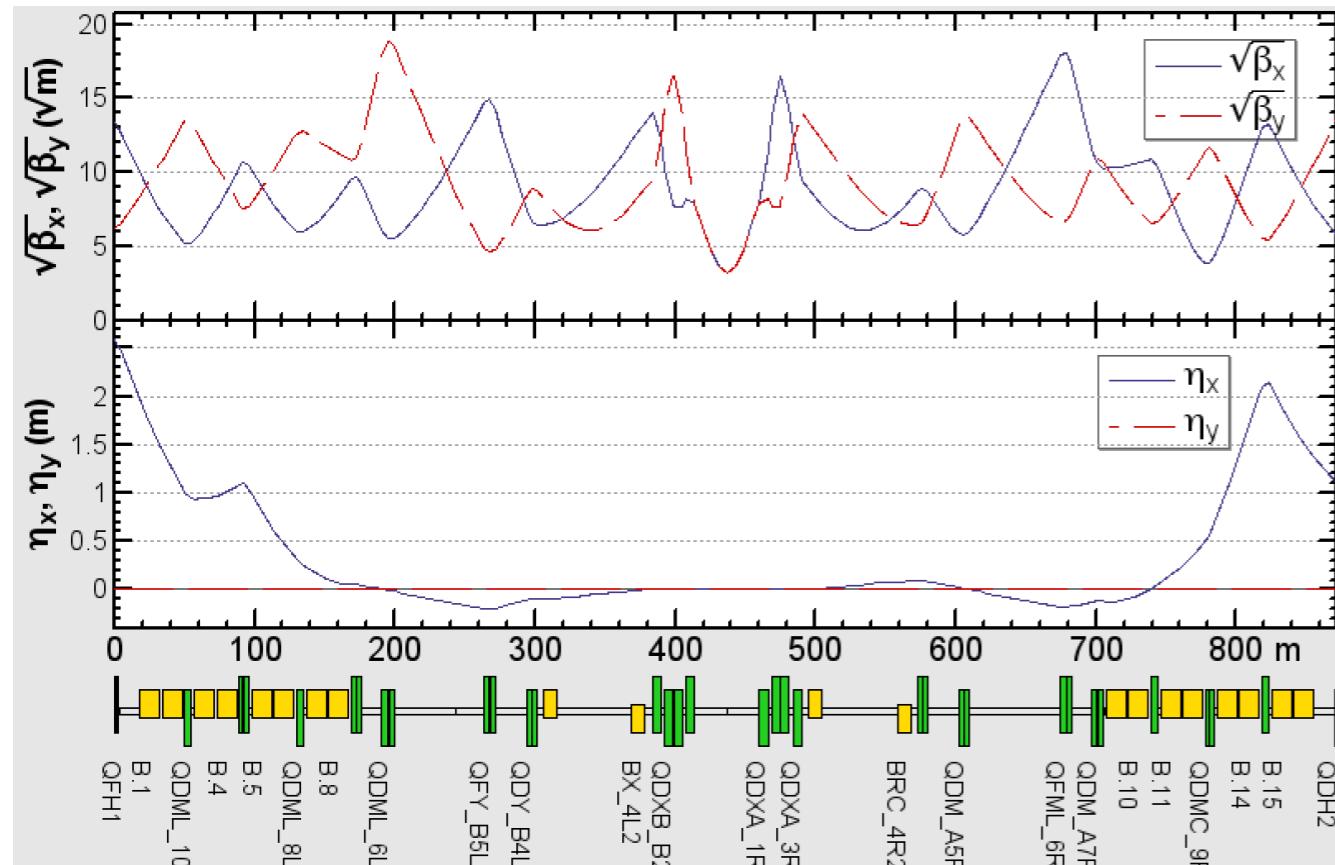
- HLLHCV1.0
  - \* `slhc/opt_inj.madx`
  - \* **Crossing disabled**
- Exactly keep the layouts of IRs and dispersion suppressors
- Use 60deg 24 cells (Yuri's idea) to replace ~90deg 23 cells of (HL-)LHC
  - SAD scripts prepared (almost finished, need better understanding of matching conditions for HL-LHC) for (semi-)automatic MADX-to-SAD translation and optics matching using SAD functions

## 2. Tests of using 60deg arc cells

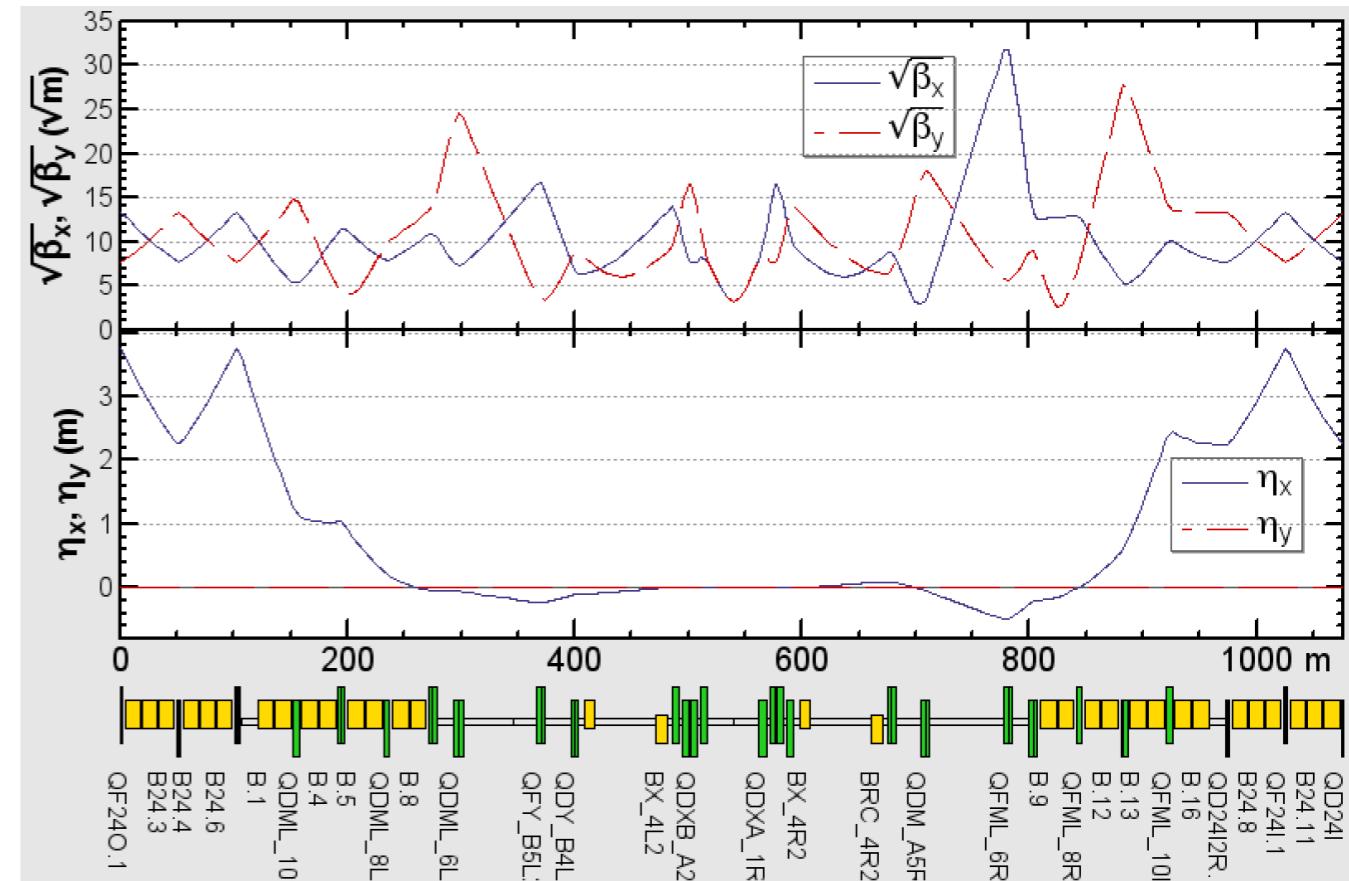
### ► Preliminary results (linear optics matching)

- IR2 (ALICE & injection b1)
- Triplets not join matching

HLLHCV1.0 (opt\_inj)



60deg-cell matched

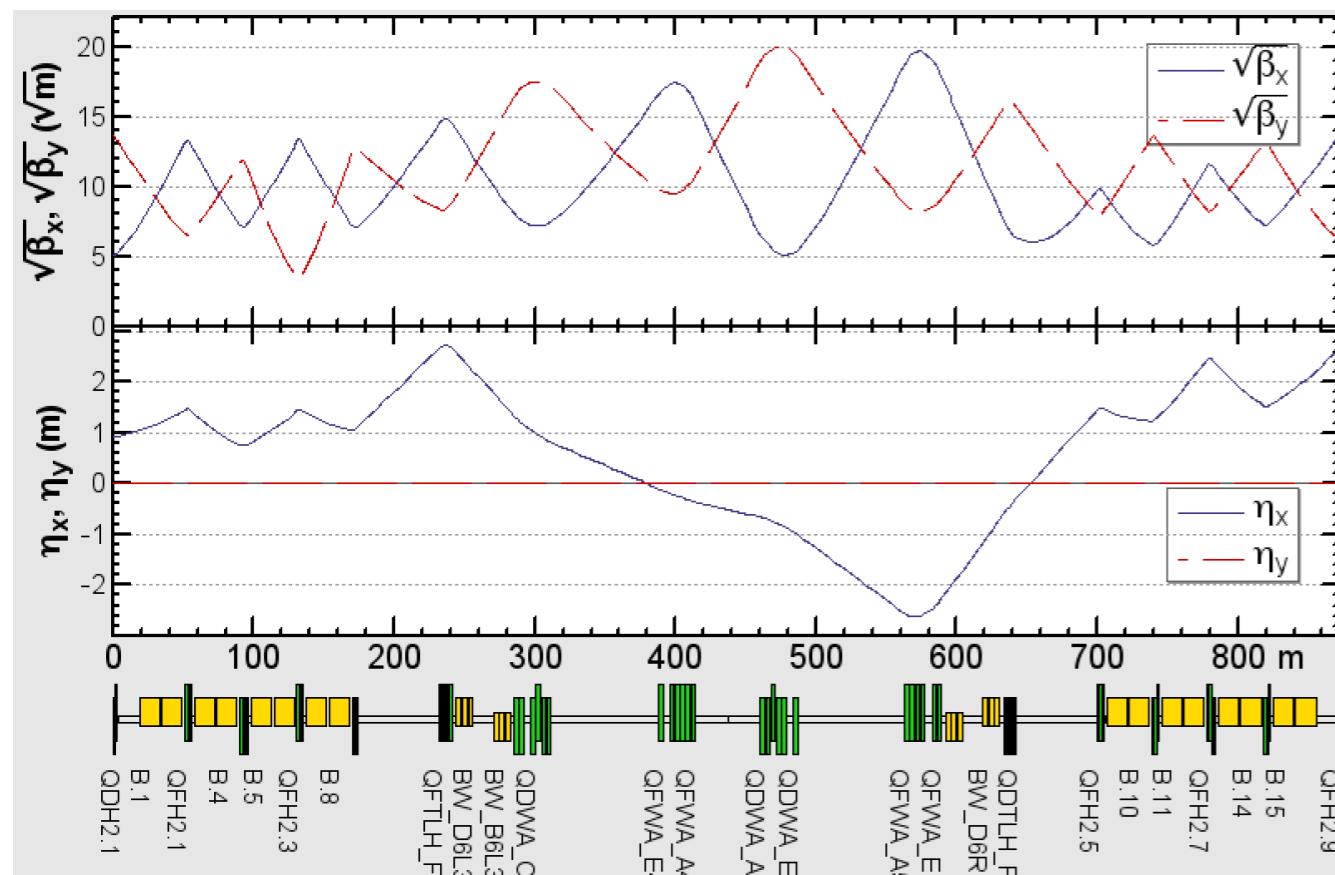


## 2. Tests of using 60deg arc cells

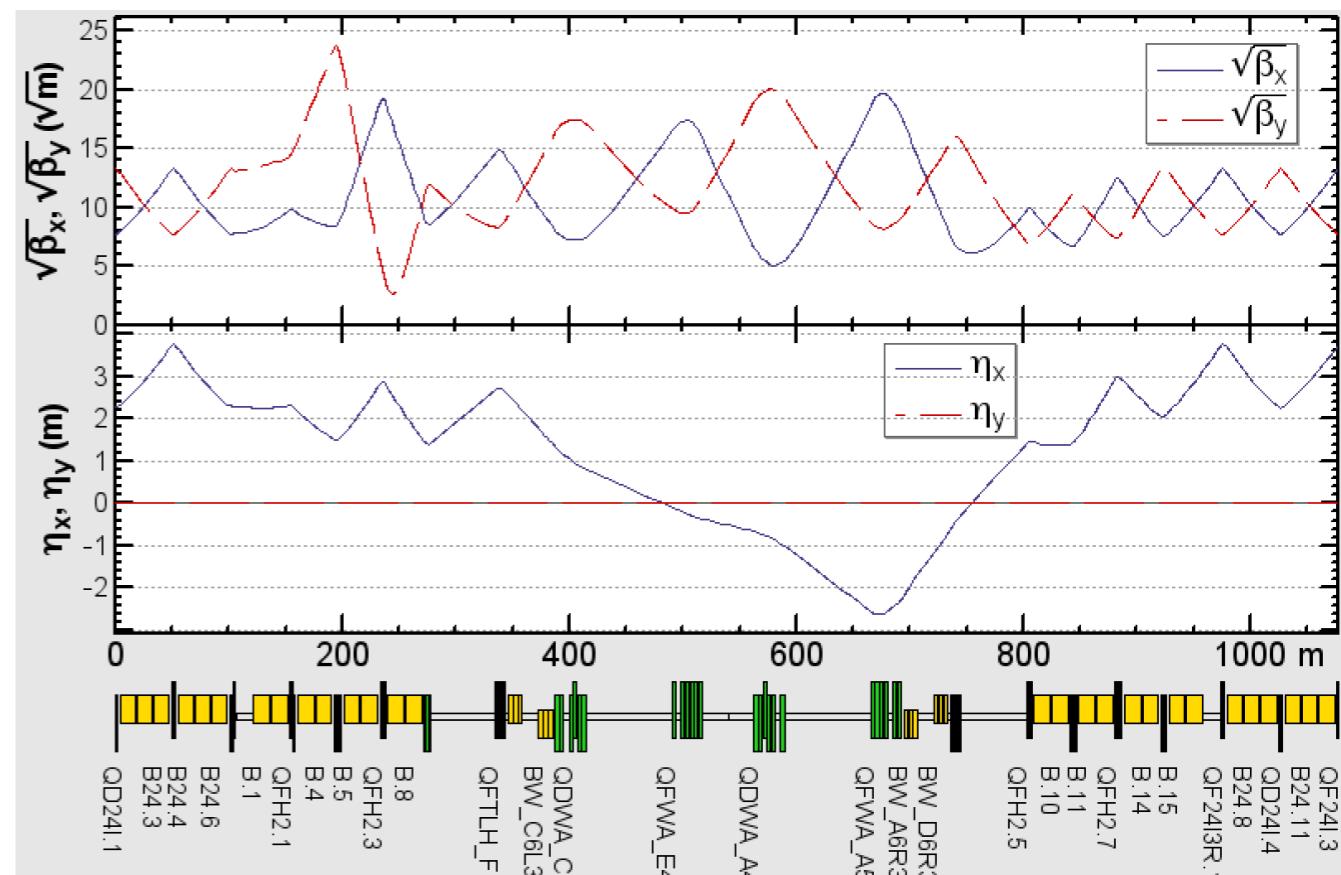
### ► Preliminary results (linear optics matching)

- IR3 (Momentum collimation)

HLLCV1.0 (opt\_inj)



60deg-cell matched

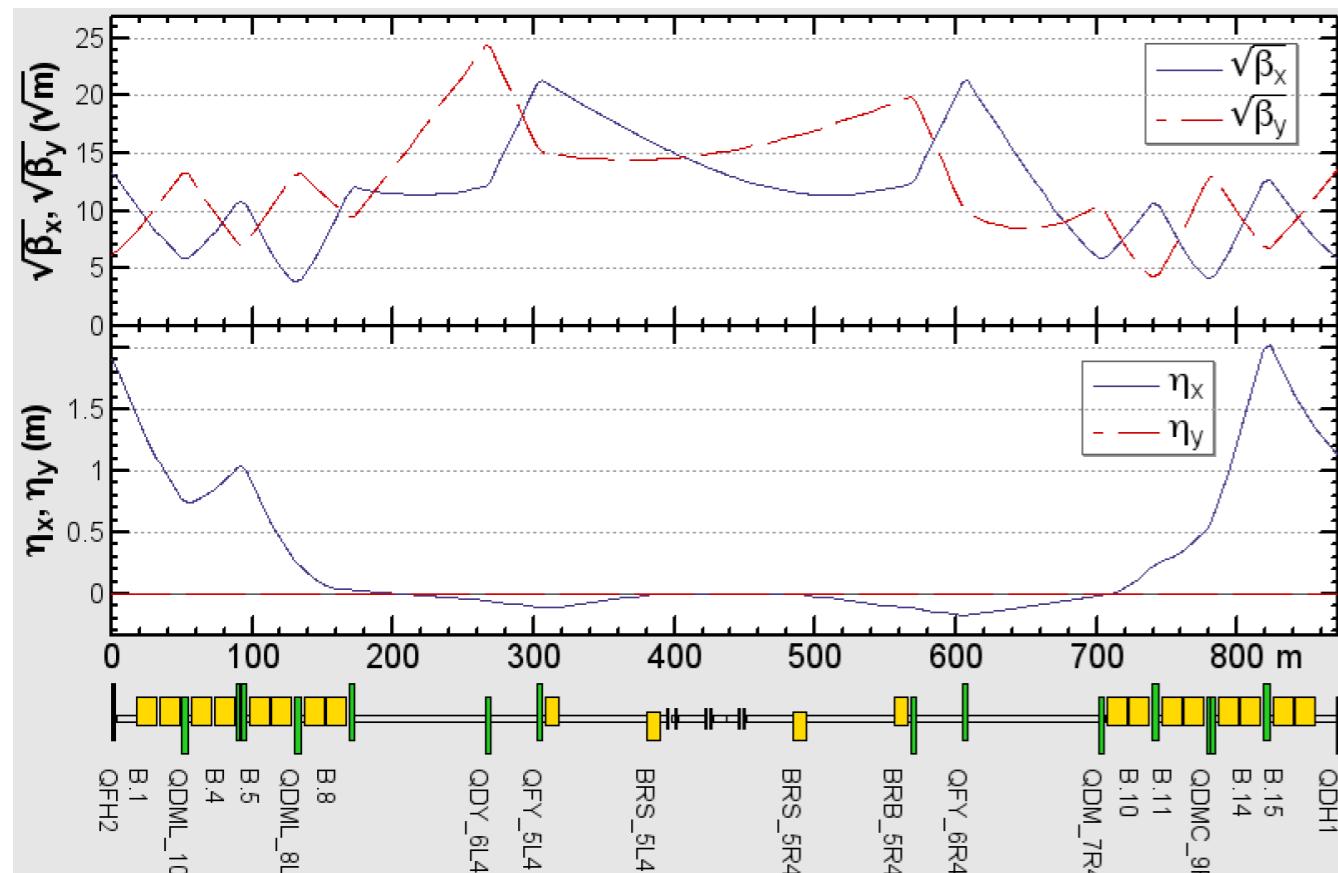


## 2. Tests of using 60deg arc cells

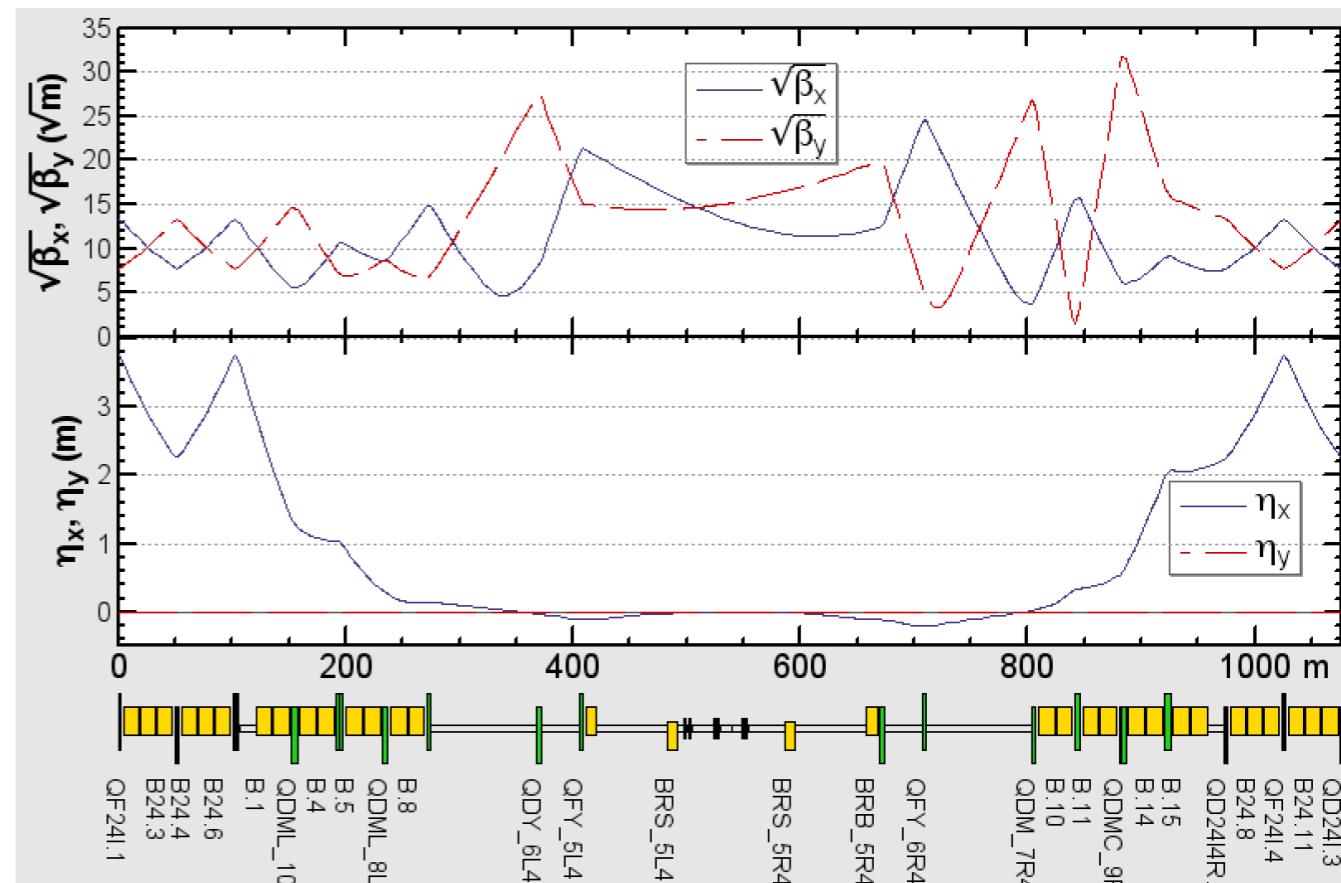
### ► Preliminary results (linear optics matching)

- IR4 (RF & BI)

HLLHCV1.0 (opt\_inj)



60deg-cell matched

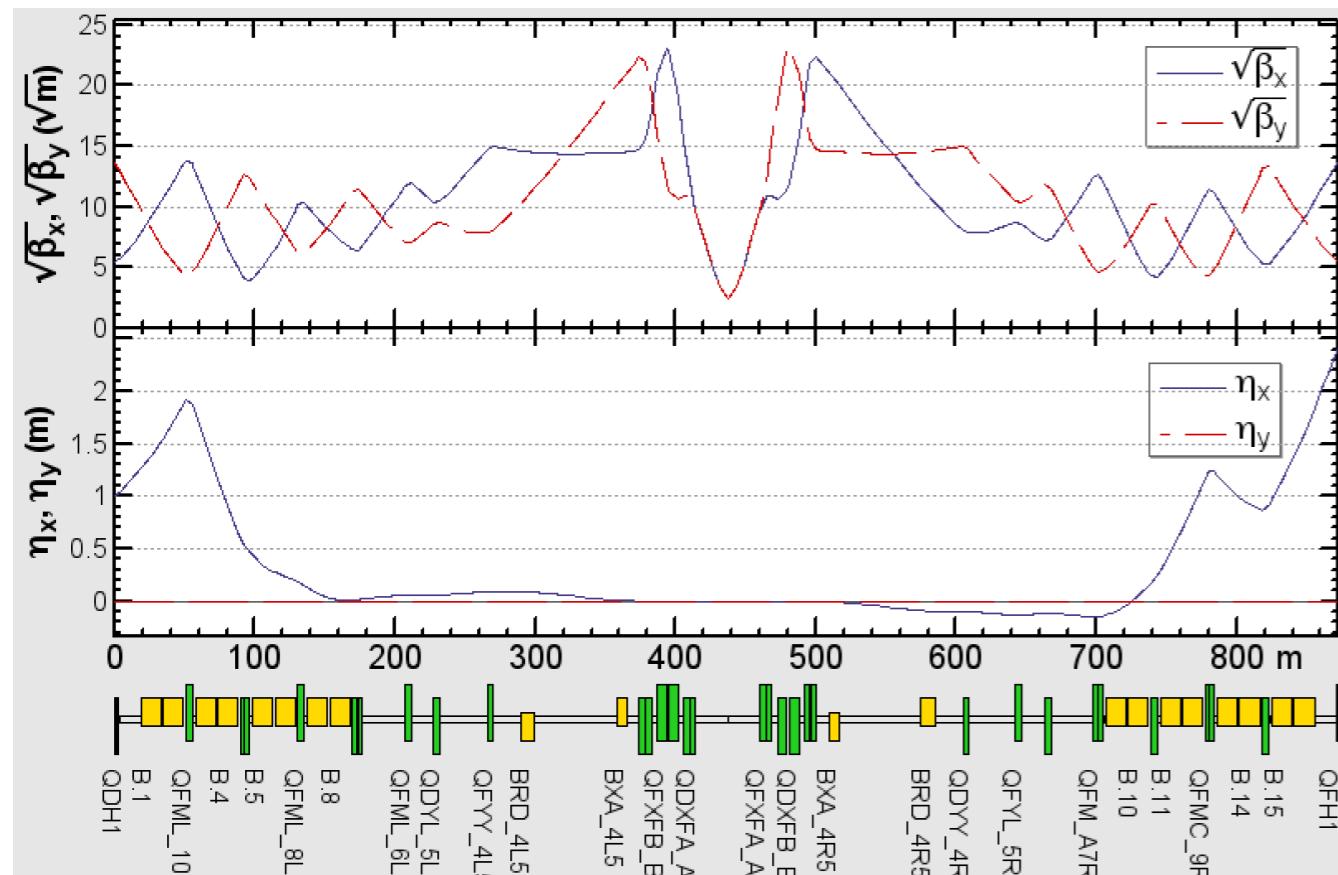


## 2. Tests of using 60deg arc cells

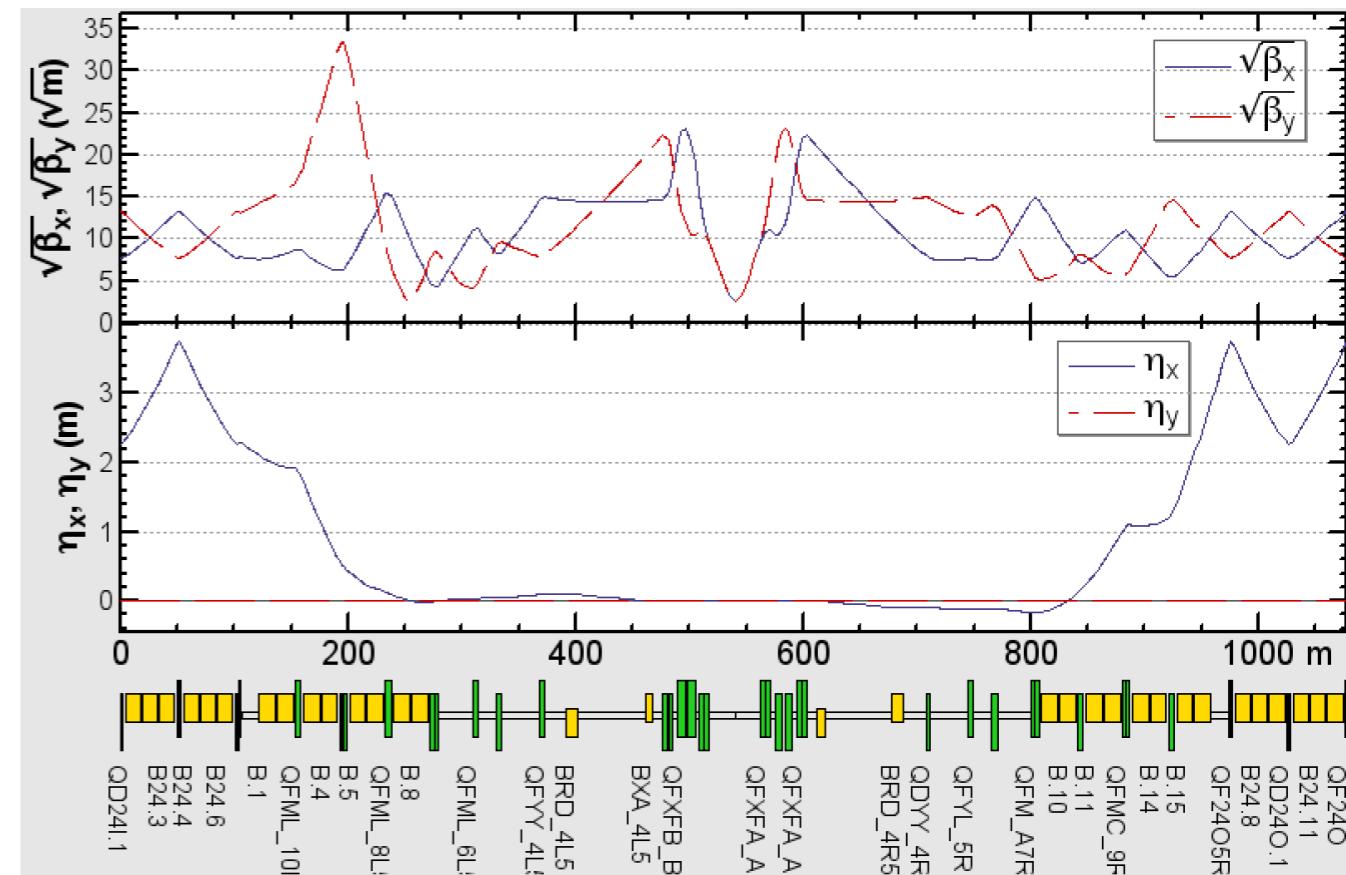
### ► Preliminary results (linear optics matching)

- IR5 (CMS)

HLLHCV1.0 (opt\_inj)



60deg-cell matched

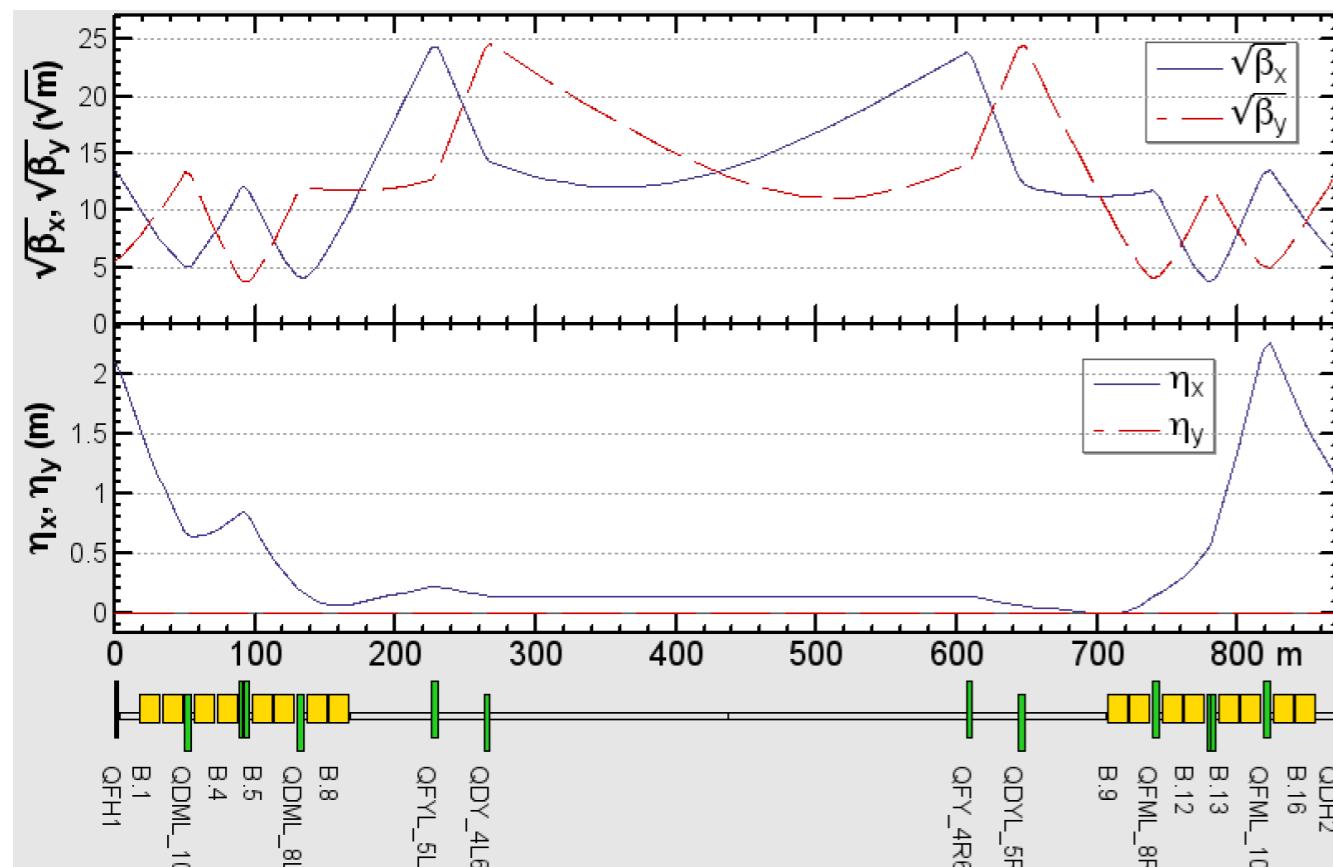


## 2. Tests of using 60deg arc cells

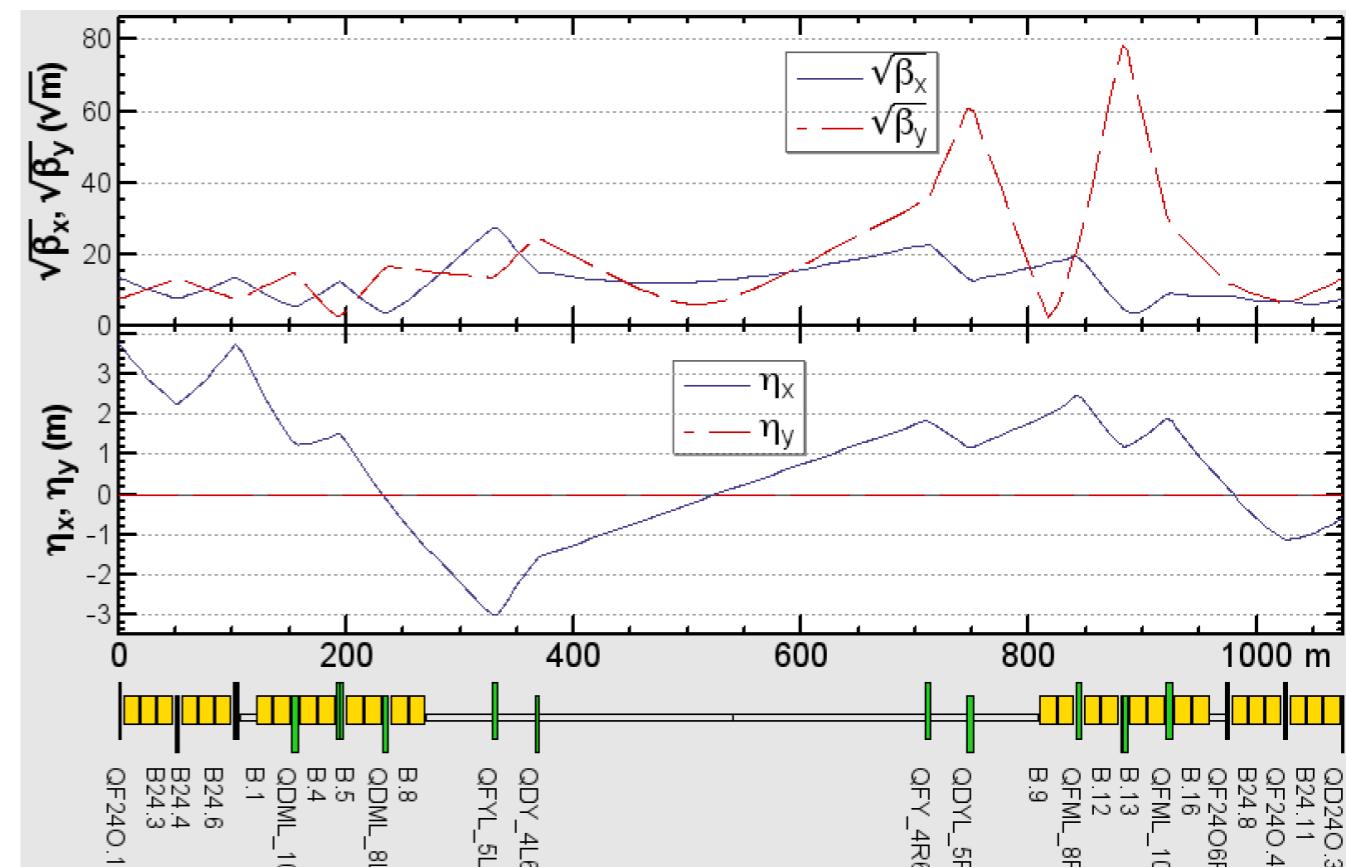
### ► Preliminary results (linear optics matching)

- IR6 (Beam dump)
- No successful (lack of variables)

HLLHCV1.0 (opt\_inj)



60deg-cell matched



### 3. Discussion and plans

#### ➤ Arcs (discussion with D.S.)

- Coil aperture:  $\phi=50\text{mm}$
- Dipole:  $B_{\max}=16\text{T}$  (correspond to  $E_{\max}=13.5\text{TeV}$ )
- Quadrupole:  $B^{(1)}_{\max}=400\text{T/m}$
- Sextupole:  $B^{(2)}_{\max}=7800\text{T/m}^2$
- Octupole:  $B^{(3)}_{\max}=240,000\text{T/m}^3$
- Arc separation = 204mm (to be finalized)

#### ➤ IRs

- Depend on beta\*, lum., etc. Independent from arcs
- To be addressed by L. Riesen-Haupt (this meeting)

#### ➤ Plans

- To finish matching with 60deg x24 arc cells
- To test 60deg x18 arc cells
- Work with Yuri on 60deg cells for HE-LHC

### 3. Discussion and plans

#### ➤ Plans (cont'd)

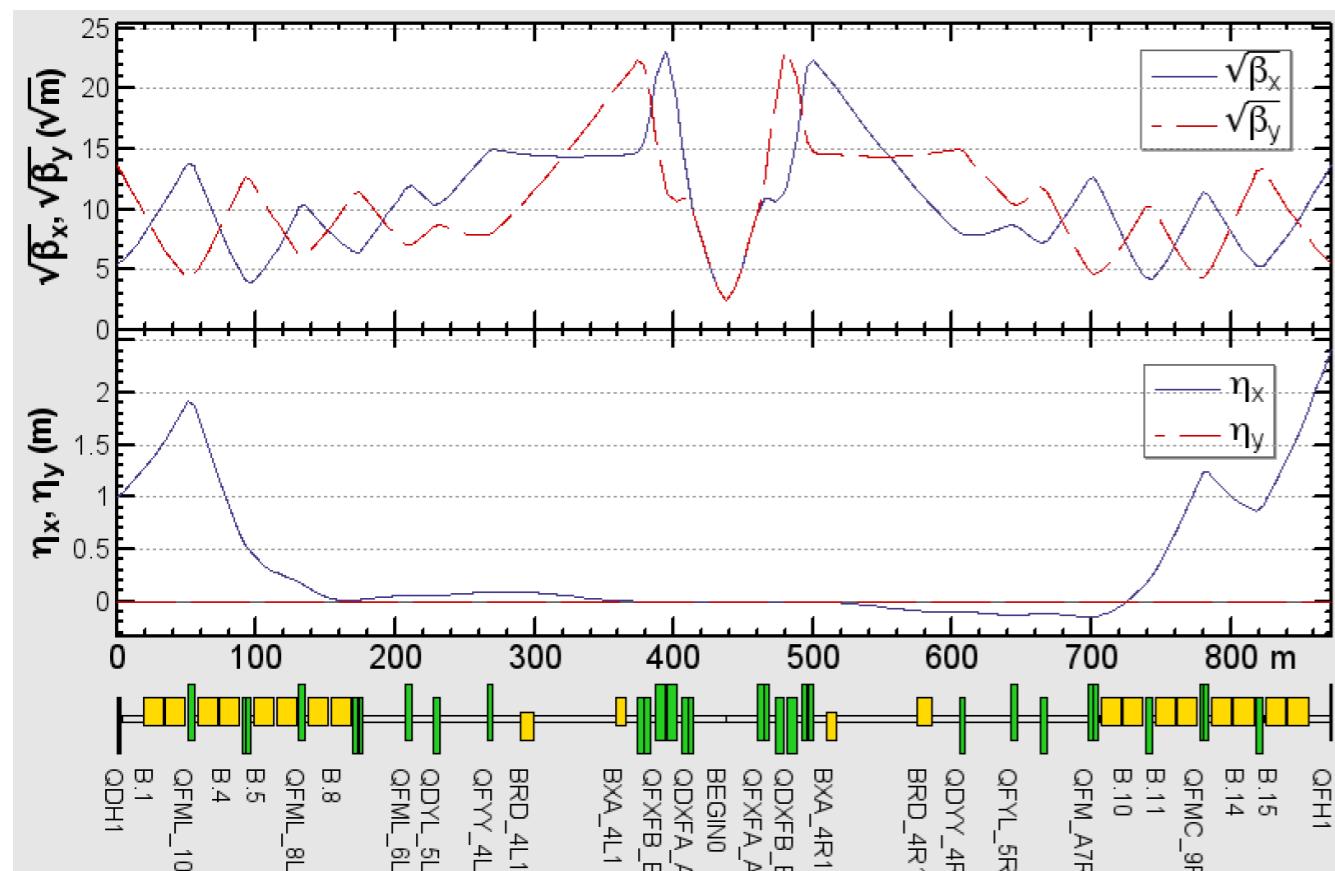
- Team-work with well-defined tasks
  - \* Directly scaling HL-LHC and outline practical challenges (D.Z., M.C., R.T., M.H., etc.)
  - \* Test 60deg arc cells and outline practical challenges (Y.N., D.Z., etc.)
  - \* MAD-X matching for HE-LHC
  - \* IR specifications (L.R., M.H., etc.)
  - \* Others?

## 2. Tests of using 60deg arc cells

### ► Preliminary results (linear optics matching)

- IR1 (ATALS)

HLLHCV1.0 (opt\_inj)

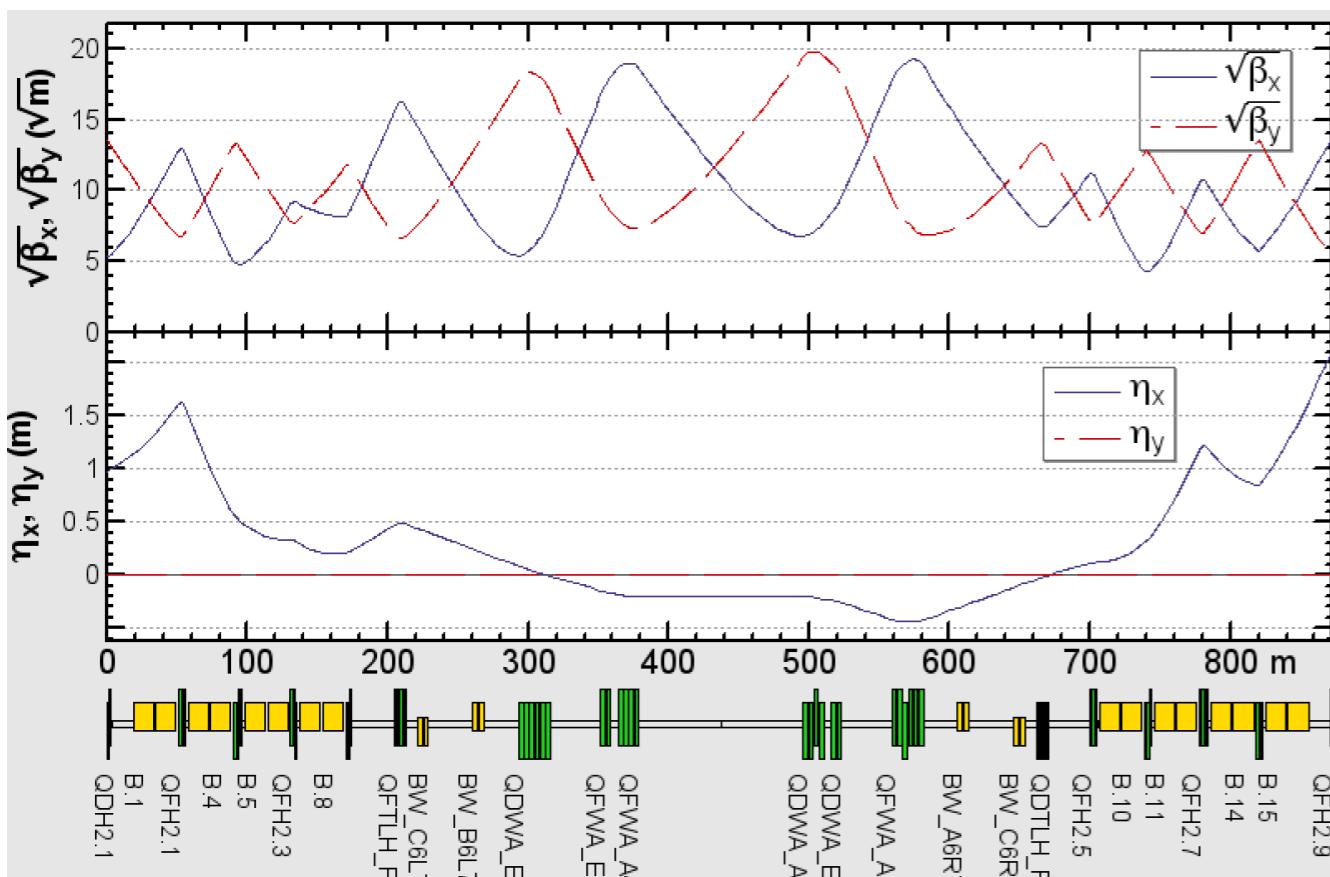


## 2. Tests of using 60deg arc cells

### ► Preliminary results (linear optics matching)

- IR7 (Betatron collimation)

HLLHCV1.0 (opt\_inj)



## 2. Tests of using 60deg arc cells

- Preliminary results (linear optics matching)
  - IR8 (LHC-B & injection b2)

HLLHCV1.0 (opt\_inj)

