CERN

Update on LHC arc heat load studies

Galina Skripka, Giovanni Iadarola and Eric Wulff

Many thanks to: Benjamin Bradu, Riccardo De Maria, Philipp Dijkstal, Lotta Mether, Annalisa Romano, Giovanni Rumolo and all the machine operators

Outline

- Recap previous reports
- Cell-by-cell heat loads
- Summary: Where are we?

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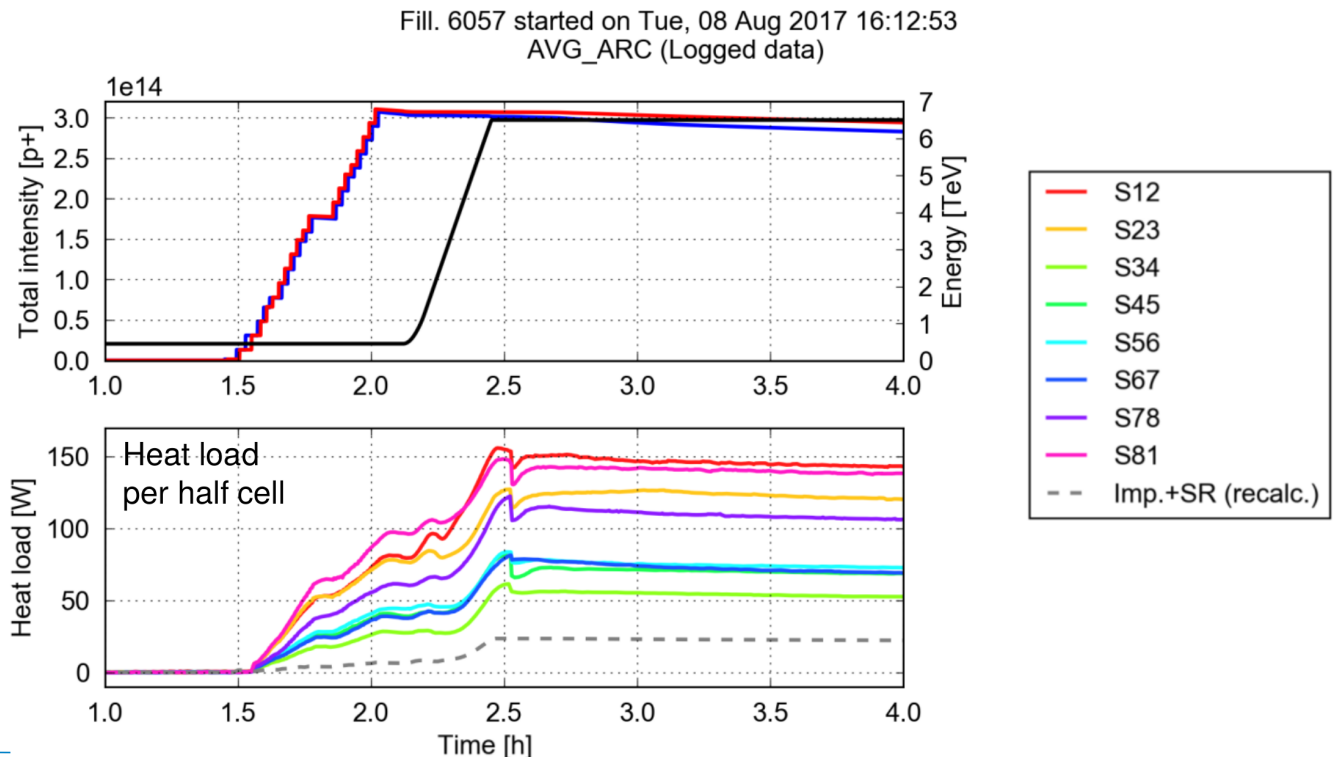
LHC heat loads

Heat loads in LHC: sectors

In Run 2 we observed **spread in heat loads**:

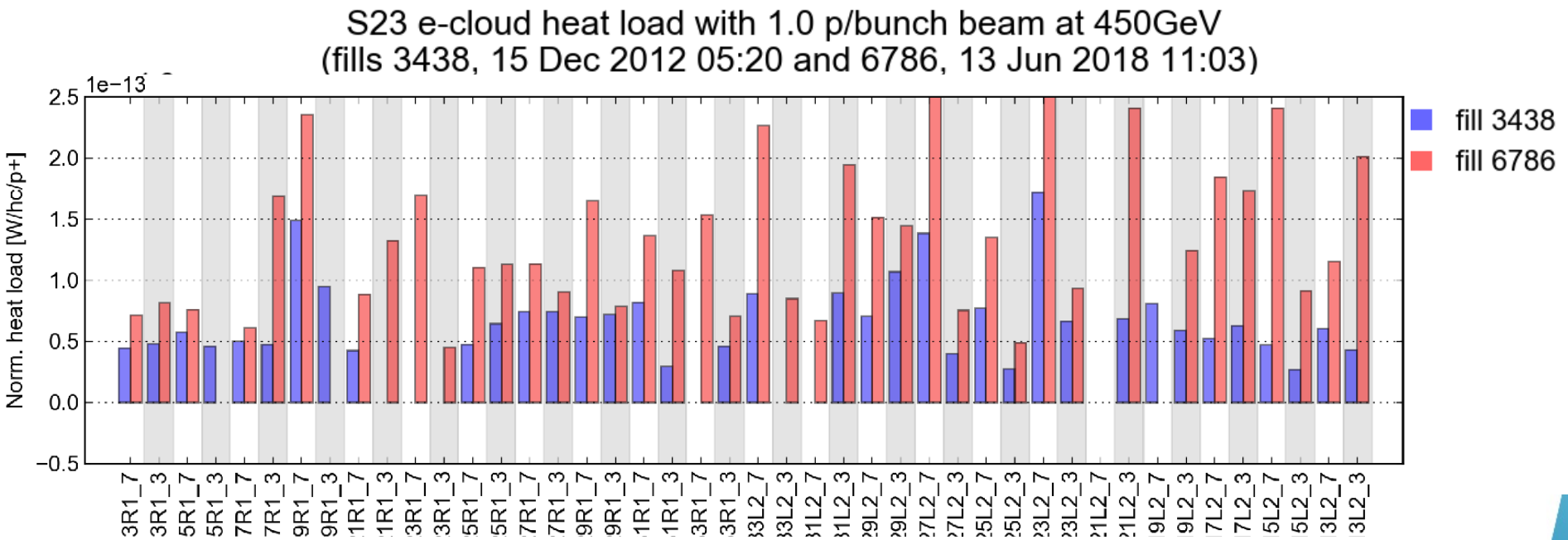
- among **sectors**



Heat loads in LHC: cells

In Run 2 we observed **spread in heat loads**:

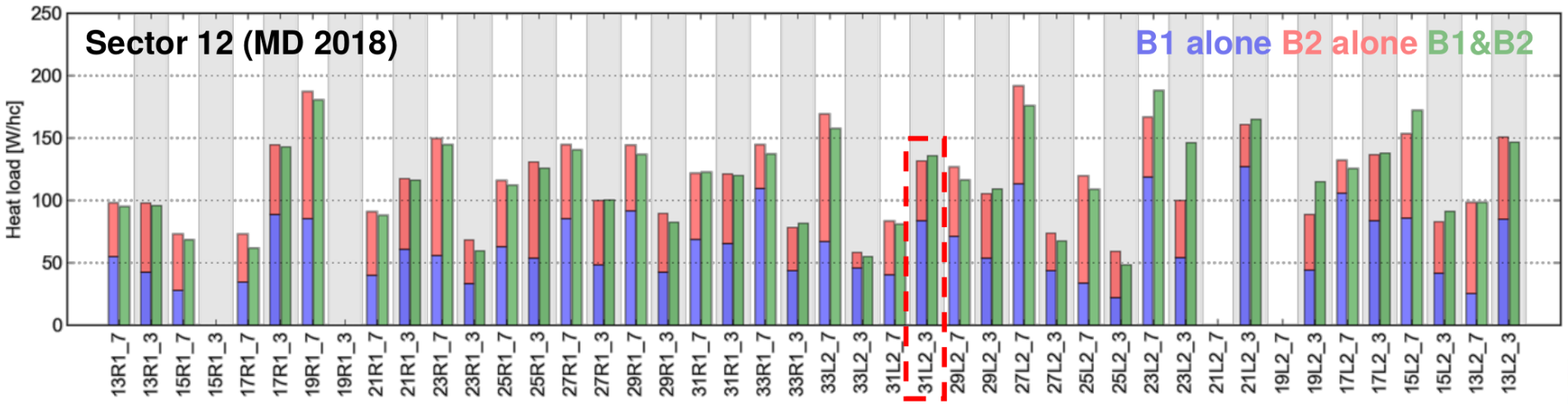
- among **sectors**
- among **cell**



Heat loads in LHC: beam screens

In Run 2 we observed **spread in heat loads**:

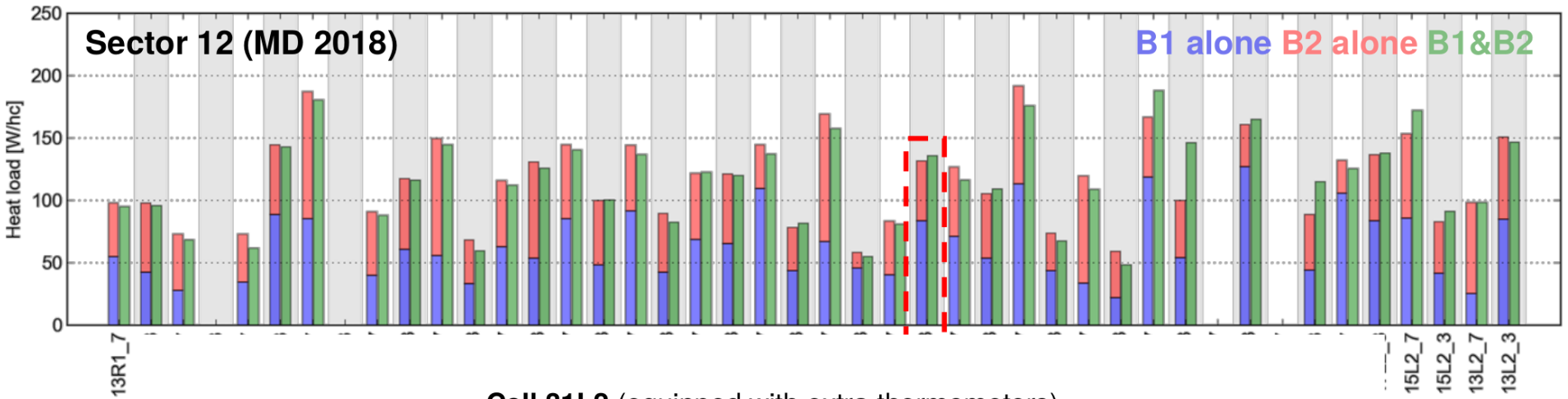
- among **sectors**
- among **cell**
- among **beam screens in same magnets**



Heat loads in LHC: magnets

In Run 2 we observed **spread in heat loads**:

- among **sectors**
- among **cell**
- among **beam screens in same magnets**
- among **magnets**



Cell 31L2 (equipped with extra thermometers)

At 450 GeV:	25 W	20 W	50 W	3 W
	Q	Dipole	Dipole	Dipole
At 6.5 TeV:	5 W	30 W	70 W	8 W

Heat loads in LHC: why different?

In Run 2 we observed **spread in heat loads**:

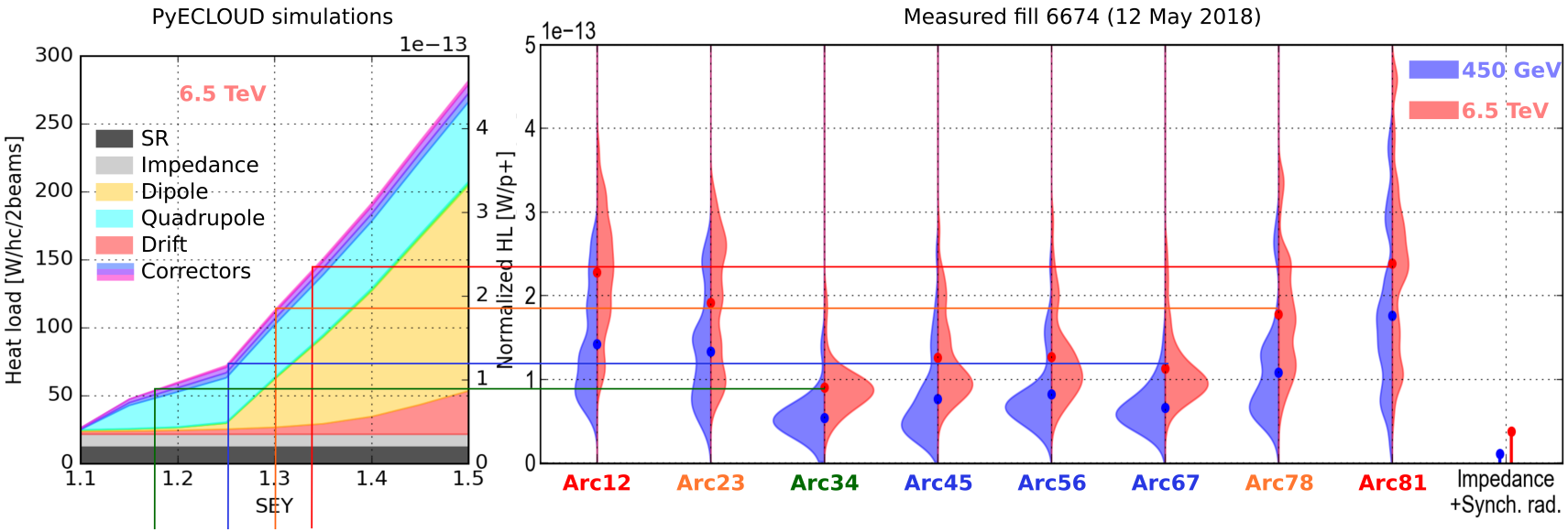
- among **sectors**
- among **cell**
- among **beam screens in same magnets**
- among **magnets**

Hypothesis:

the differences in HL are caused by different SEY

SEY models

- Using simulations we can estimate SEY from measured heat loads



Arcs **Cells** **Magnets** **BS**

SEY models

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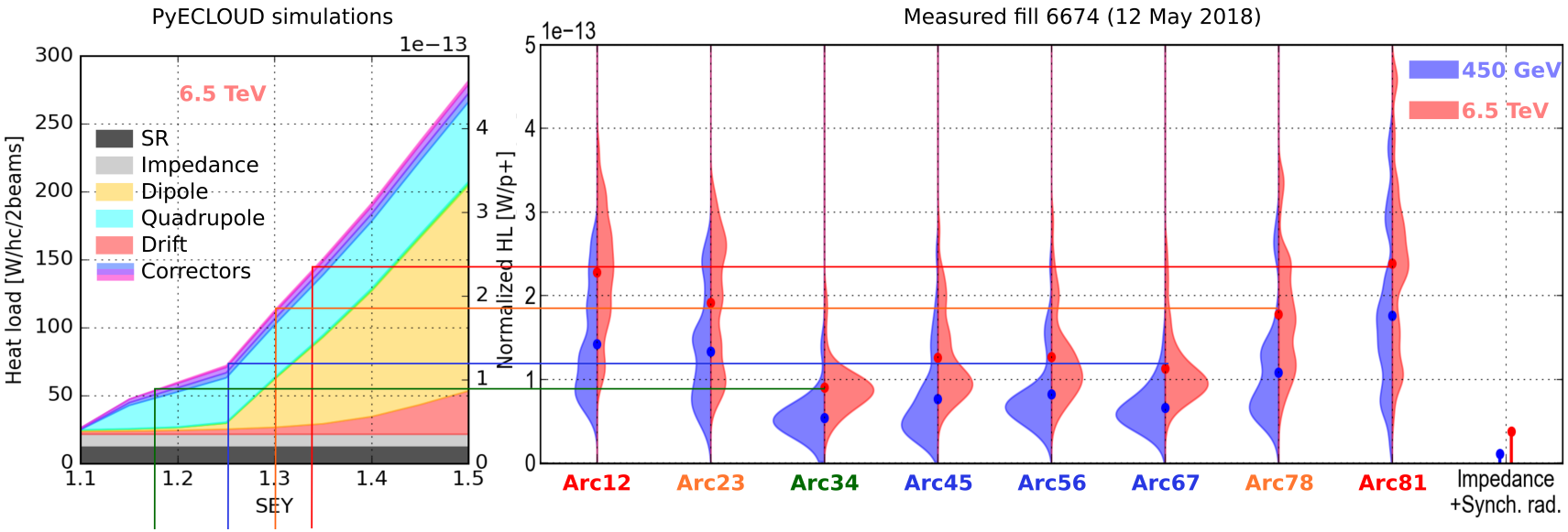


Arcs	Cells	Magnets	BS
✓	?	✓	✗

(for arcs and individual magnets see Electron Cloud Meeting #62)

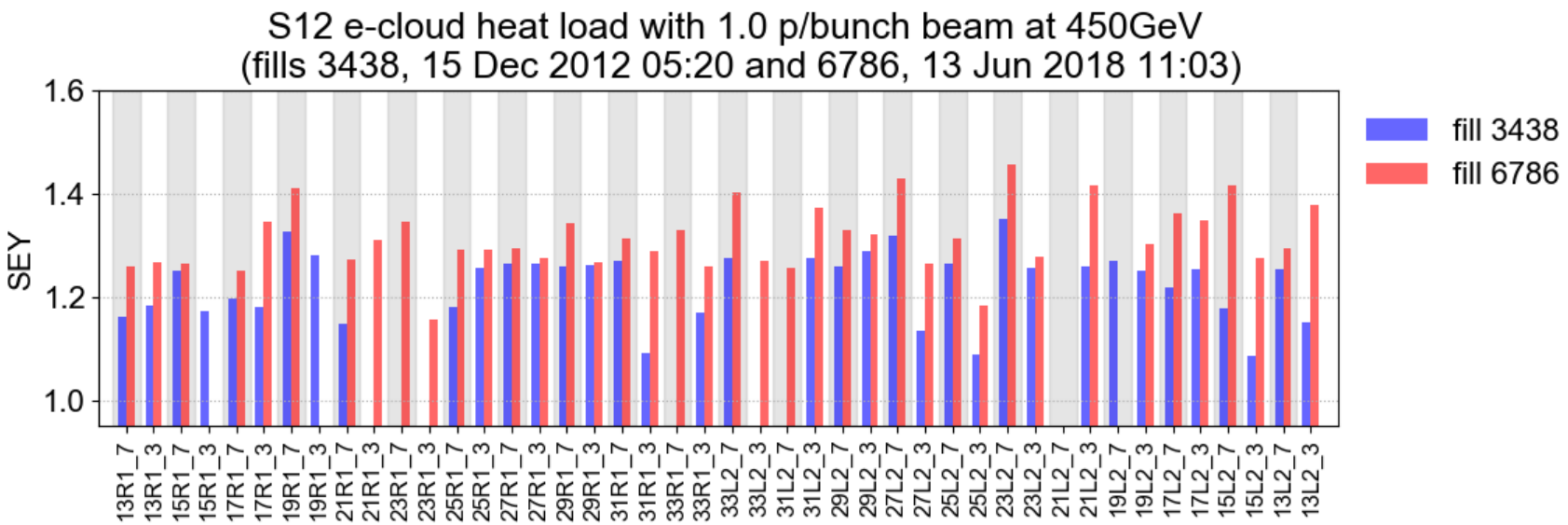
Outline

- Recap previous reports
- Cell-by-cell heat loads
- Summary: Where are we?

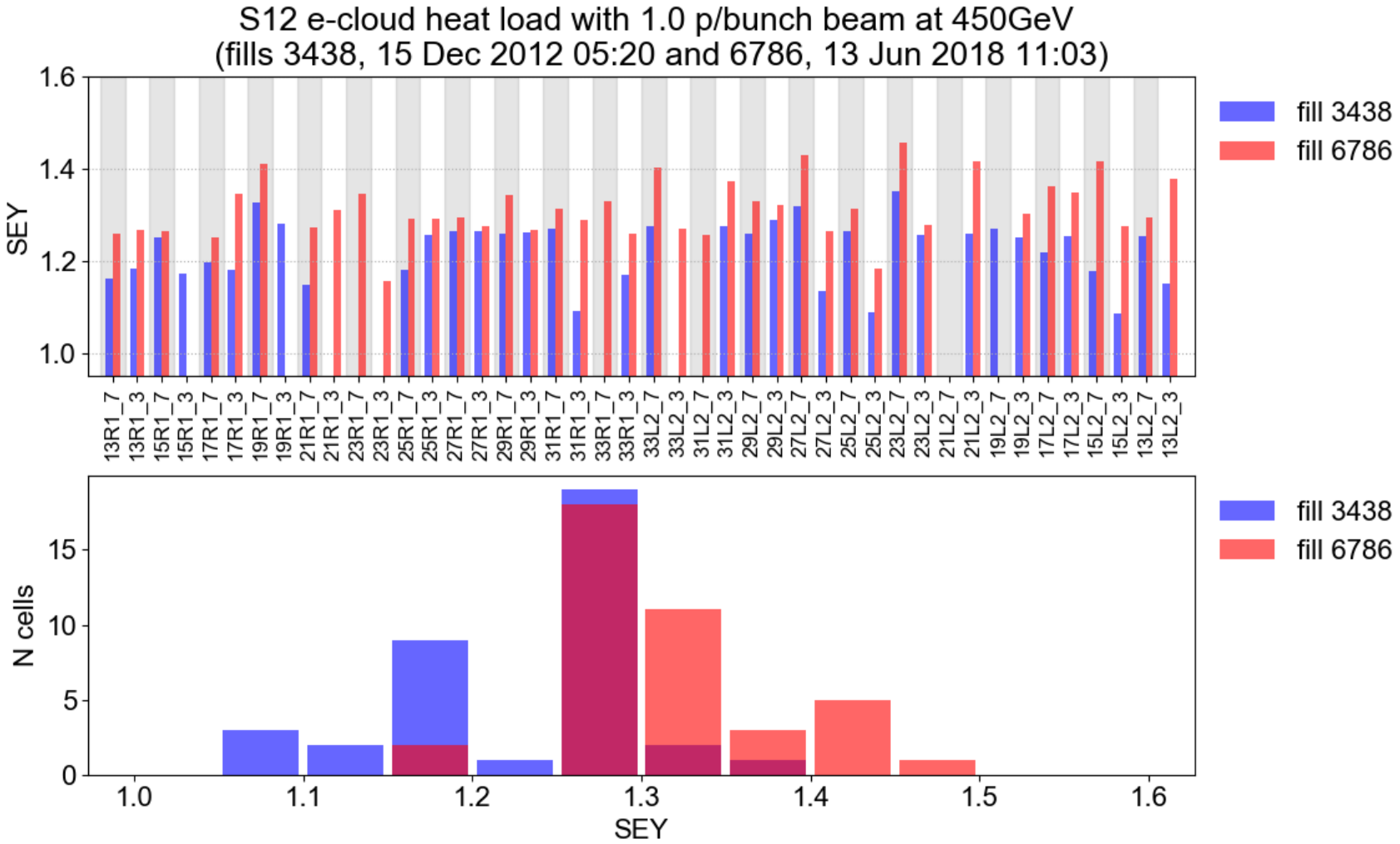
Cell-by-cell: finding SEY values

Hypothesis: the differences among cells are caused by different SEY

- Find modeled SEY corresponding to the measured heat loads in each cell
  - assuming uniform SEY along the cell



Cell-by-cell: 2012 vs 2017



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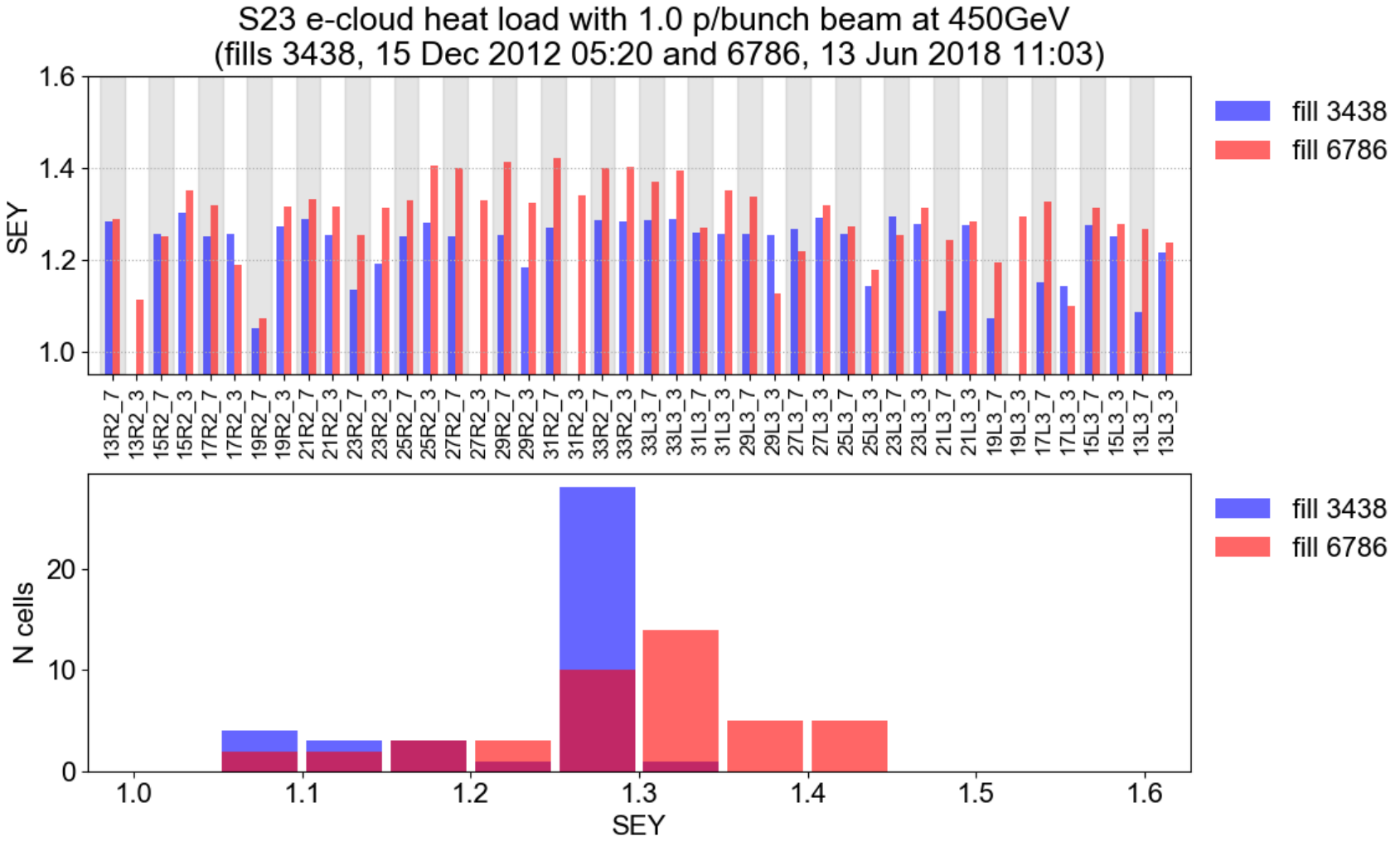

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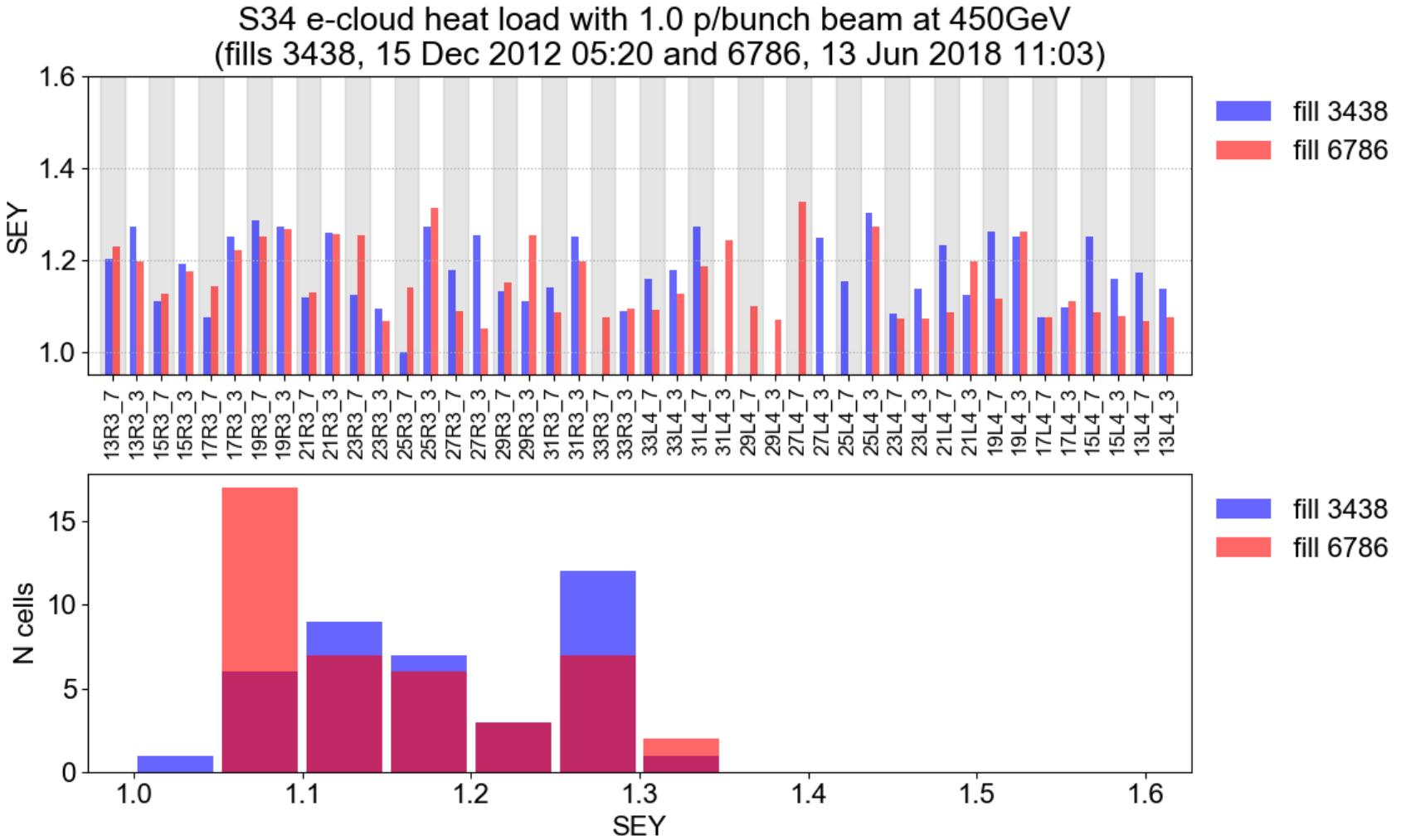

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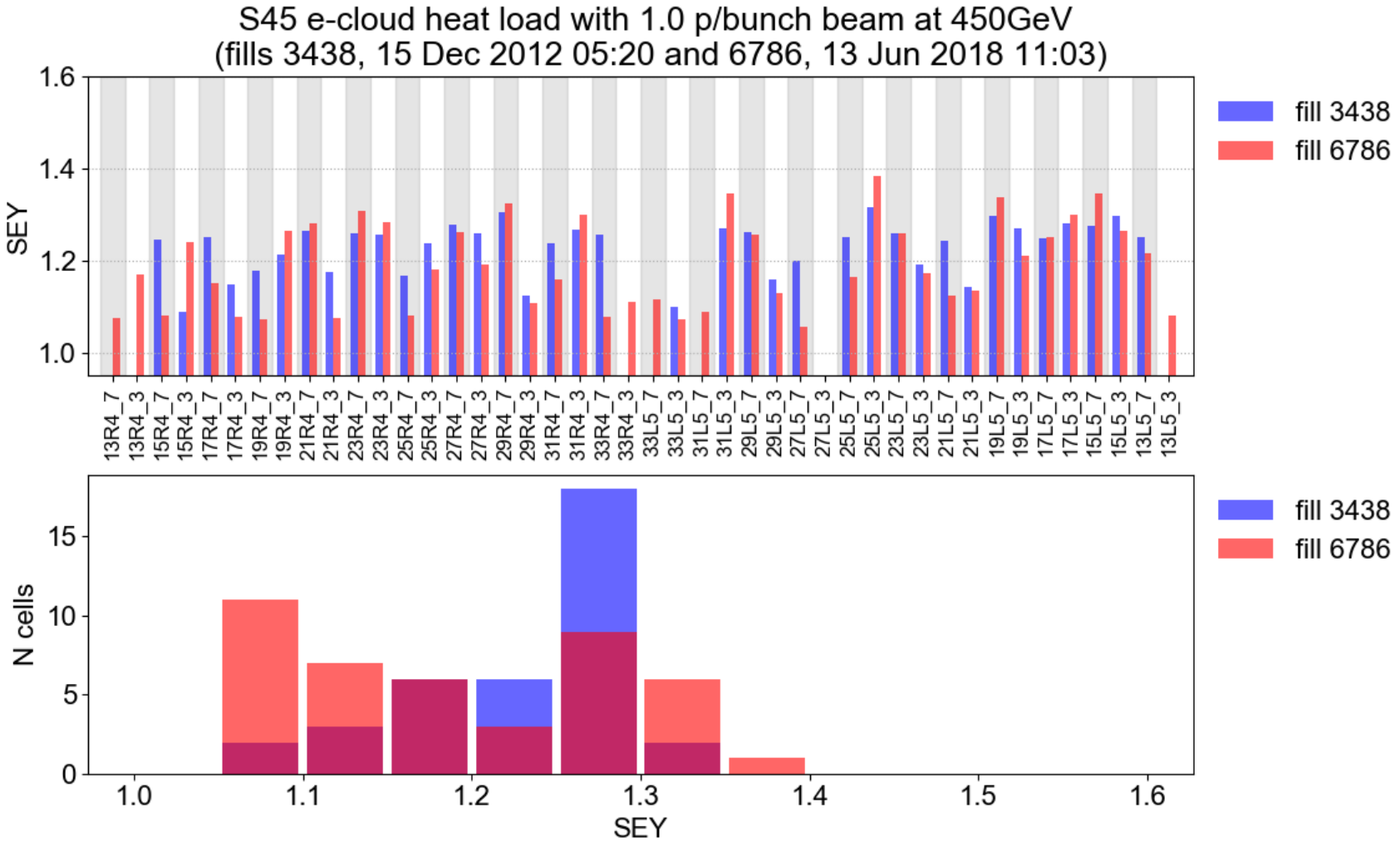

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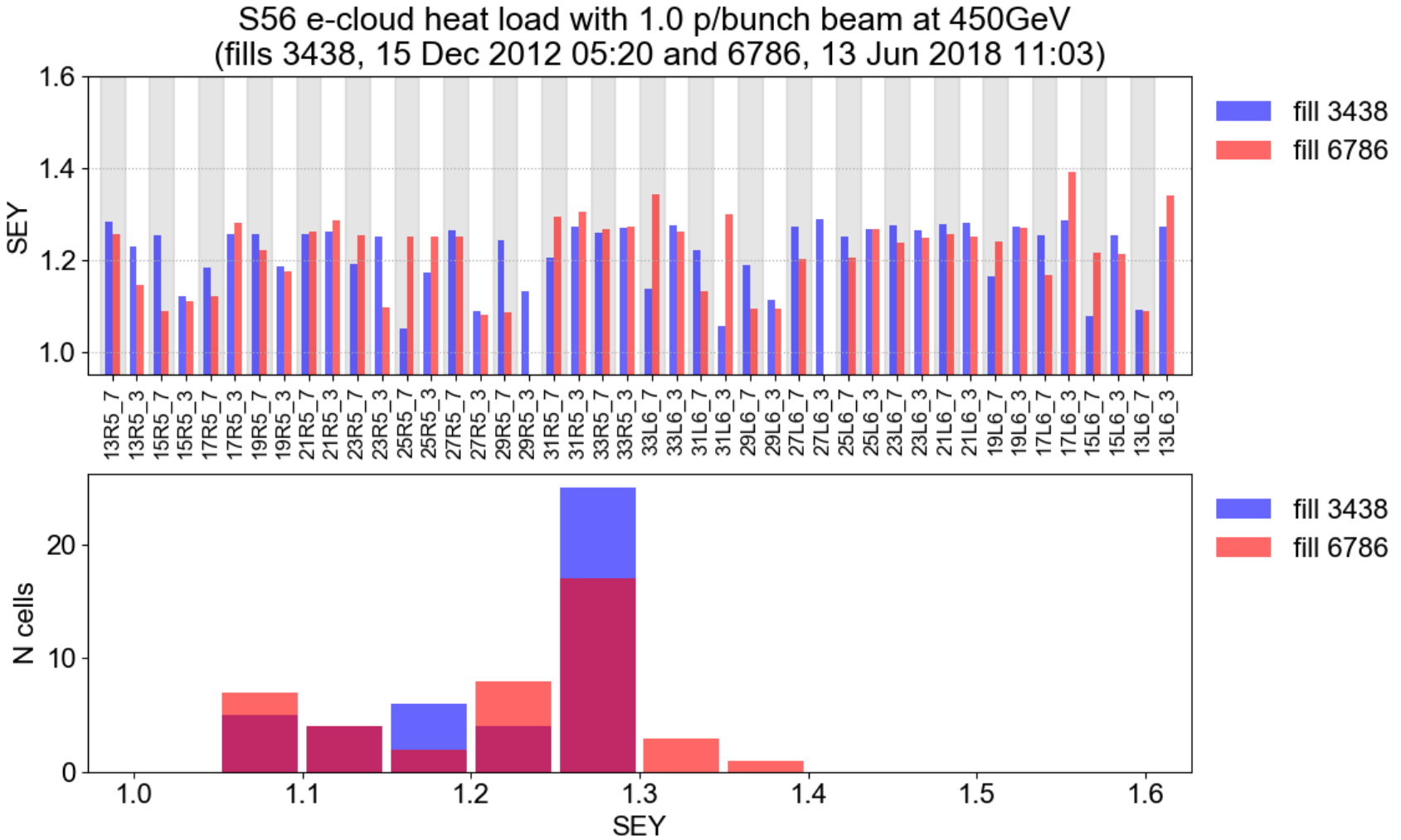

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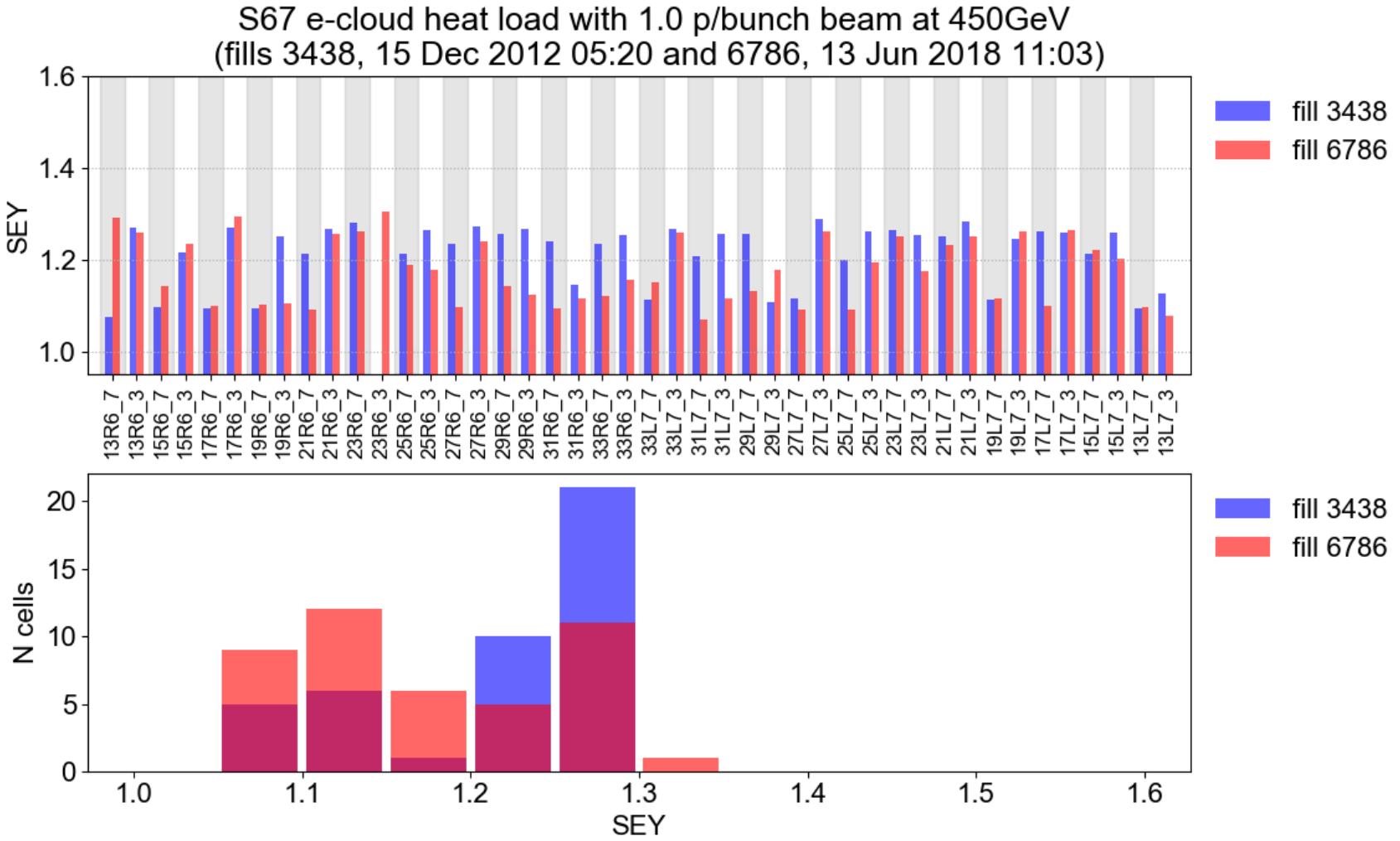

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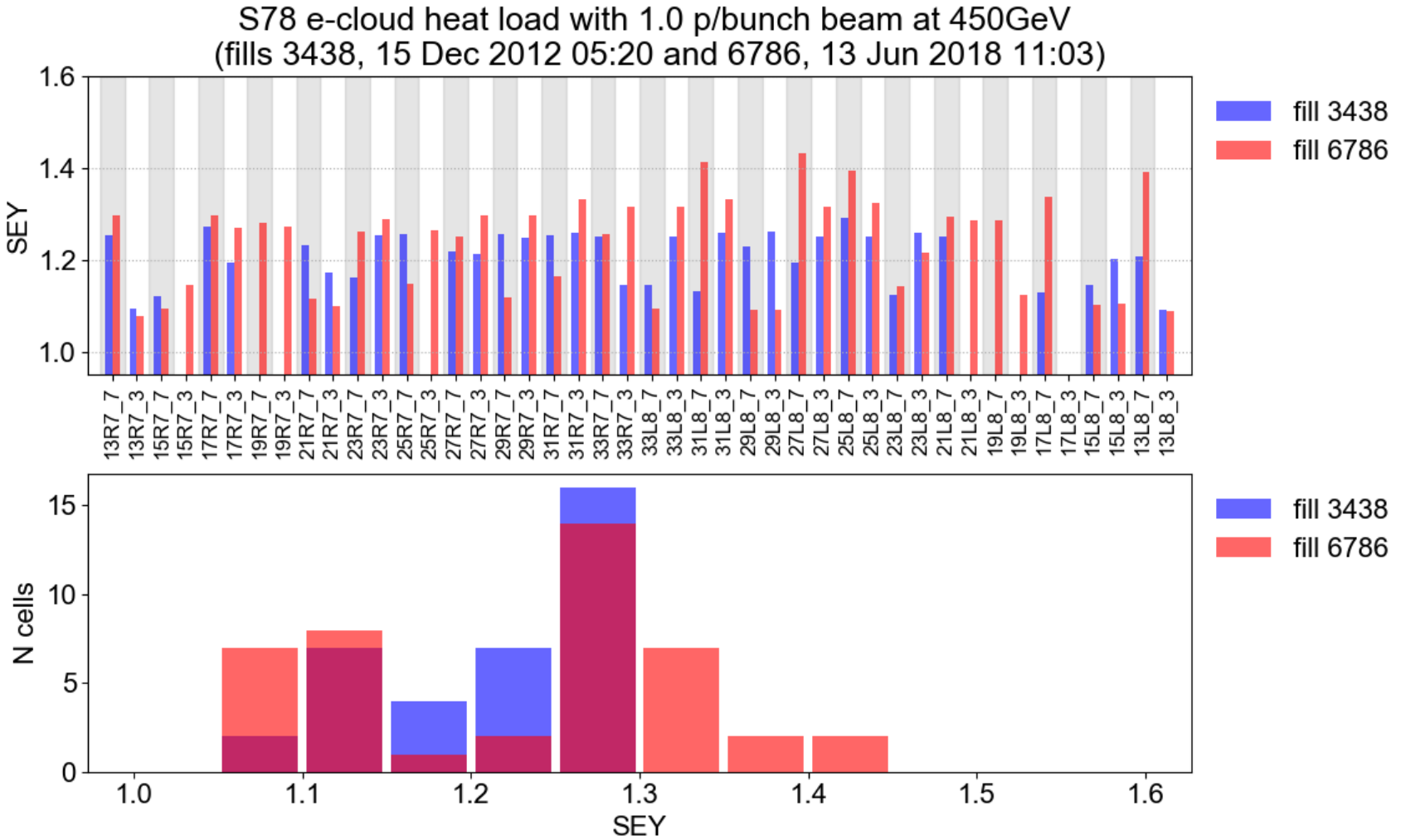

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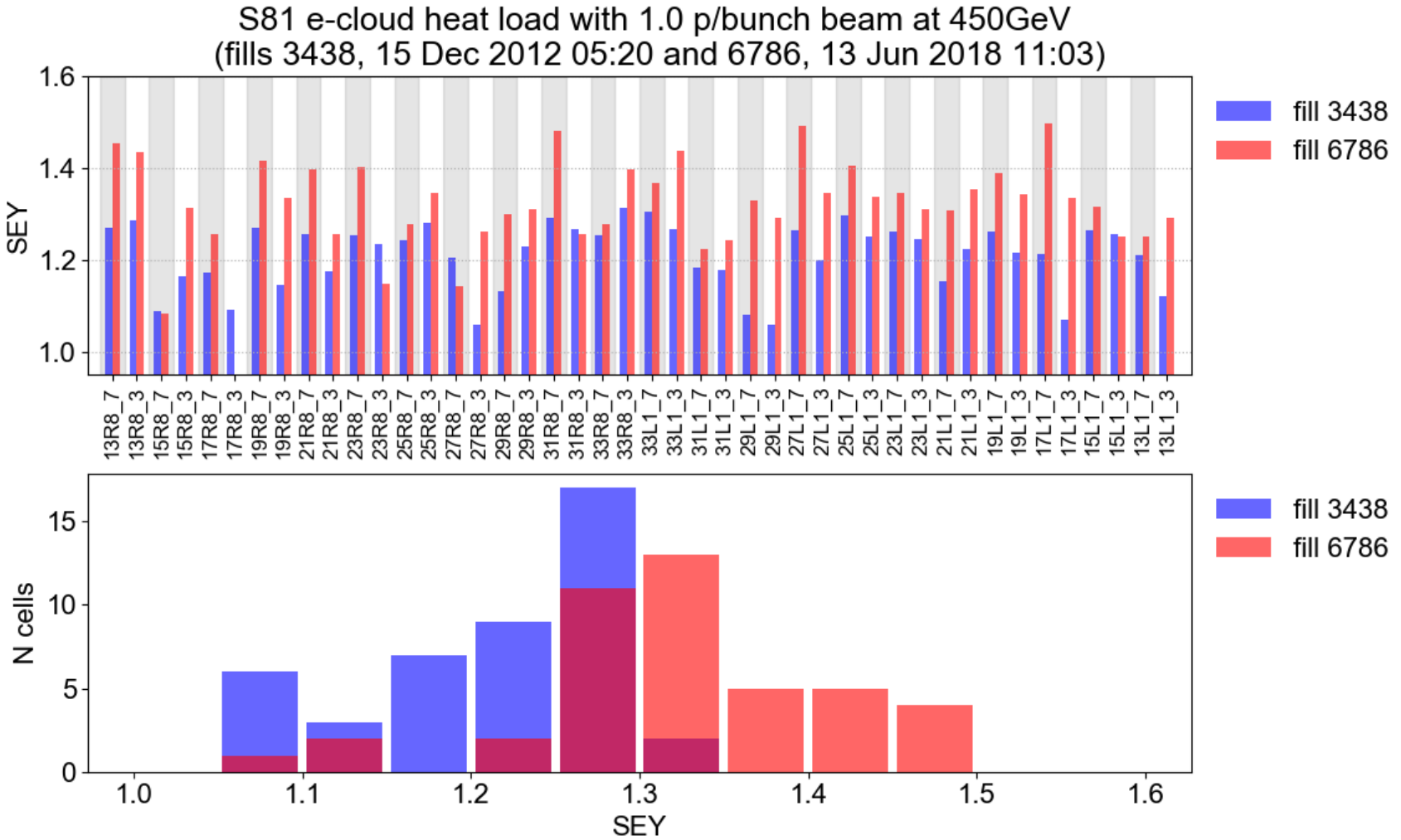

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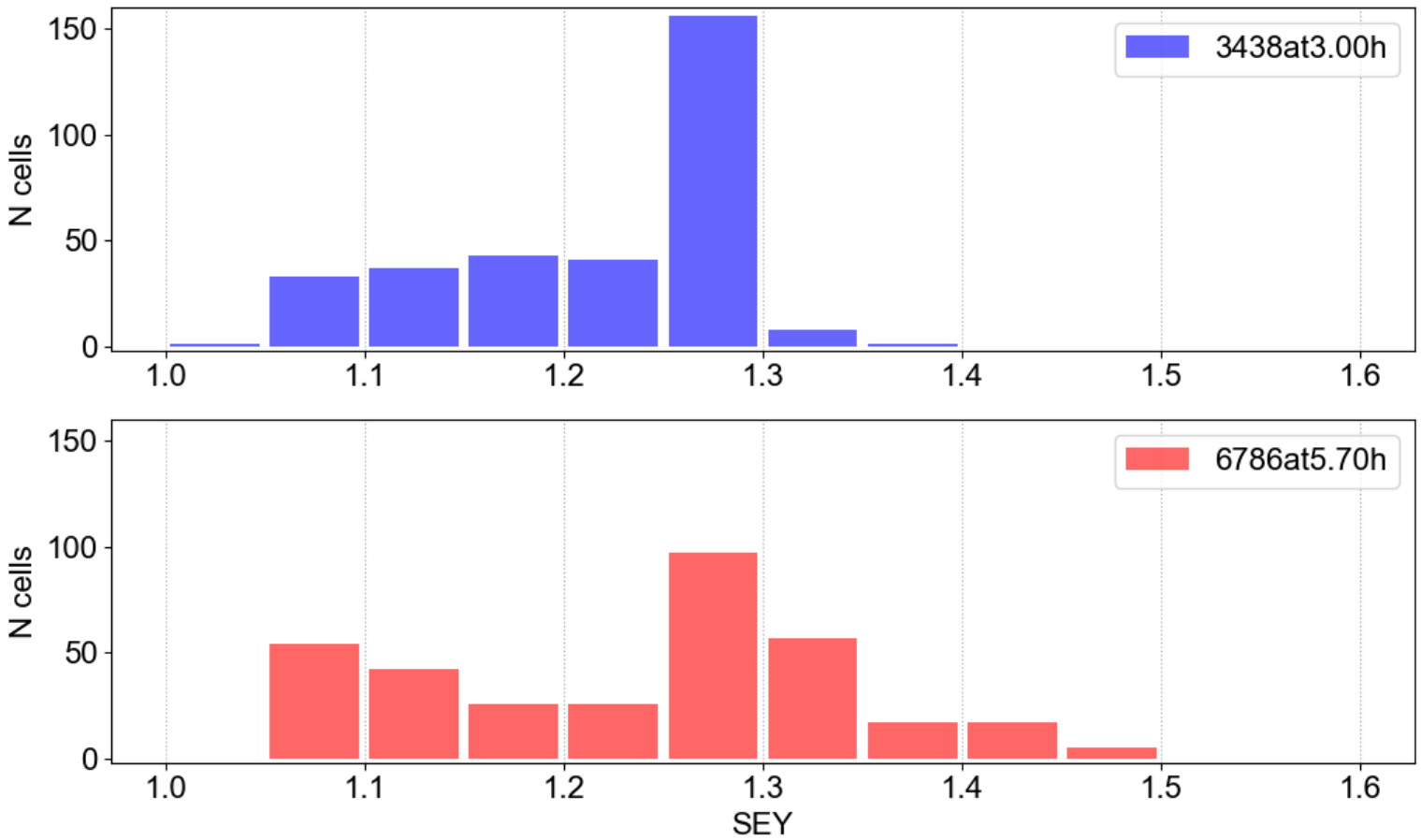


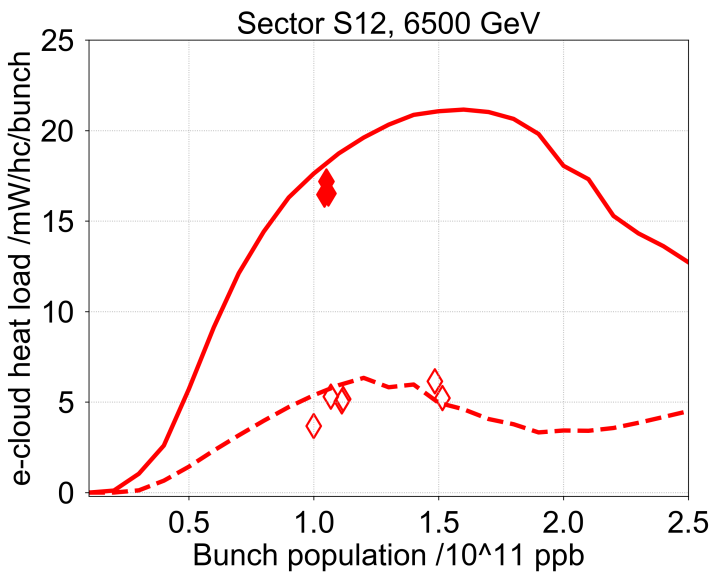
In 2017

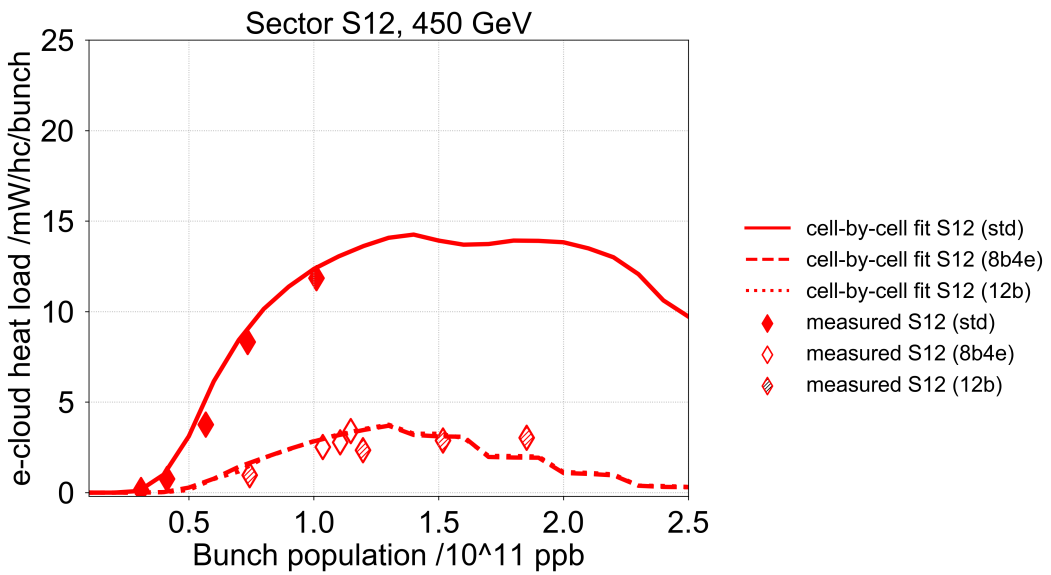
- still most of the ring is at 1.2-1.25 SEY
- Run 2 tail expands up to SEY 1.5-1.55

S12 HL intensity dependence (high HL)

Average over the fitted SEY cell-by-cell to compare with experiment at other filling schemes and energies

- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities





S12 HL contributions

Average over the fitted SEY cell-by-cell to compare with experiment at other filling schemes and energies

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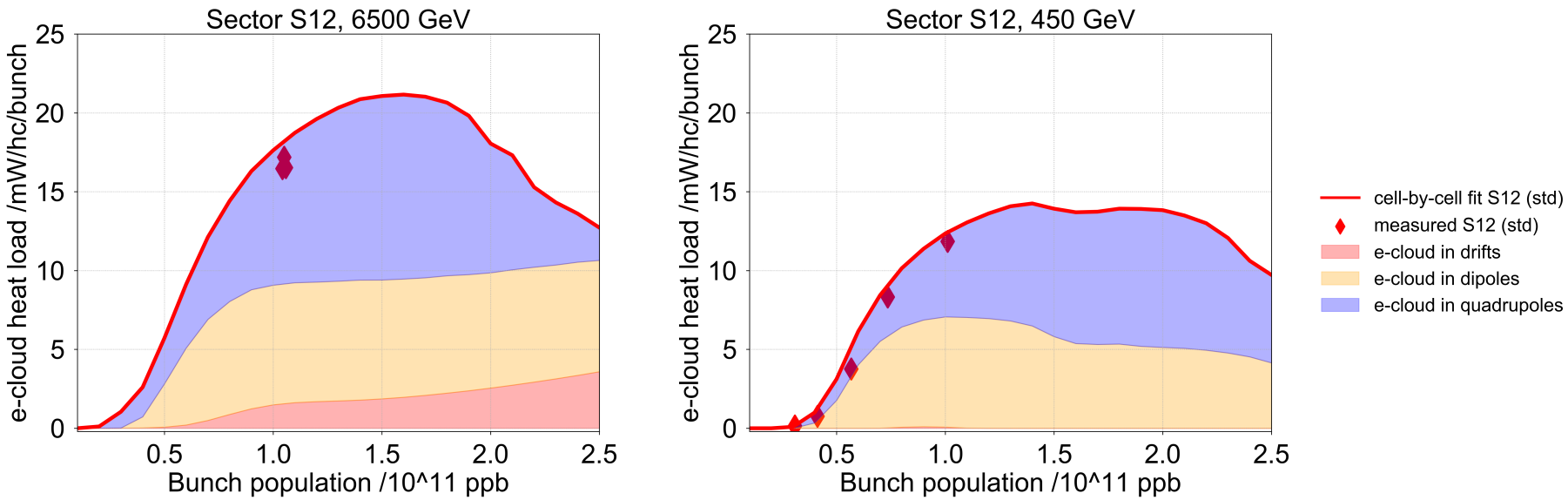
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch



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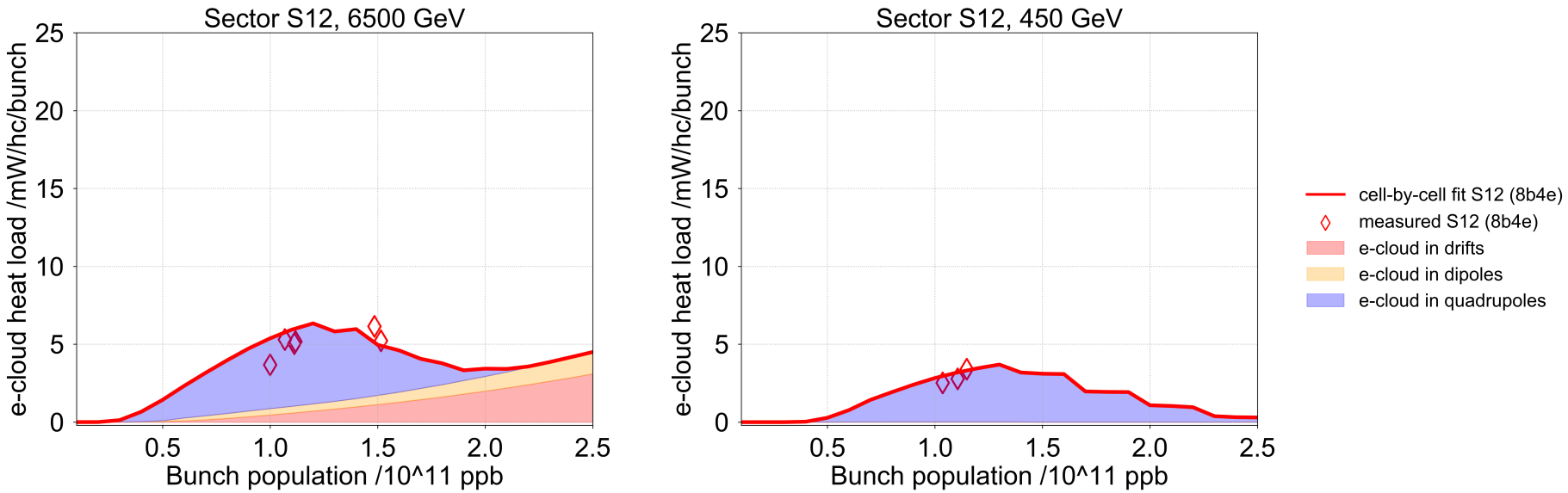
- Quadrupoles are main contributors with *8b4e* beam int $< 2.0 \times 10^{11}$



S67 HL intensity dependence (low HL)

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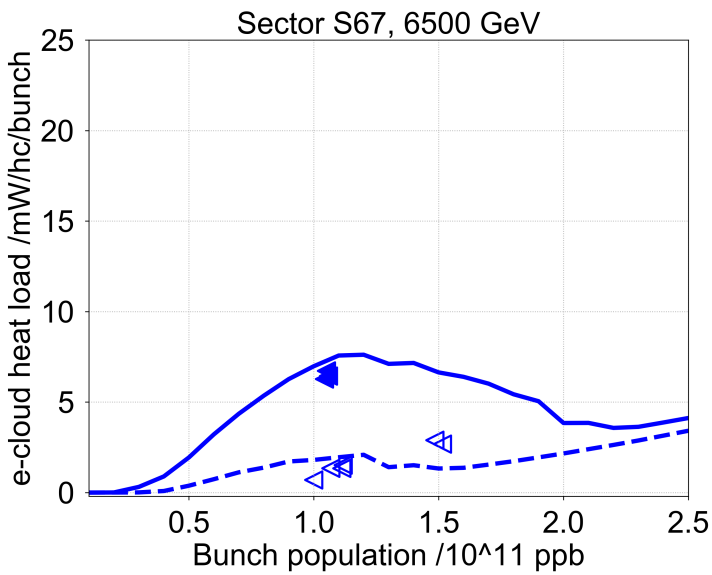

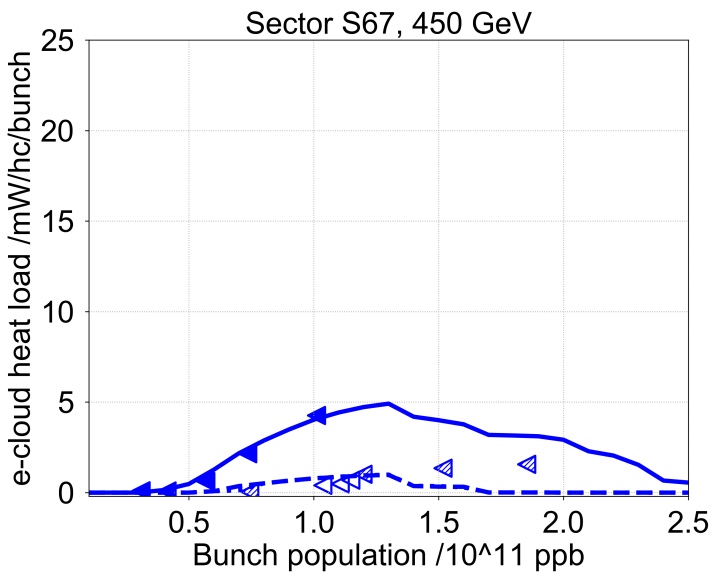

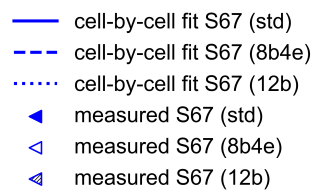

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Average over the fitted SEY cell-by-cell to compare with experiment at other filling schemes and energies

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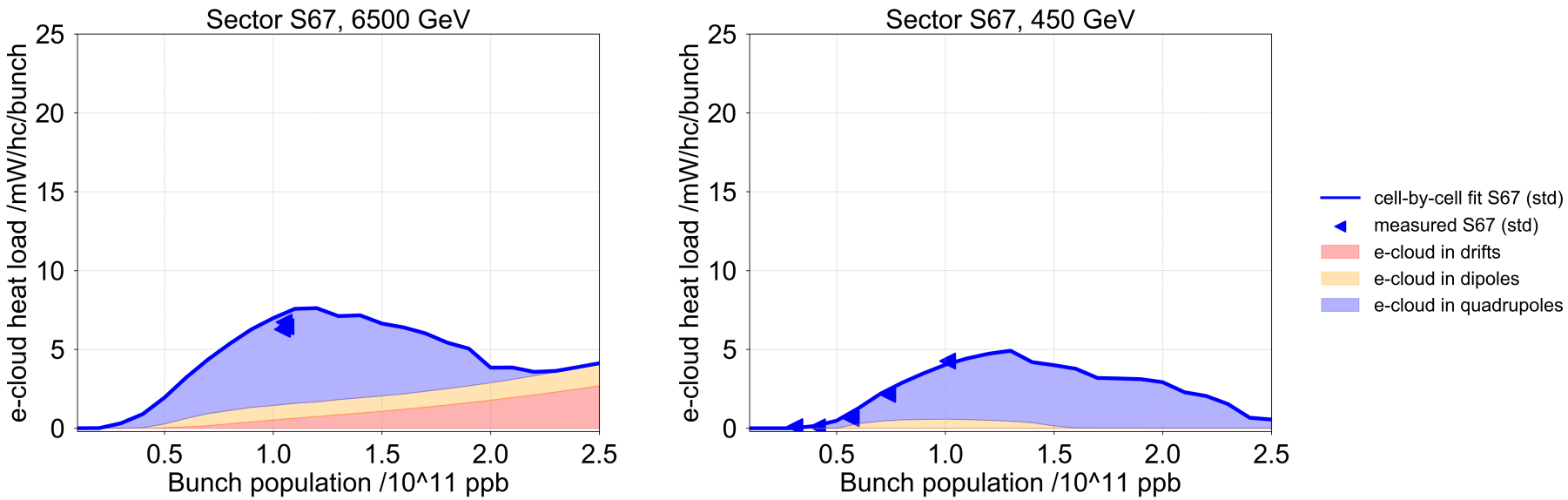

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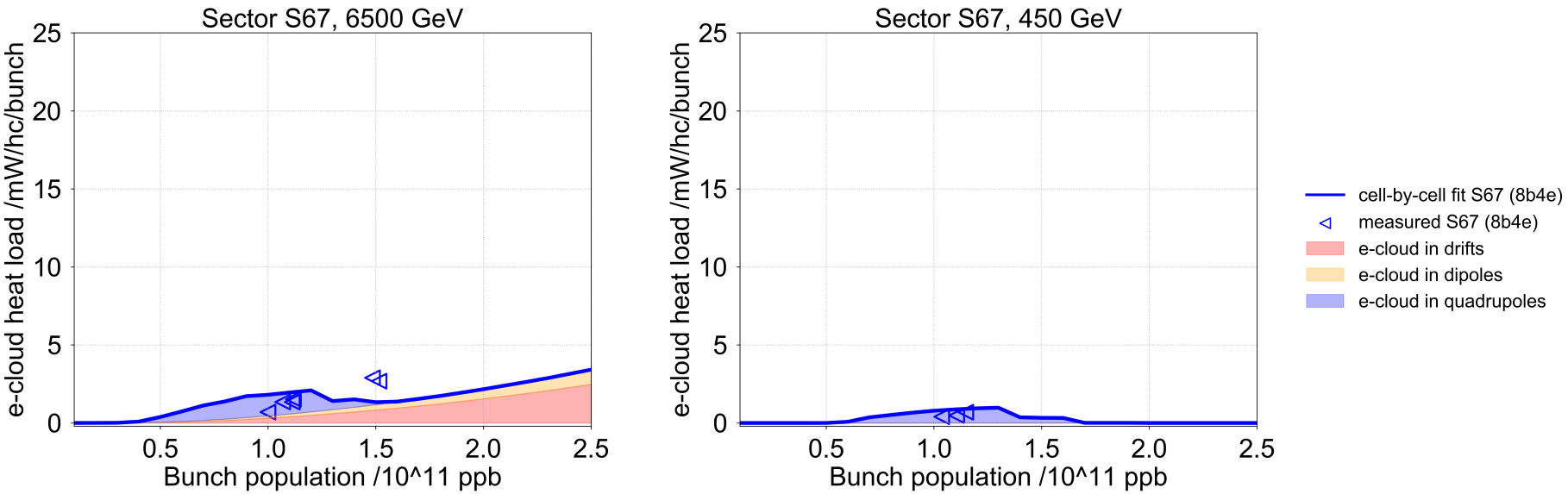

Cell-by-cell fit results

Assuming uniform SEY along the cell first fit attempts show:

- the fitted SEY values reach 1.55-1.6 in some cells
- on the arc level improve agreement at low load sectors compared to average arc SEY fit
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for the bump in HL dependence on intensity

Outline

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Summary: where are we?

Observed differences in heat loads in LHC sectors were analyzed

- first SEY models describing the observations are available

ARCS	CELLS	Magnets (31L2)	Beam Screens
✓	✓	✓	✗

- SEY fitting on cell-by-cell level assuming **unifrom SEY within the cell** instead of uniform over the whole sector
  - **better represents** the intensity scan **data** with all tested filling schemes and energies
  - shows that quadrupoles are responsible for the heat load peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch

Planned:

- look more into cell-by-cell
- look into individual beam screens cell-by-cell

Latest MD2018 with high intensity 8b4e beams proved them to be a good back-up filling scheme for higher intensity!

Thank you

EXTRA

S12 HL intensity dependence

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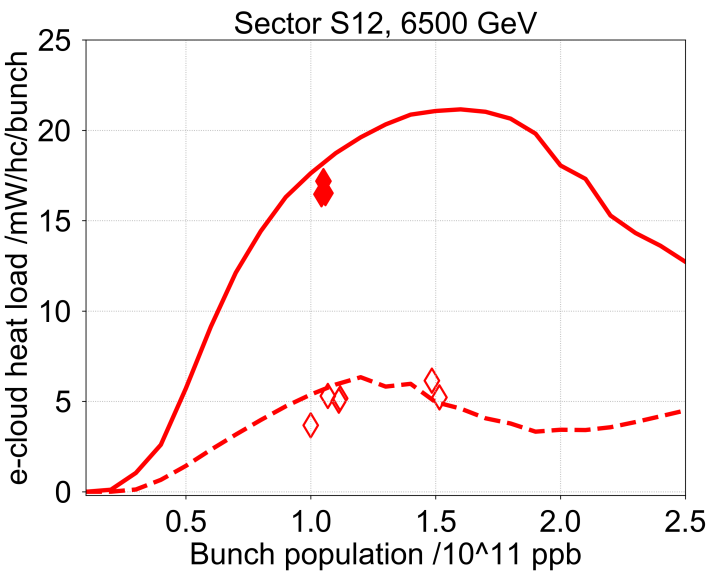

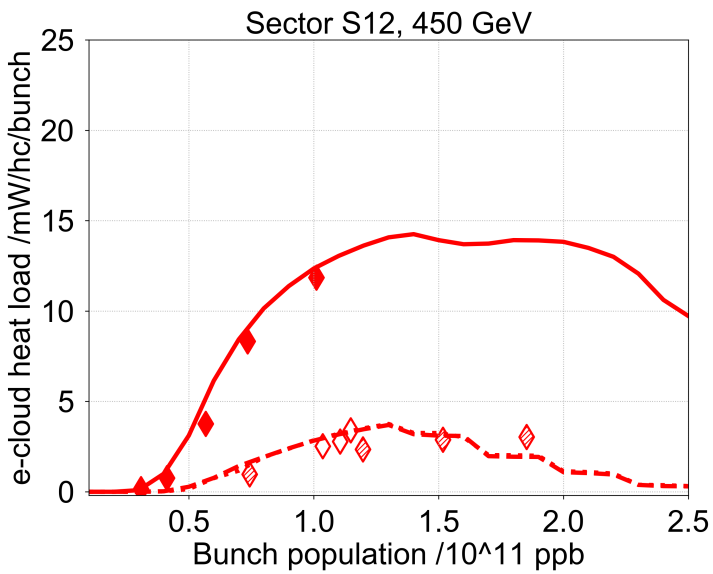

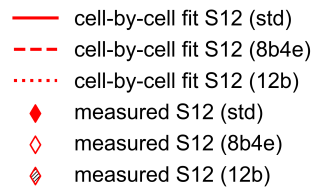

S12 HL contributions

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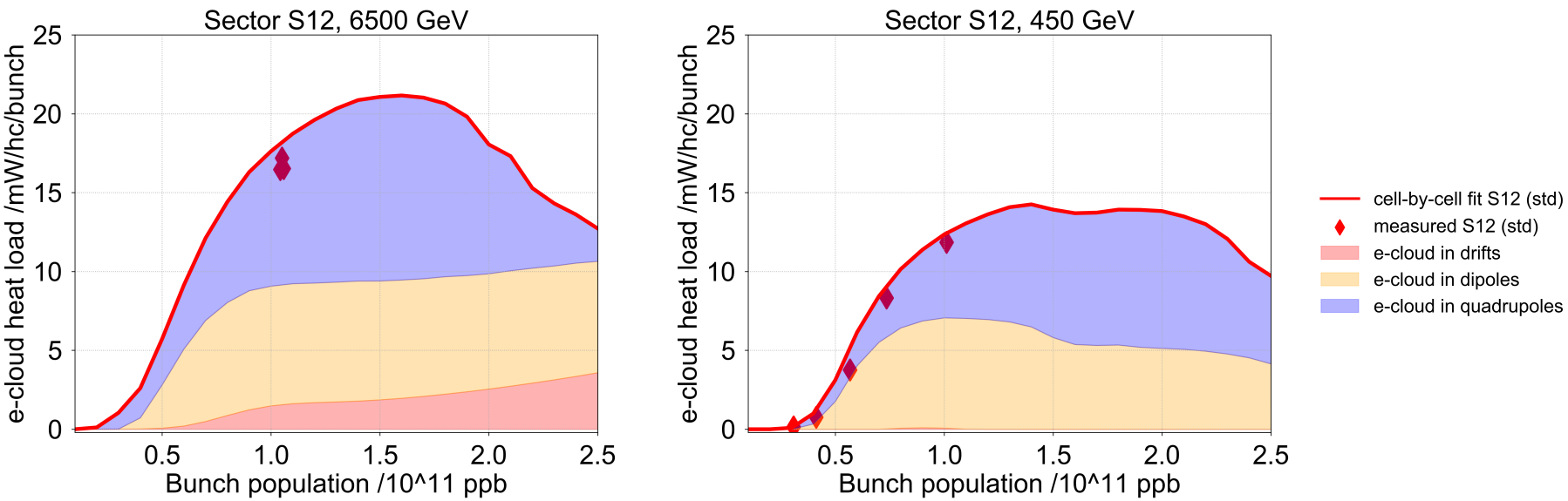

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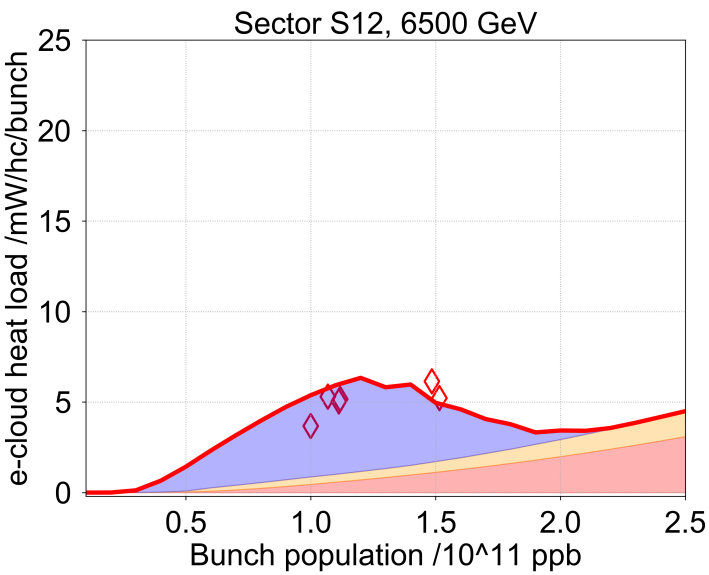

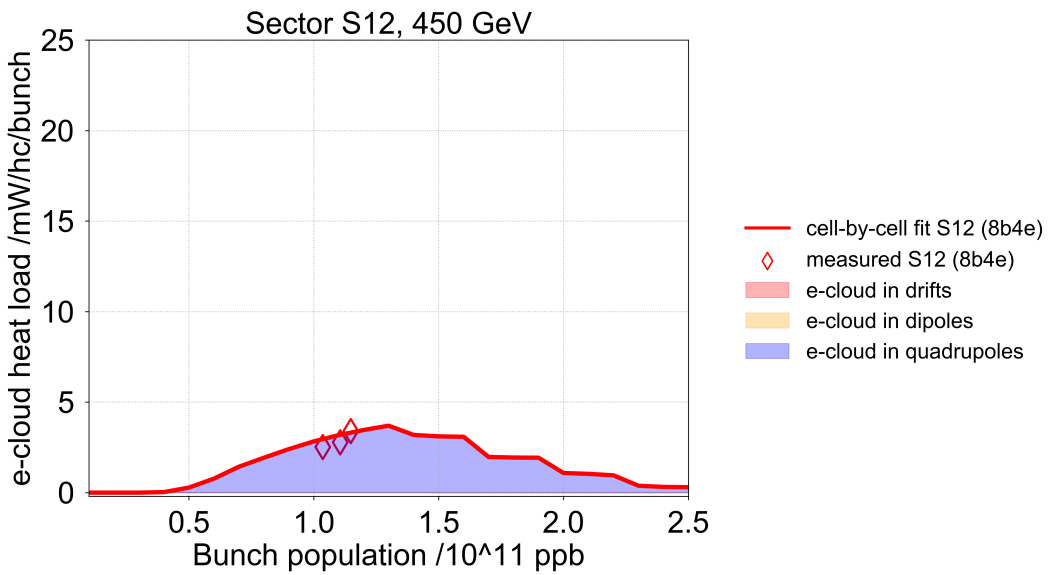

S23 HL intensity dependence

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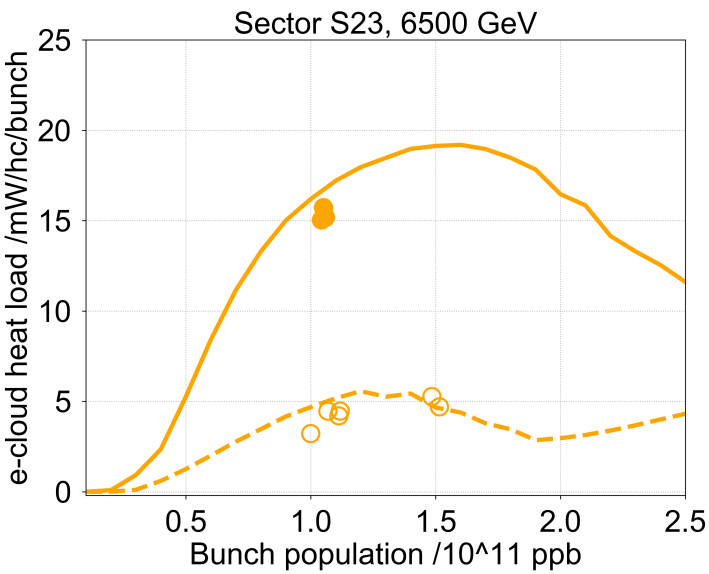

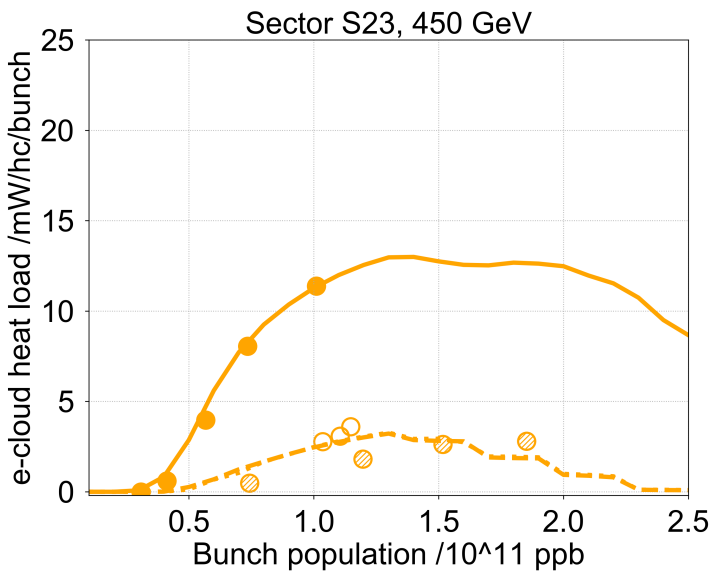

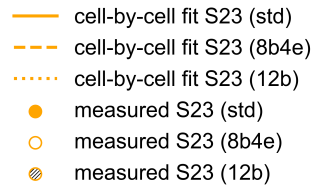

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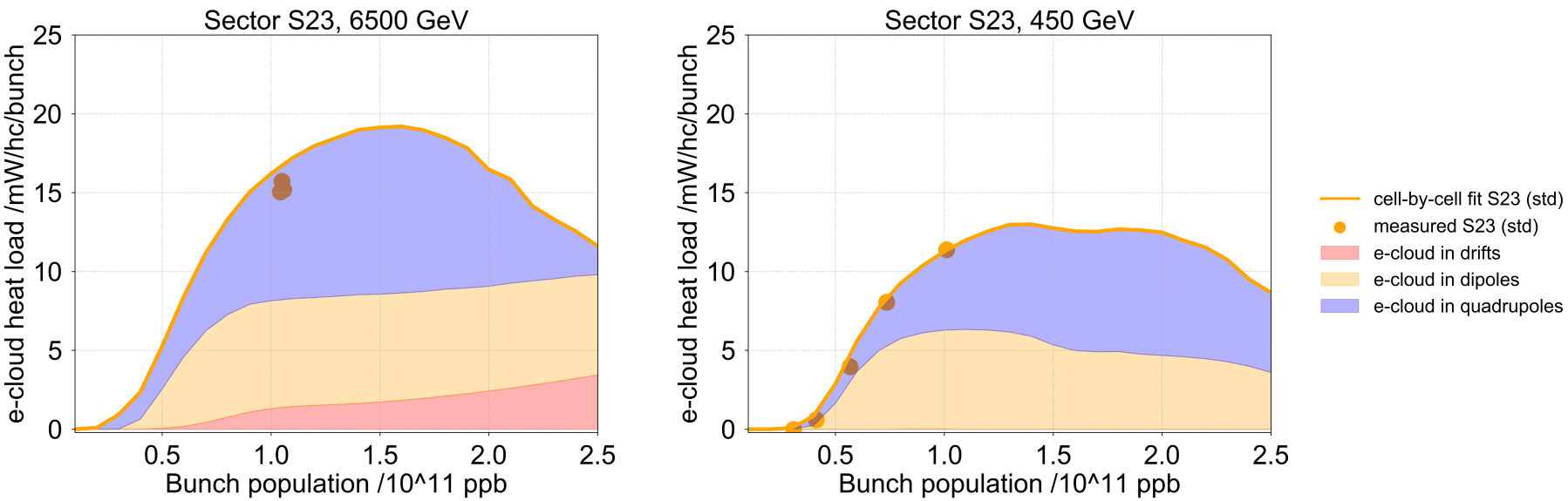

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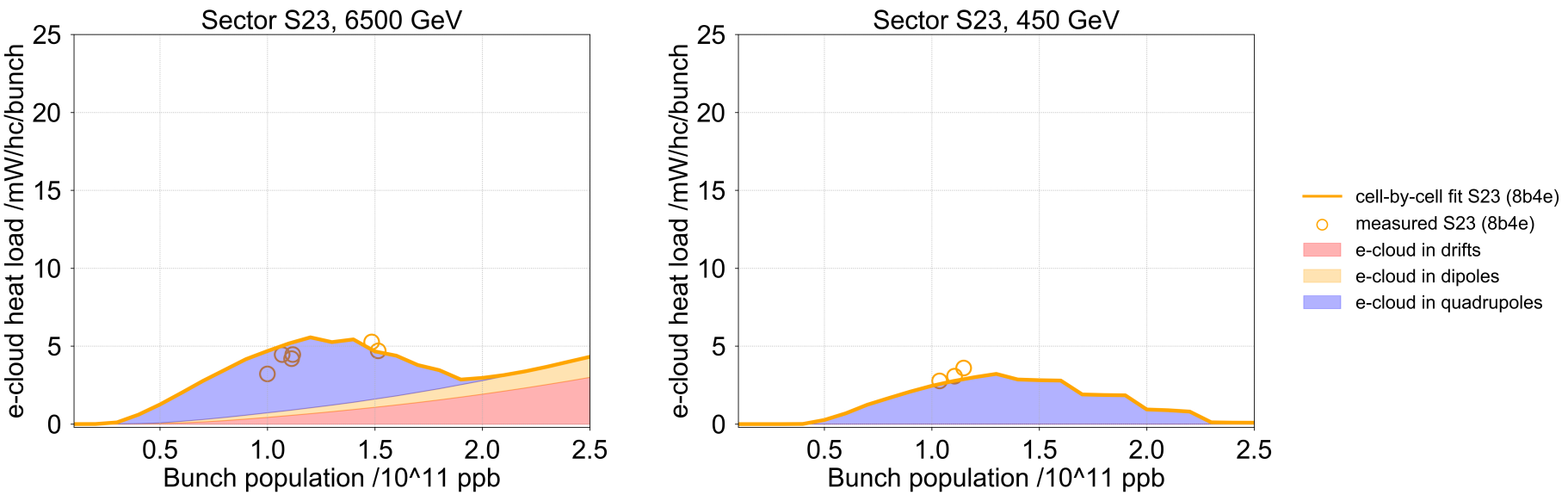

S34 HL intensity dependence

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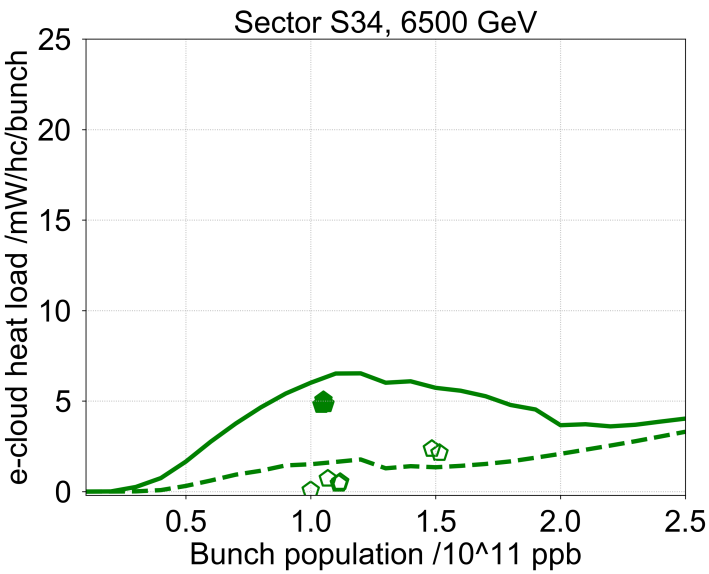

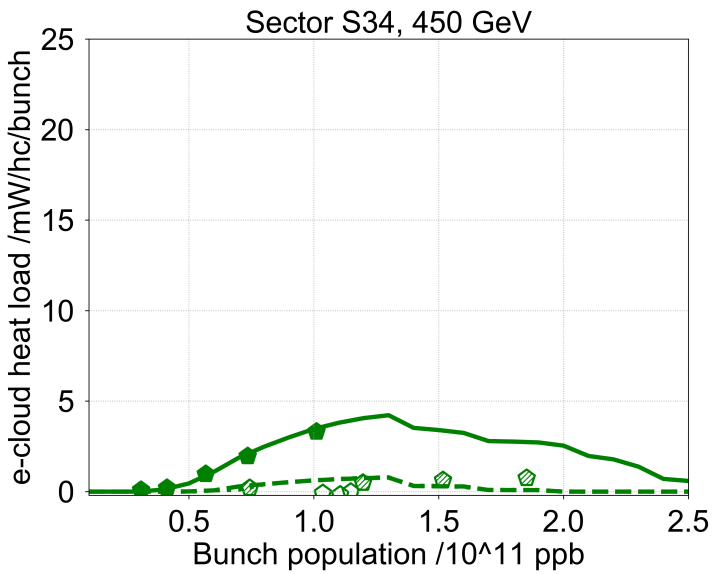

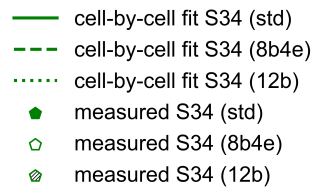

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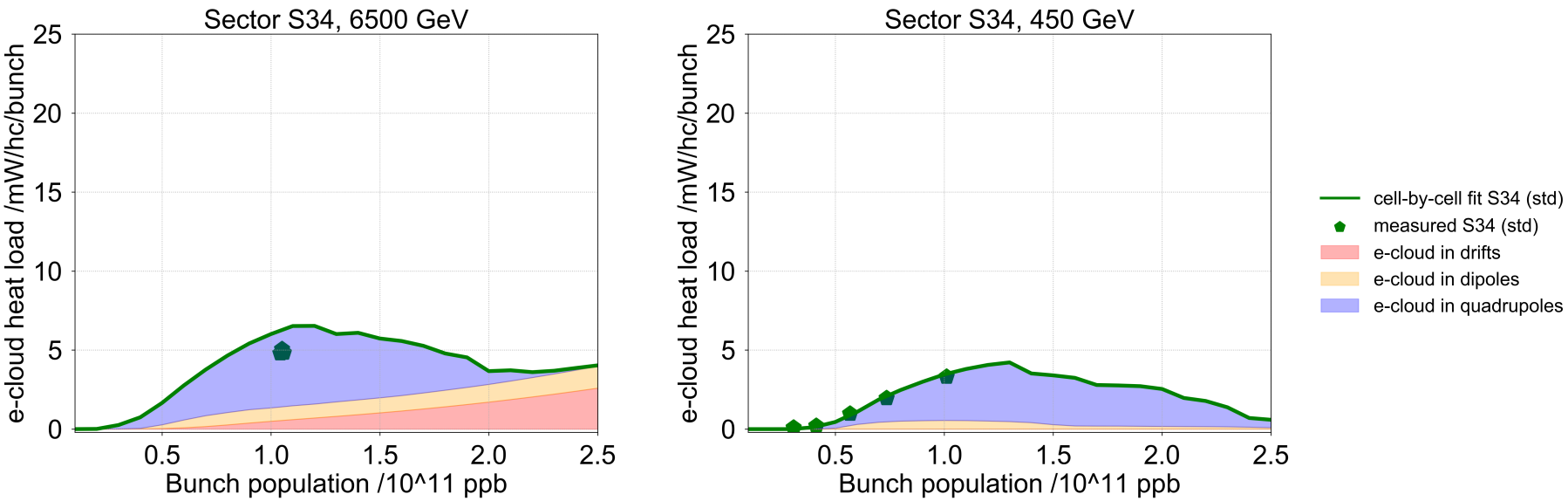

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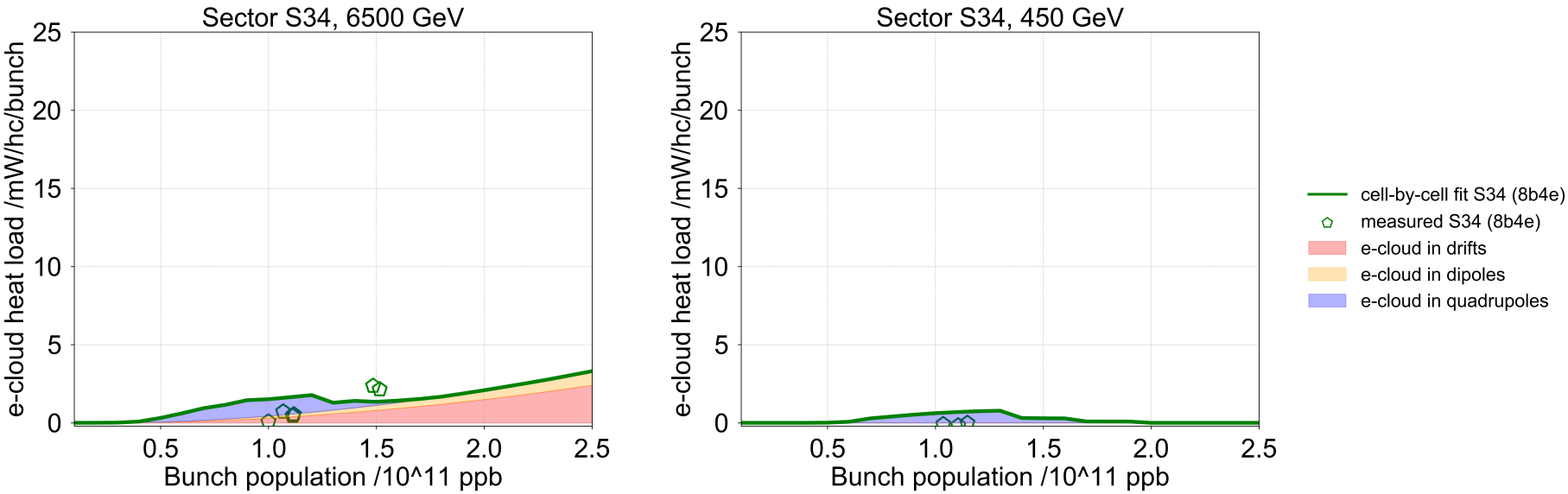
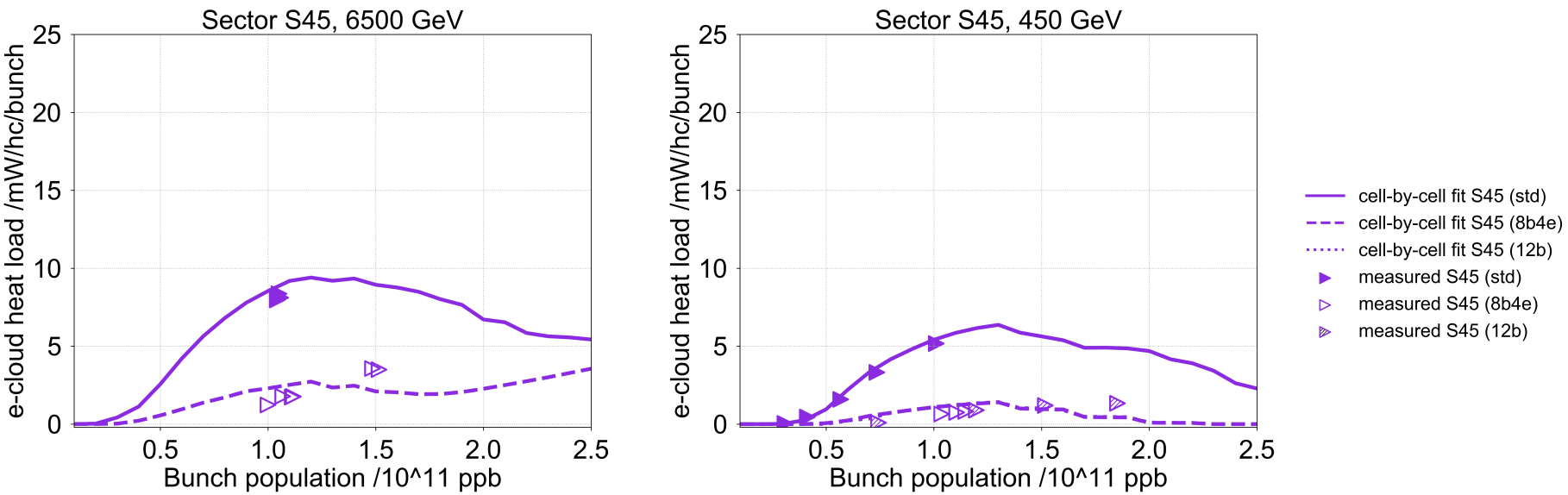
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch
- Very low HL with *8b4e* beam. Quads are main contributors int $< 1.2 \times 10^{11}$, then drifts



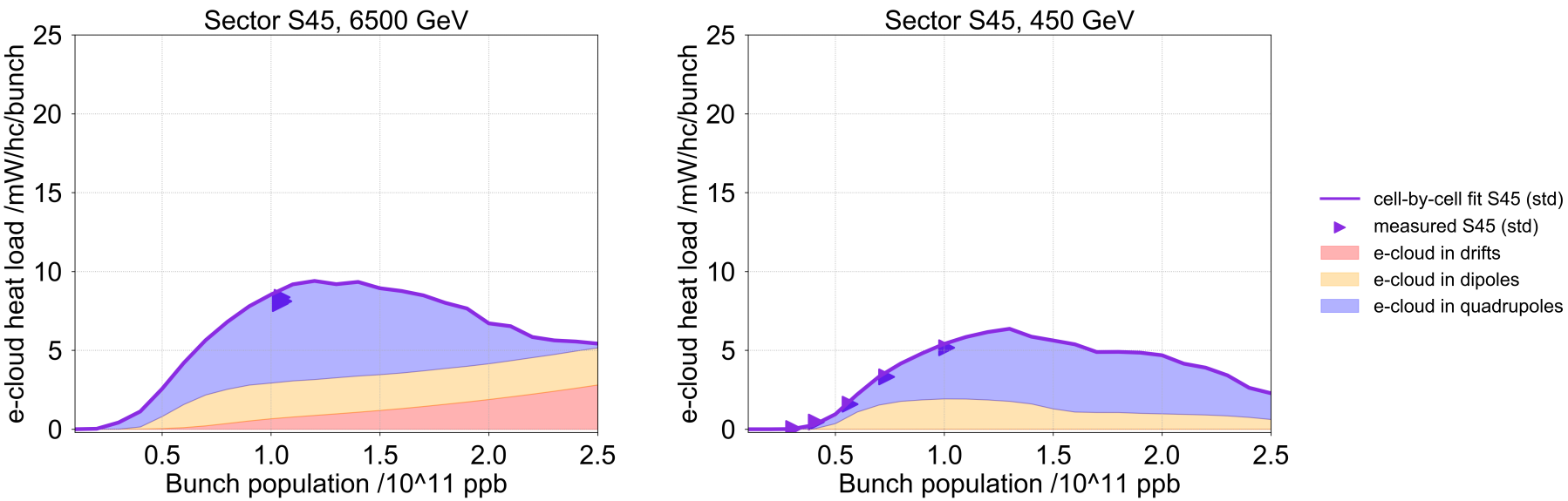
S45 HL intensity dependence

- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities



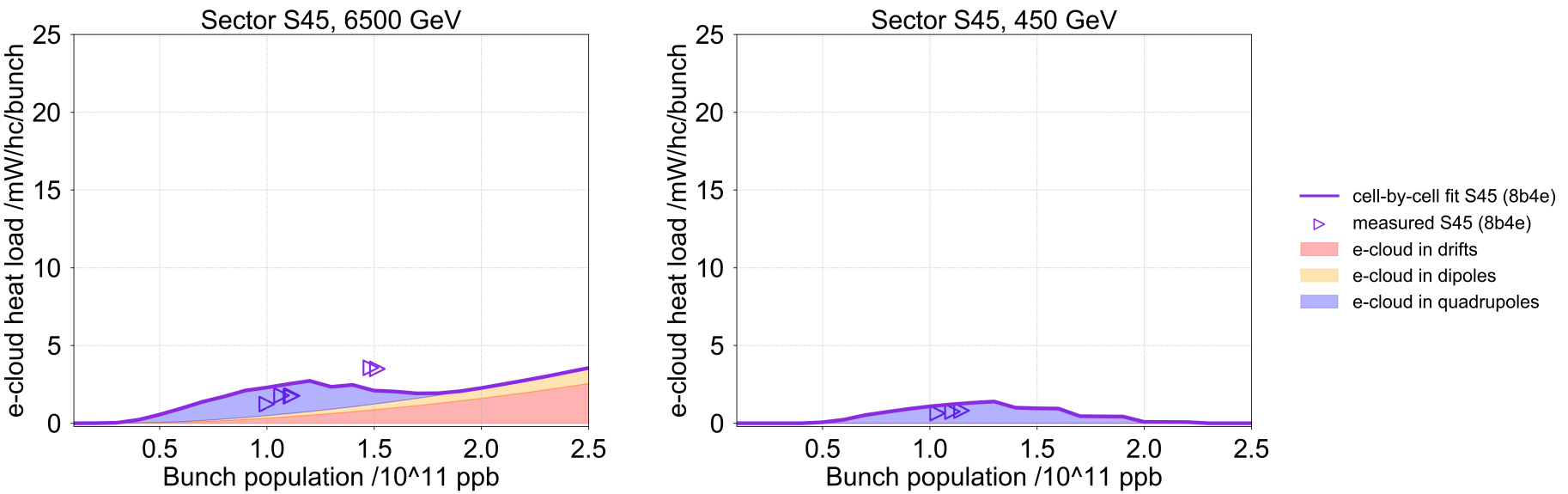
S45 HL contributions

- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch



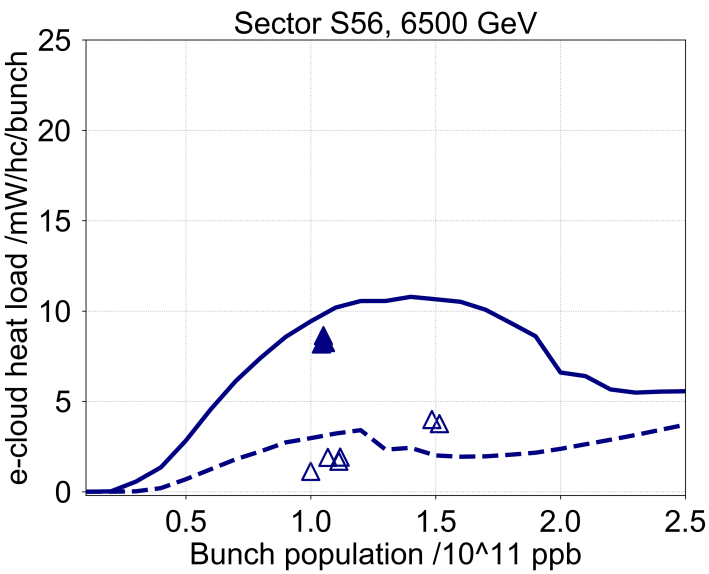
S45 HL contributions

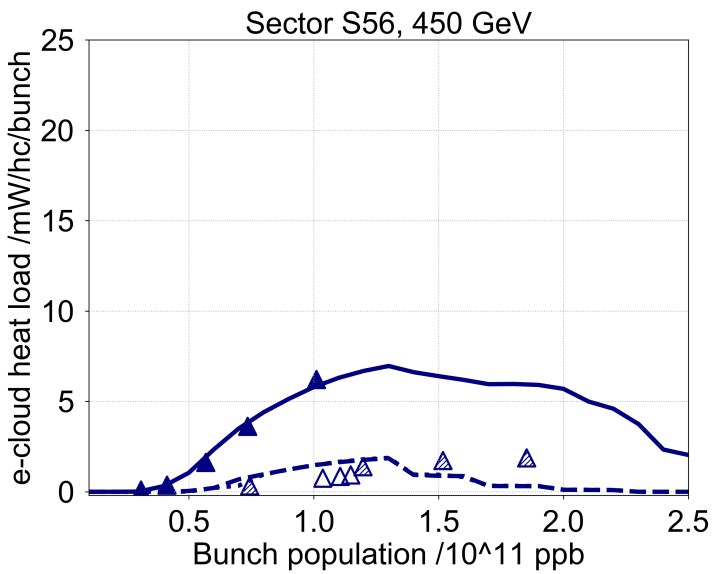
- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch
- Quadrupoles are main contributors with *8b4e* beam int $< 2.0 \times 10^{11}$

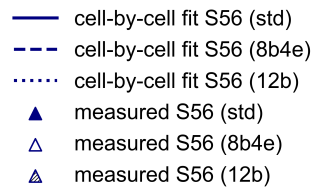


S56 HL intensity dependence

- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities

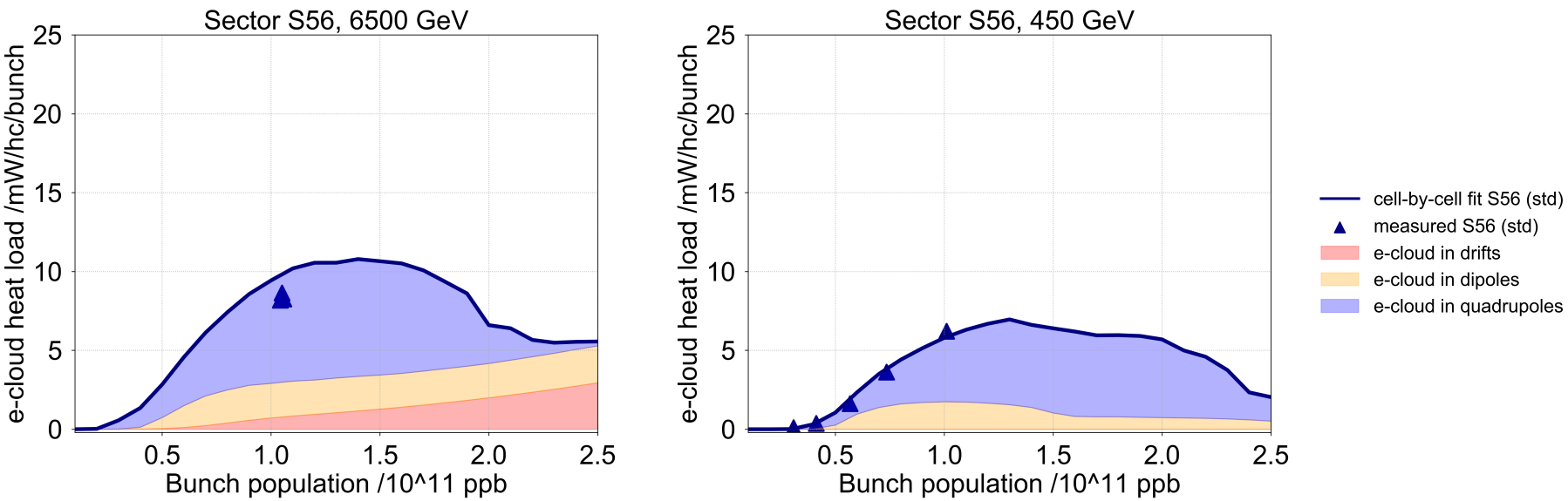






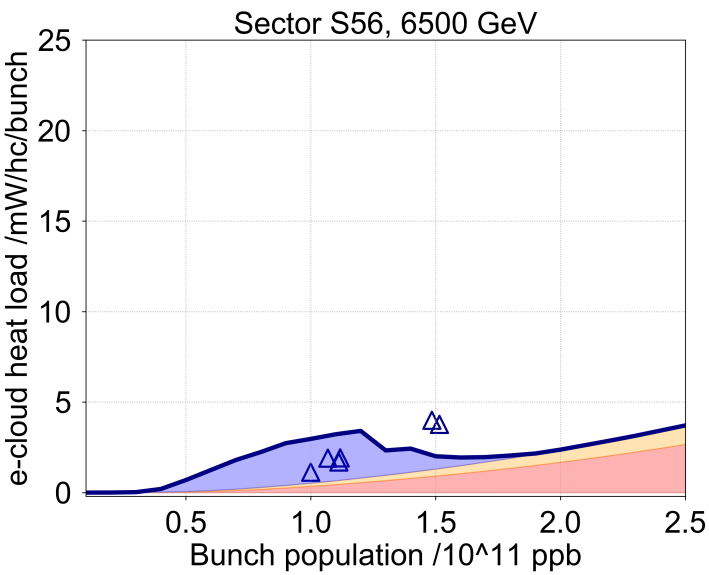
S56 HL contributions

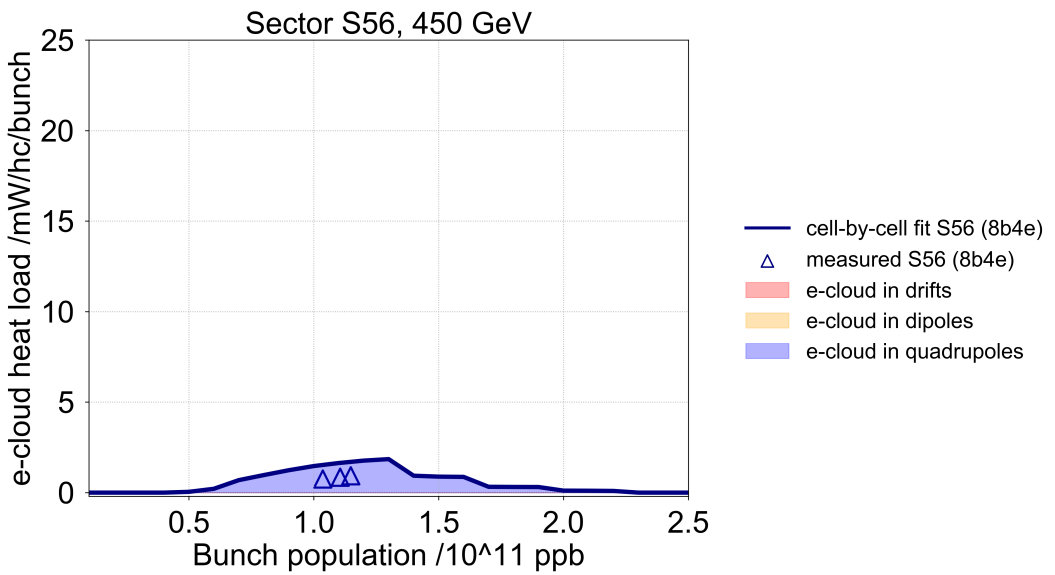
- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch



S56 HL contributions

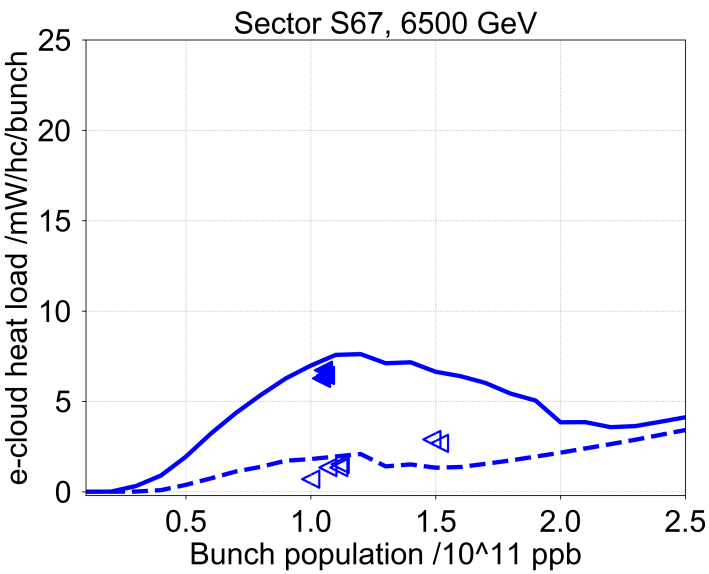
- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch
- Quadrupoles are main contributors with *8b4e* beam int $< 2.0 \times 10^{11}$

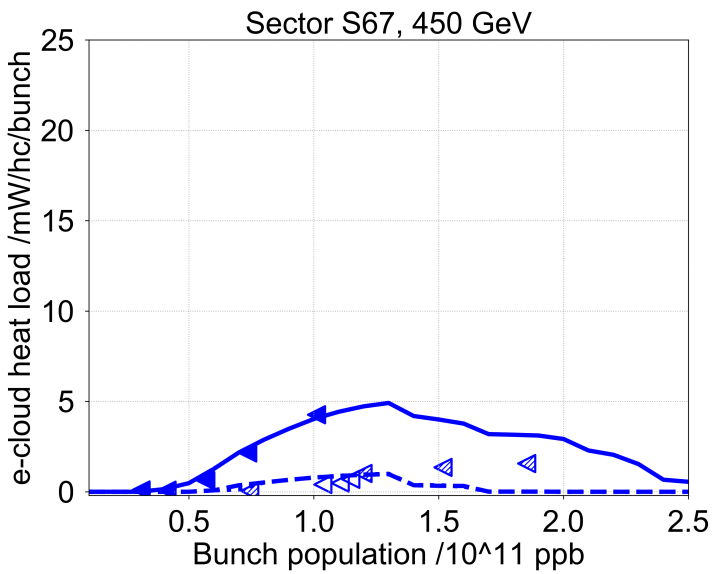


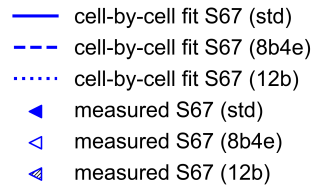


S67 HL intensity dependence

- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities

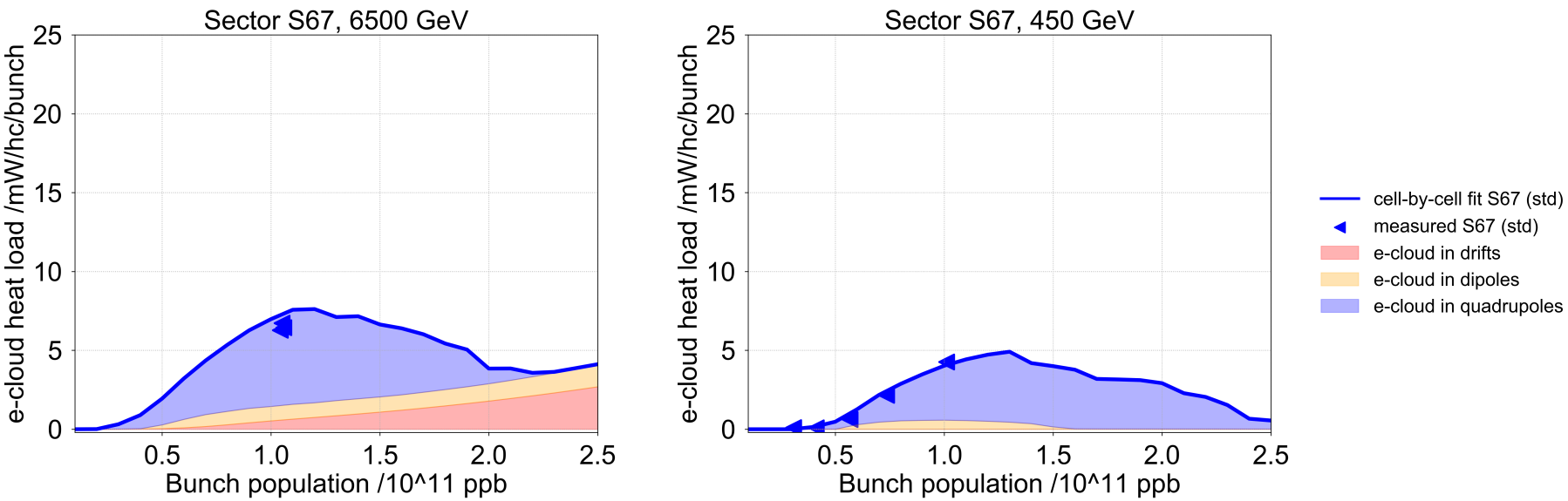






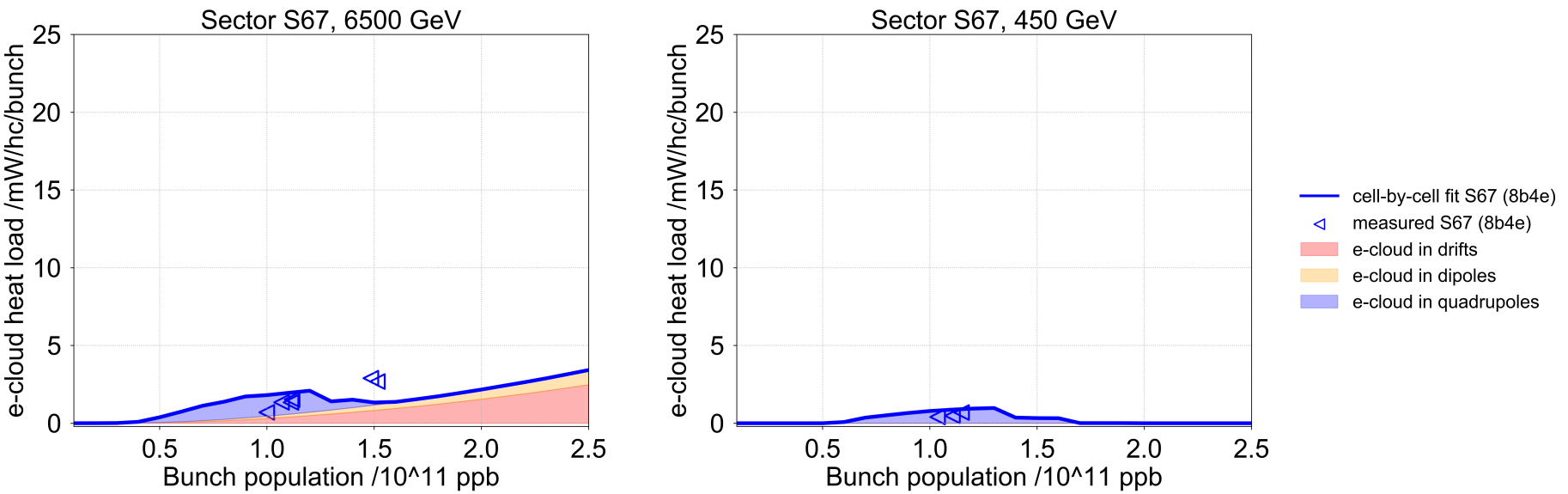
S67 HL contributions

- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch



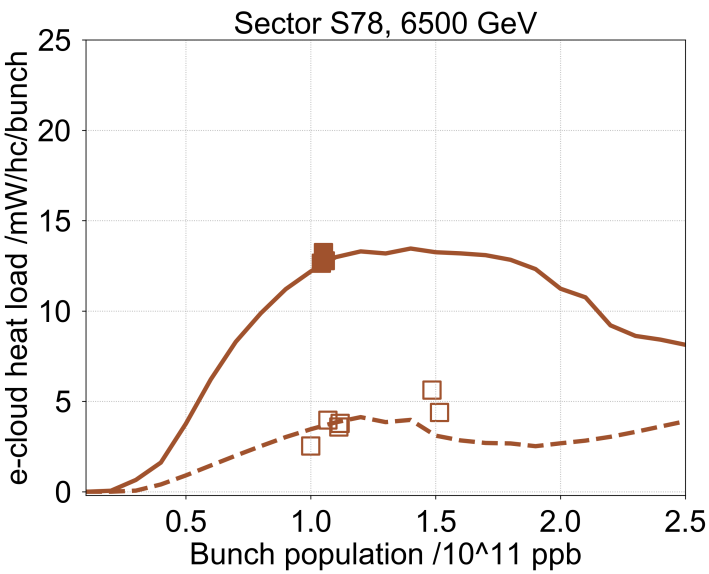
S67 HL contributions

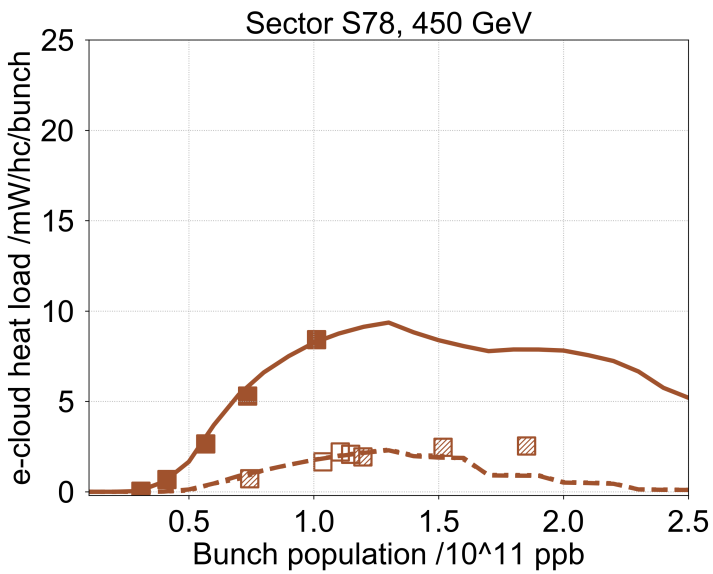
- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch
- Quadrupoles are main contributors with *8b4e* beam int $< 2.0 \times 10^{11}$

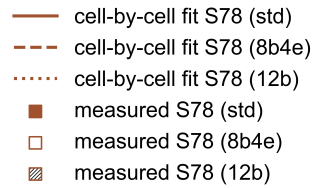


S78 HL intensity dependence

- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities

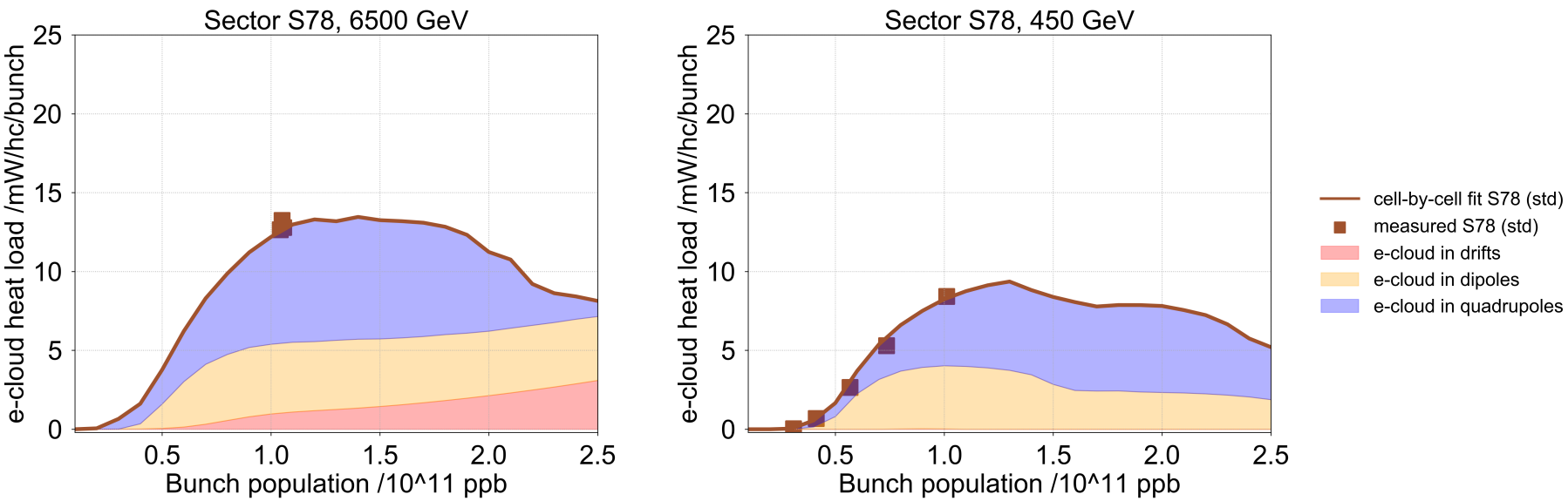






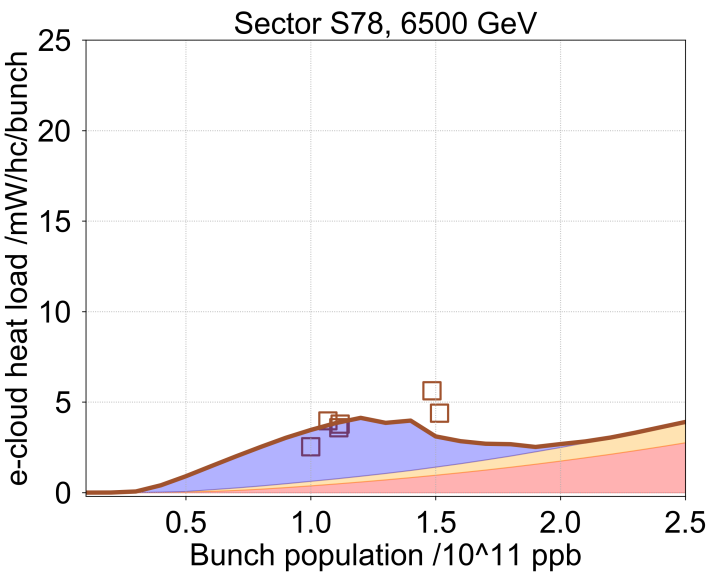
S78 HL contributions

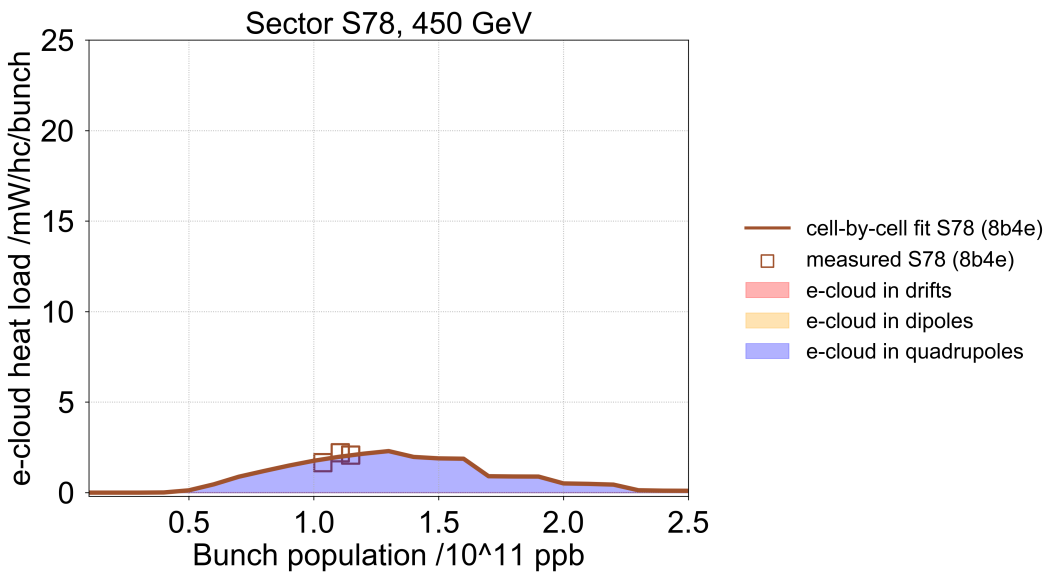
- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch



S78 HL contributions

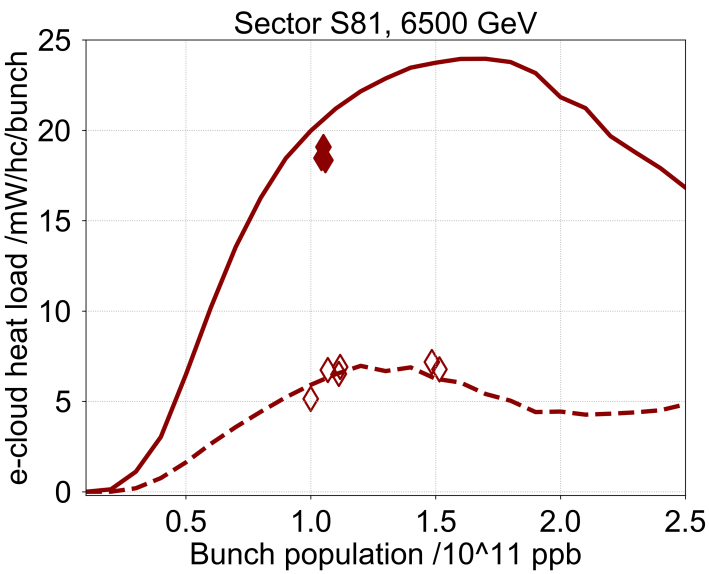
- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch
- Quadrupoles are main contributors with *8b4e* beam int $< 2.0 \times 10^{11}$

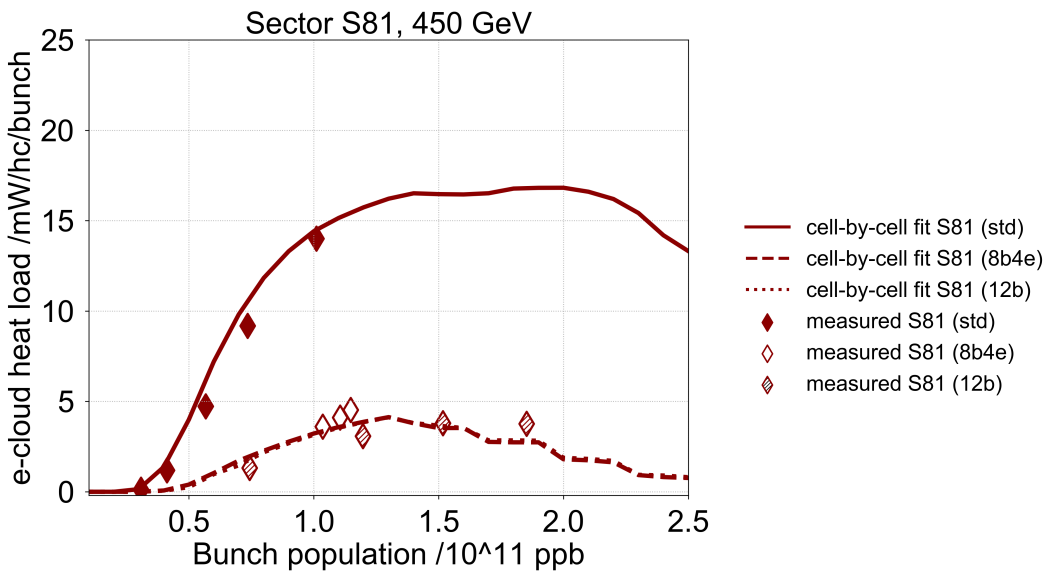




S81 HL intensity dependence

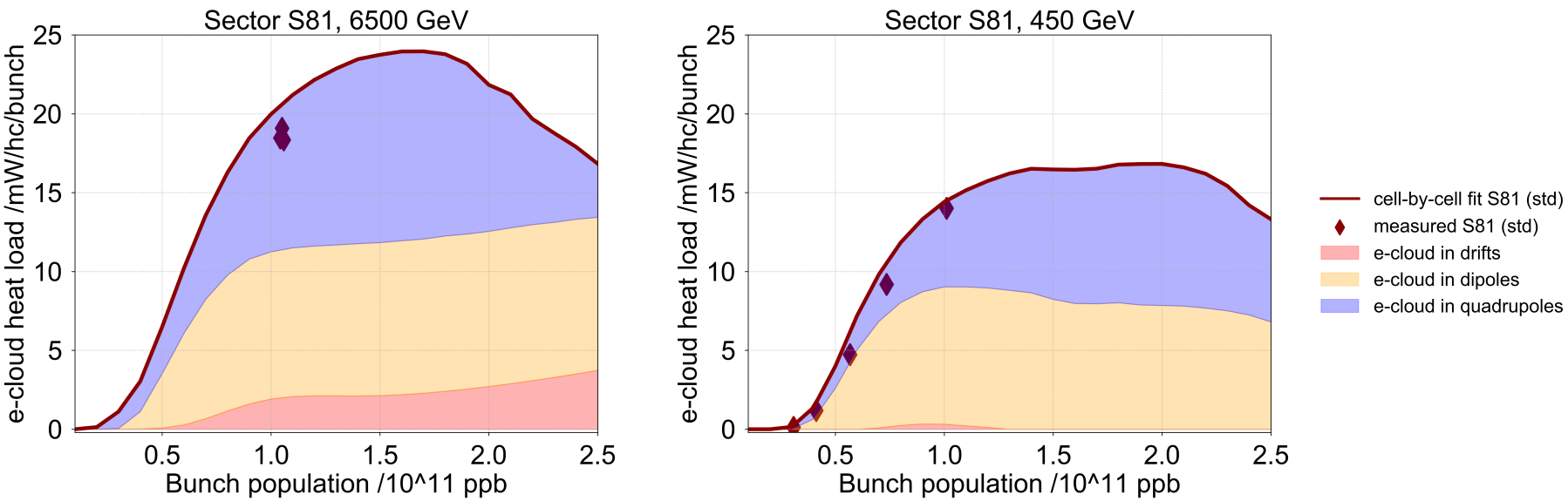
- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities

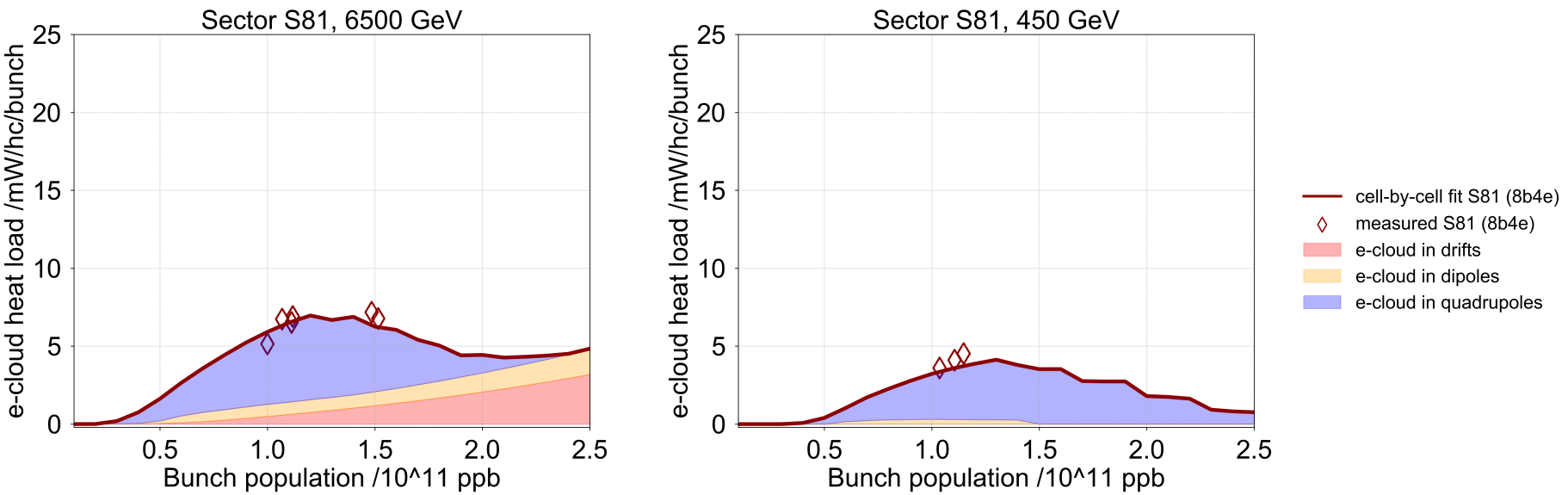




S81 HL contributions

- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch



S81 HL contributions

- Data better represented if using the cell-by-cell SEY averaging
- HL drops or changed insignificantly at higher bunch intensities
- Quadrupoles are responsible for HL peak in intensity region $1.0 - 2.0 \times 10^{11}$ p/bunch
- Quadrupoles are main contributors with *8b4e* beam int $< 2.0 \times 10^{11}$