Max-Planck-Institut für Plasmaphysik

ITER-HNB plasma and extraction grids in BUG: Characterization of magnetic deflection correction

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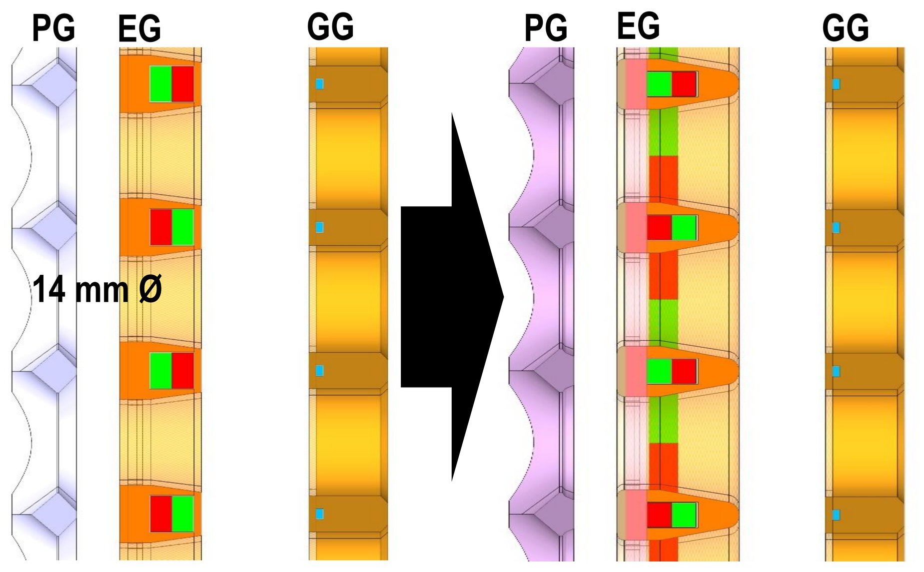
Abstract

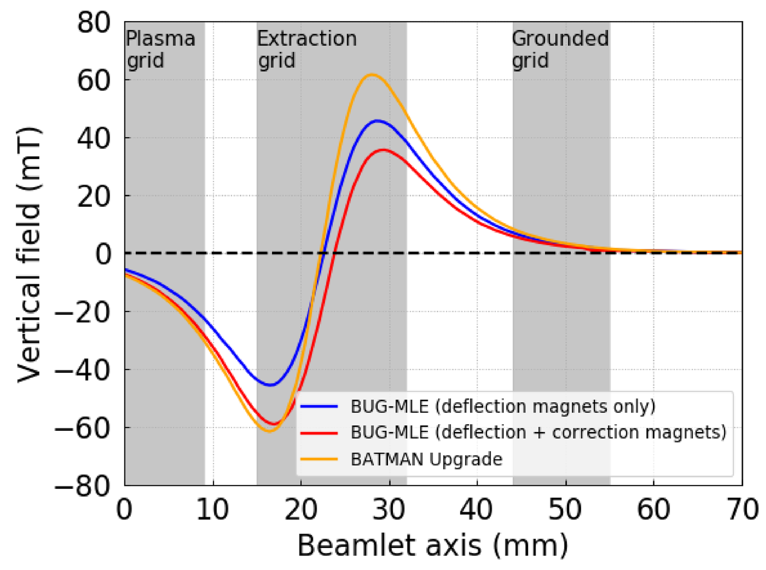
BATMAN Upgrade: high current density H^-/D^- beam extraction (⅛ ITER source size)
Co-extracted electrons magnetically deflected onto extraction grid
Leads to small and unwanted deflection of the ions: unacceptable for ITER
New in BUG: ITER-HNB plasma and extraction grid, magnetic correction of deflection
BUG-MITICA Like Extraction designed in collaboration with ITER Organization
Beamlet properties of new grid system studied with CFC calorimeter and spectroscopy

Negative ion beams and magnetic fields

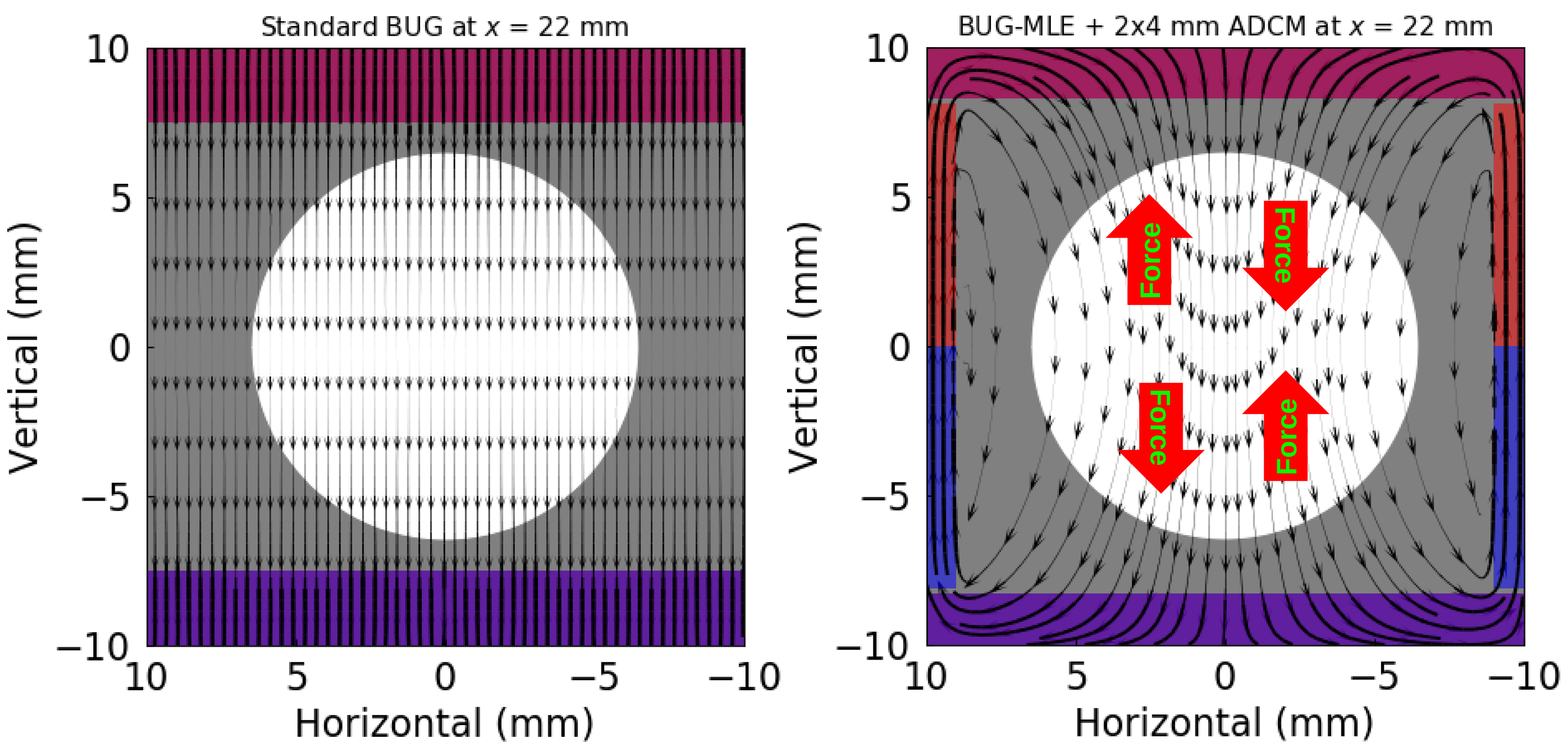
Negative ions are extracted by potential between plasma grid and extraction grid
Co-extracted electrons are magnetically deflected onto EG before further acceleration
Magnetic field also deflects the ions, to first approximation: $\delta = \sqrt{\frac{q}{m}} \frac{\int_{meniscus}^{\infty} B_{\mathrm{vertical}}(x)\, dx}{\sqrt{2 U_{\mathrm{tot}}}}$
Magnetic deflection correction by additional magnets that create asymmetric field



BUG grid system   BUG-MLE grid system



Deflection correction magnets add horizontal component to magnetic field
Horizontal component focuses/defocuses vertically: increased divergence!



Modeling the ion-optics

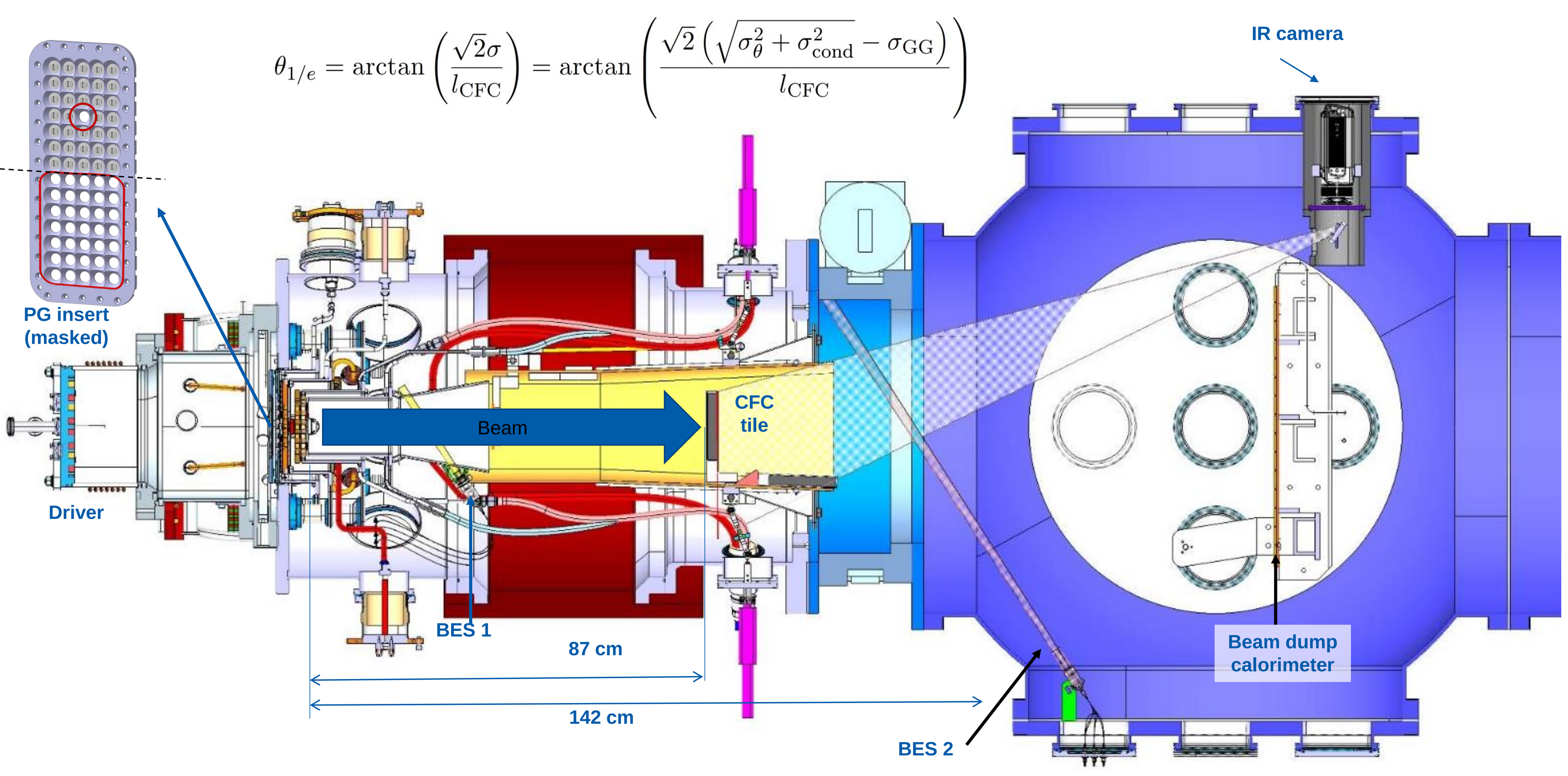
IBSimu: self-consistent modeling of ion-optics including space charge
Solution of Poisson equation found iteratively
Input: geometry, magnetic field, potentials U_{ext} and U_{acc}, current density J_{inj}
Output: spatial and velocity distribution of beamlet particles (divergence $\theta_{1/e}$, power density)
Grid design goal: no average horizontal deflection angle in divergence optimum

BUG: a well-diagnosed test facility

BUG: extraction of H^-/D^- from RF generated plasma
Plasma grid masked to observe single deflection corrected beamlet
Diagnostics used in this contribution:

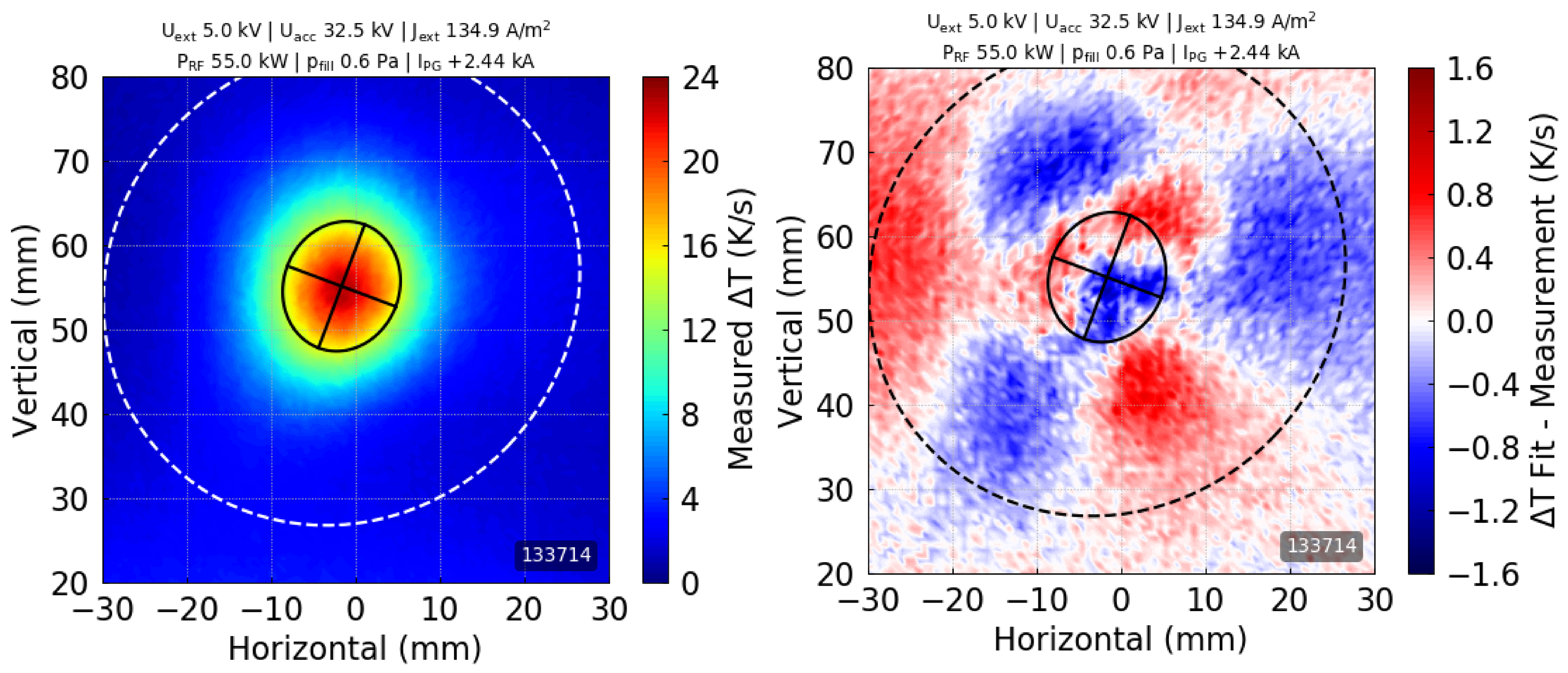
- ➔ Beam Emission Spectroscopy to derive beam divergence and relative angle
- ➔ CFC tile observed by IR camera to obtain beam profile

$$\theta_{1/e} = \arctan\left(\frac{\sqrt{2}\sigma}{l_{\mathrm{CFC}}}\right) = \arctan\left(\frac{\sqrt{2}\left(\sqrt{\sigma_\theta^2 + \sigma_{\mathrm{cond}}^2} - \sigma_{\mathrm{GG}}\right)}{l_{\mathrm{CFC}}}\right)$$



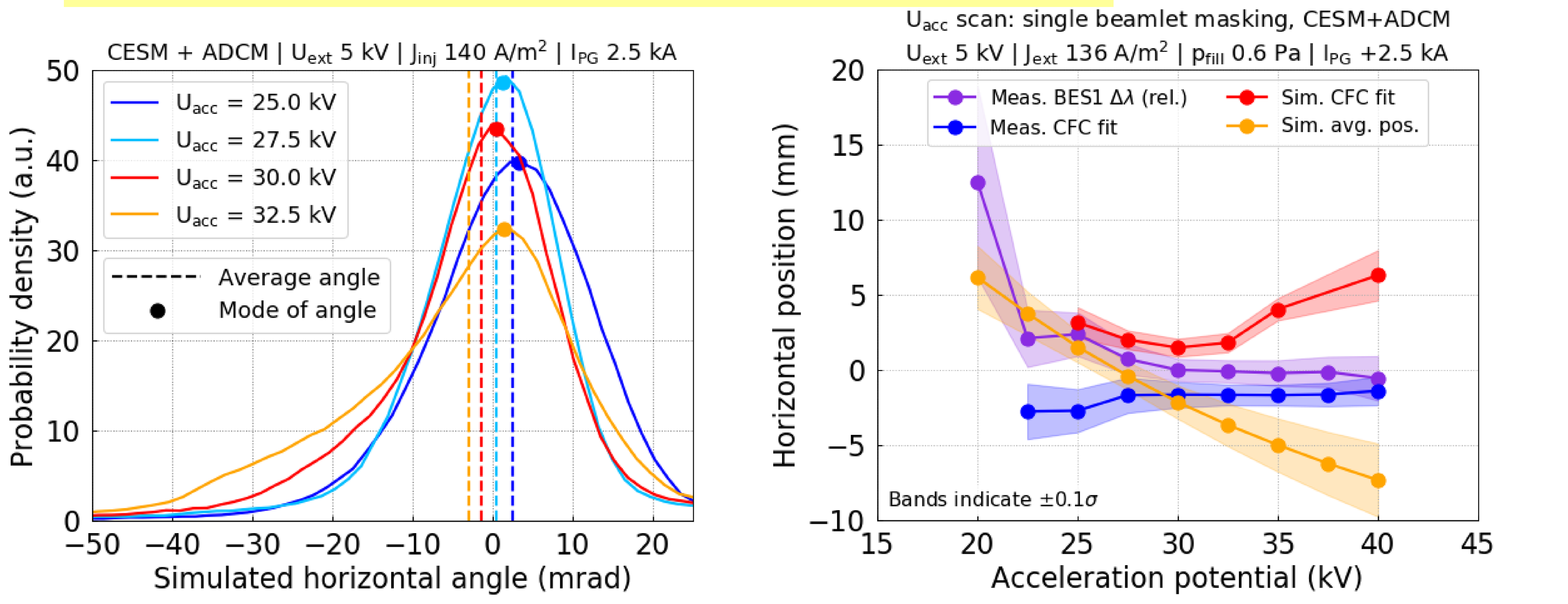
Measured single beamlet profiles

Plasma grid masked: single beamlet isolated on CFC
Measured IR data converted to temperature and perspective corrected
Fitted with double rotatable 2D Gaussian which share center
Triangular shape due to horizontal magnetic field component clearly observed!



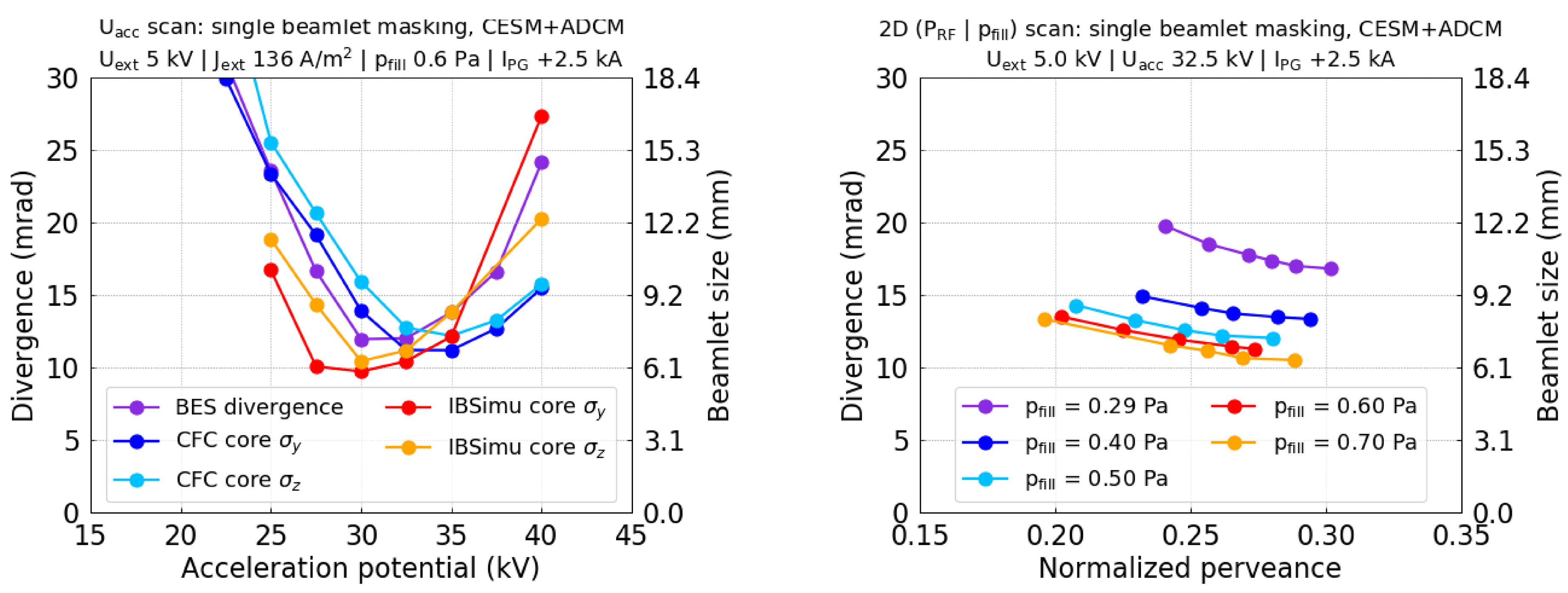
Measured single beamlet position

Single beamlet position derived from fit: complicated by triangular shape
Relative horizontal deflection angle calculated from emission wavelength
Added complication: simulations indicate highly asymmetric angular distribution!
Measured and simulated position agree in divergence optimum within systematic uncertainty
Experimental data shows: beamlet angle robustly compensated!



Measured single beamlet size

Single beamlet size derived from fit: complicated by triangular shape
Size to divergence conversion is worst case: no width at GG, no lateral heat conduction in CFC
Single beamlet divergence measured with BES
Measured divergence increases below threshold source filling pressure
Reasonable agreement between measured and simulated beamlet size at 0.6 Pa p_{fill}



Conclusions

BUG-MLE grid system characterized in experiment: single beamlet properties measured
Measured beamlet position robustly compensated
Modeling and measurements: deflection correction magnets worsen vertical divergence
Reasonable agreement between simulated and measured beamlet size at 0.6 Pa p_{fill}
Measured beamlet size increases below a threshold source filling pressure of 0.4 Pa
Beamlet shape triangular: complicates size and position determination
Outlook: study impact of angular distribution on calculated transmission

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