

Stage 1 Energy Selection

Holistic Optimisation

Matt Pereira

(matthew.pereira.2023@live.rhul.ac.uk)

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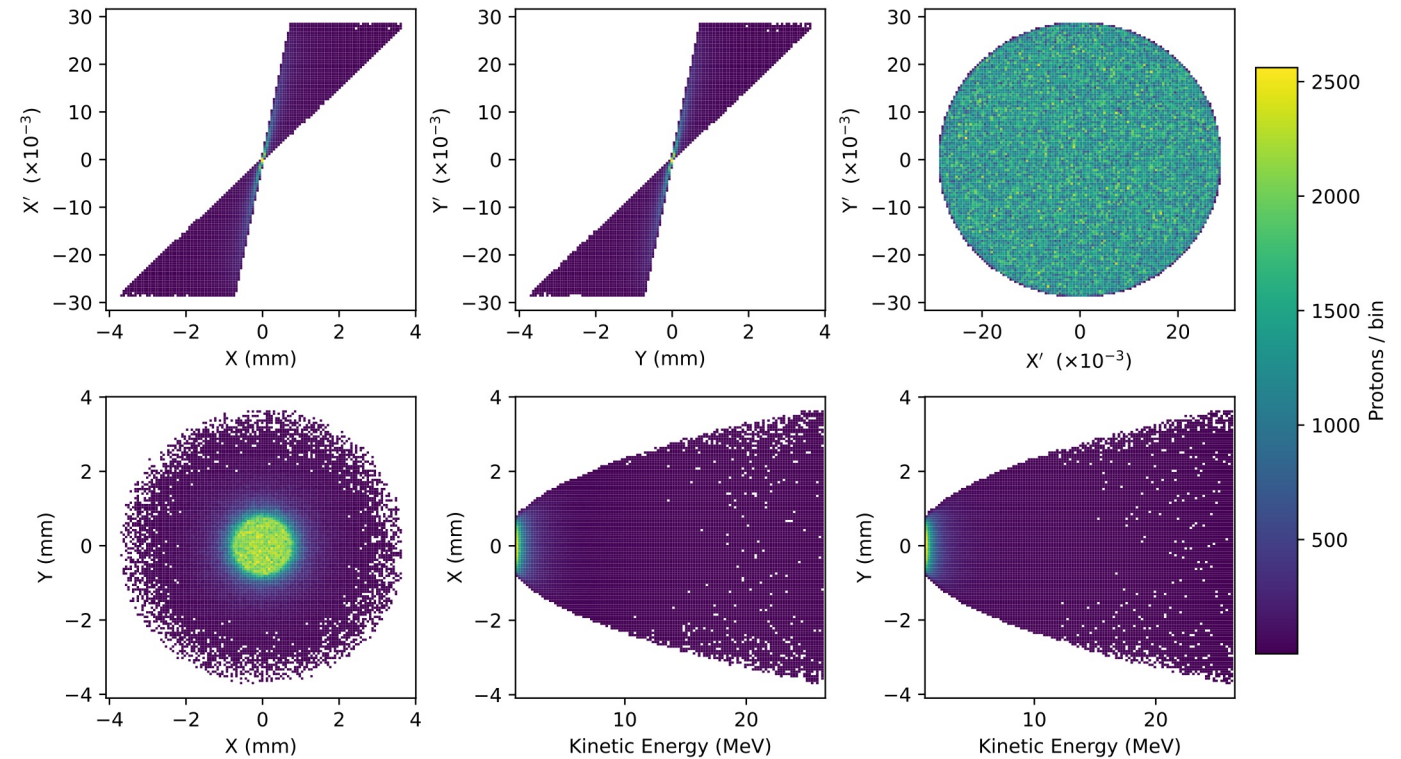
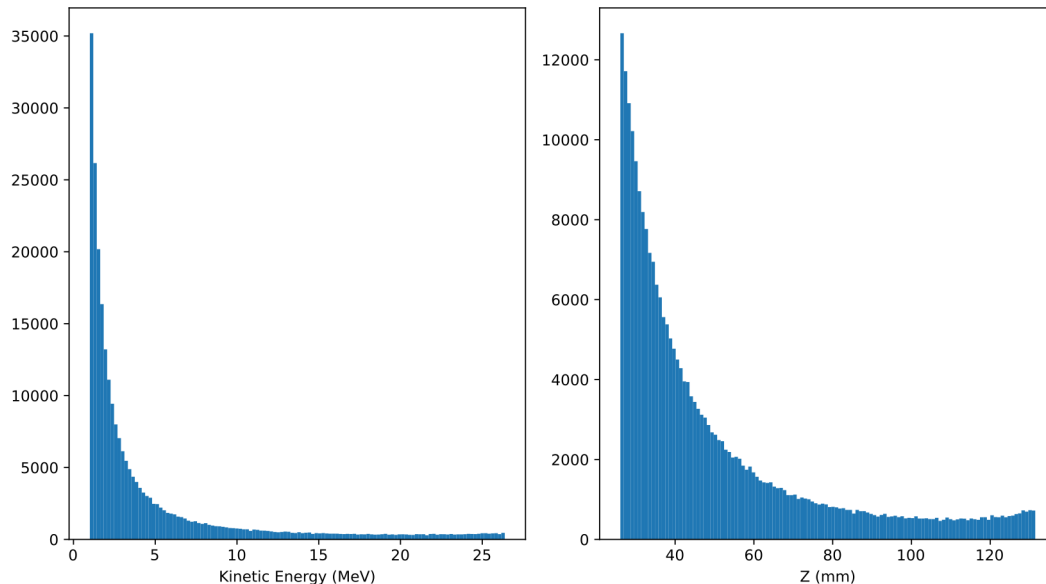


Stage 1 Full Spectrum Beam

Source parameters taken from LhARA CDR for LhARA Linear Optics TNSA beam generation.

Source-Nozzle region simulated in RF Track with space charge.

Particle coordinates at the nozzle exit as input to BDSIM tracking of the Stage 1 lattice
(Shown on this slide)



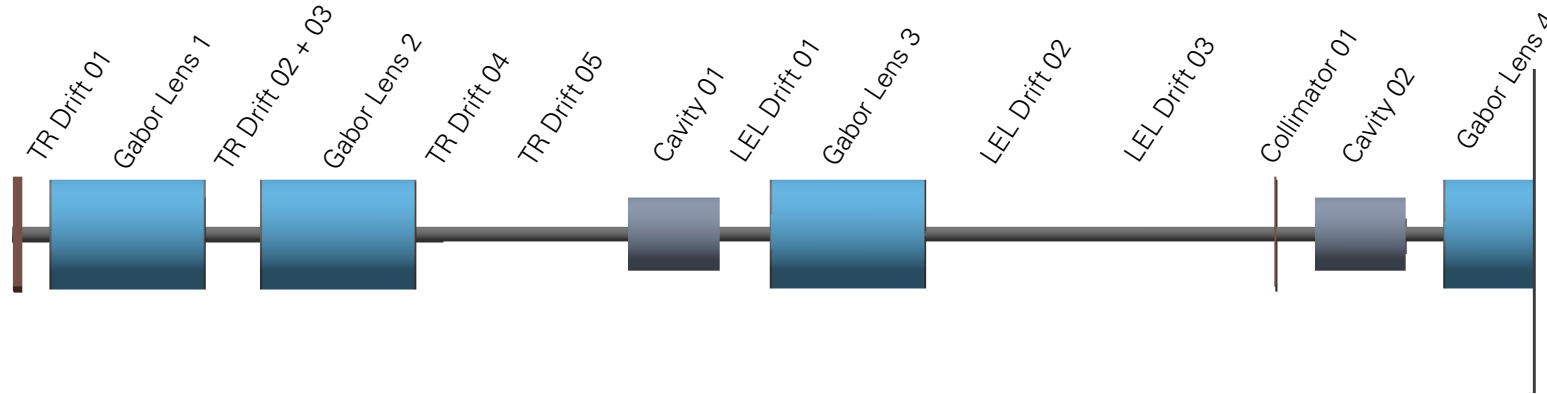
3M protons at source generation

~29,000 protons in $15 \pm 2\%$ MeV band (~1% of total pop.)

250k protons survive the nozzle

~1230 protons in $15 \pm 2\%$ MeV band (~0.5% of total pop.)

Stage 1 Energy Selection



Cavity 1 – Increase the population of the nominal energy band at Collimator 1

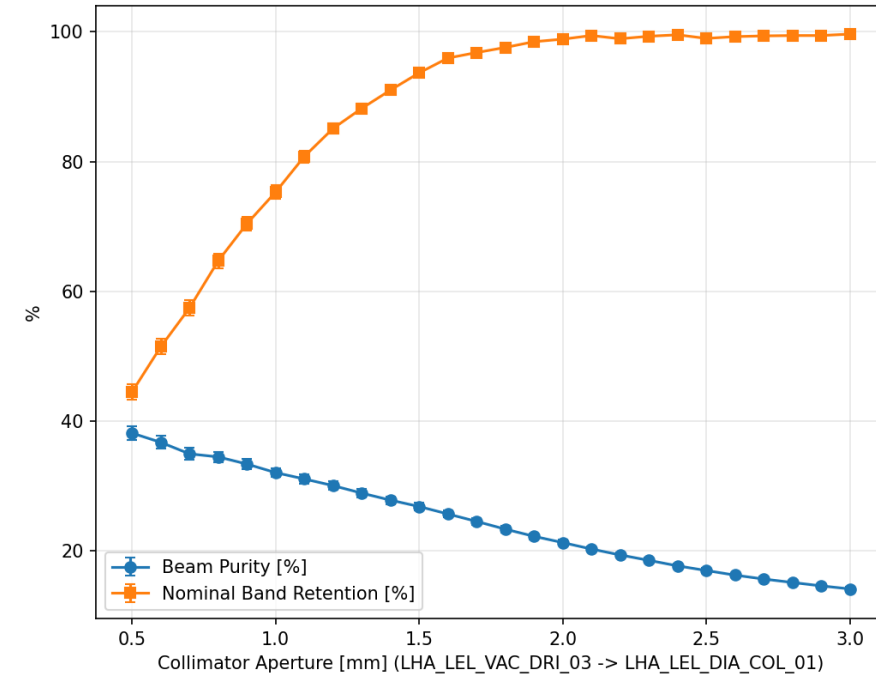
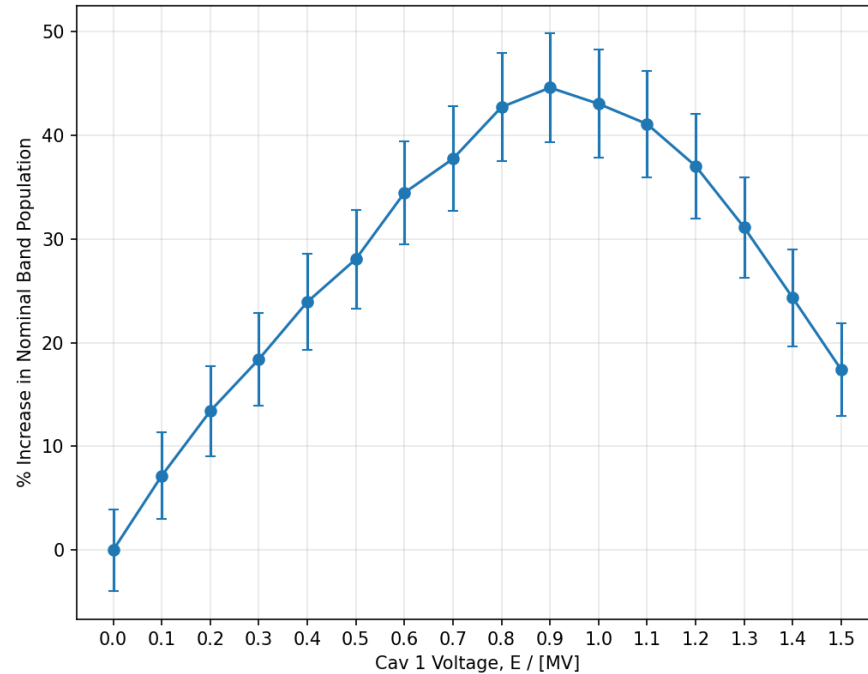
Collimator 1 – Energy Cleaning at a hard focus

Cavity 2 – Longitudinal Phase Space rotation for bunch length compression

Recap: Sequential Grid Scans

Optimising one parameter at a time:

- Cavity 1 voltage (50 MHz) -> Gabor Lens 3 field strength -> Collimator 1 radial aperture



Achieved a 37% increase in the nominal band population with a beam purity of 21% (Sampled after Cavity 2)

- Cavity Voltage – 0.9 MV, GL3 Field – 0.84 T equivalent, Collimator Aperture – 2.0 mm radius

Gap – Sequential scans do not see interaction effects between parameters

Rather than scanning for optima element-by-element, Multi Objective Bayesian Optimisation (MOBO)

Free Parameters – {Bounds}

- RF Voltage – {0.5, 1.5} MV
- Gabor Lens 3 Field Strength – {0.1, 1.4} T Equivalent
- Collimator Aperture – {0.5, 3.0} mm

Initial bounds are the same as the sequential scans for comparisons of runtime and convergence.

Objectives – [Bounds]

- Yield - Total particles in the nominal energy band (normalised to primary population) – [0, 1]
- Purity – Band Population / Beam Population – [0, 1]

Objectives are assessed at a sampler placed immediately after the second RF cavity

All optimisation runs begin with 24 quasi-randomly sampled points (SOBOL)

First search follows the random samples with 15 batches of 12 points.

MOBO – Wide Search

44 minute Run – 12 Core Machine

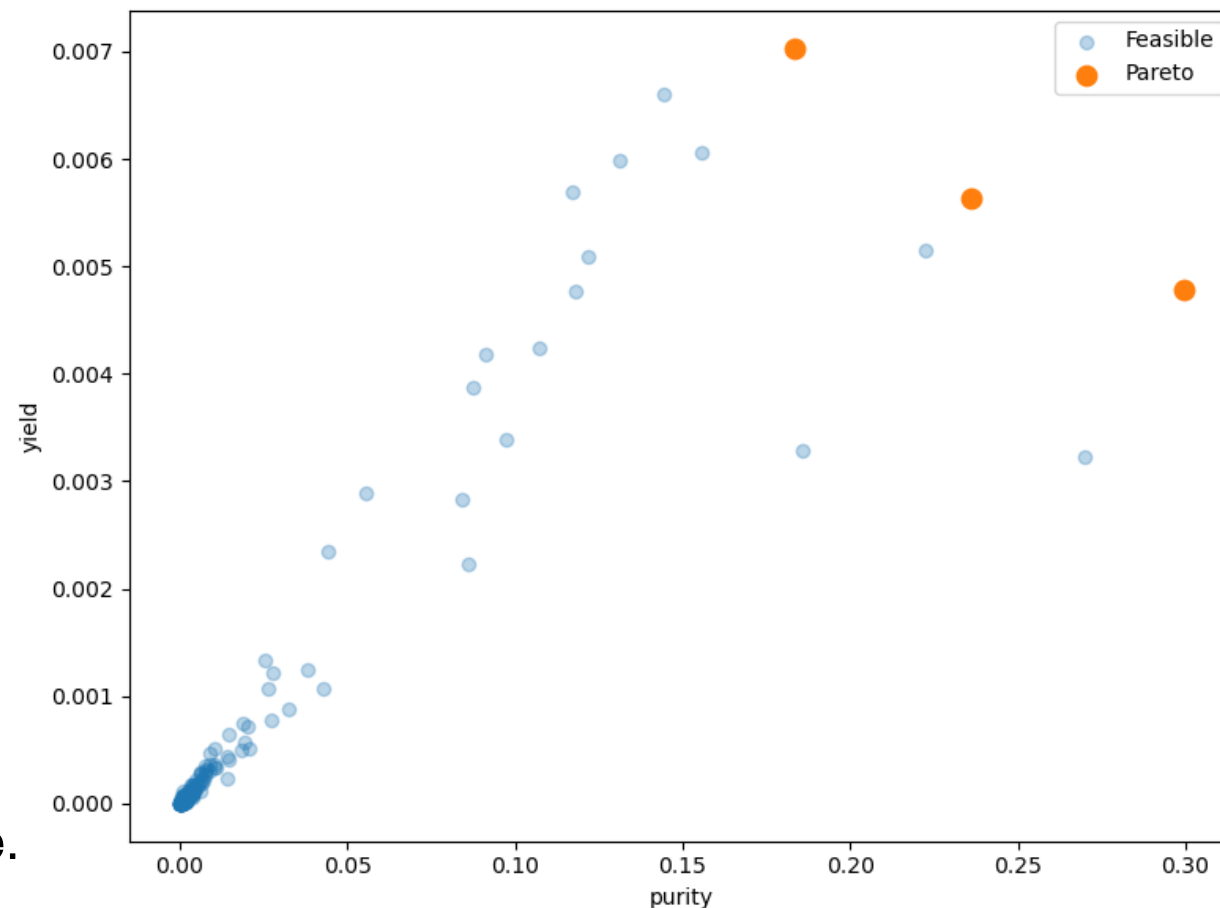
3 Point Pareto Front

RF Voltage (MV)	GL3 Field (T Equiv.)	COL Aper. (mm)		Purity	Yield
0.934	0.831	0.969		0.2996	-2%
0.787	0.852	1.44		0.2360	+16%
0.912	0.849	2.30		0.1834	45%

We can see the Yield vs Purity trade-off
Parameters surround the grid scan optima

Yield values in the table are presented as % increase.

Yield values on the plot are normalised to primary beam population.



MOBO Finer Search

Tighter Bounds

- RF Voltage – {0.65, 1.05} MV
- GL3B – {0.75, 0.92}
- COL Aper. – {0.3, 4} mm

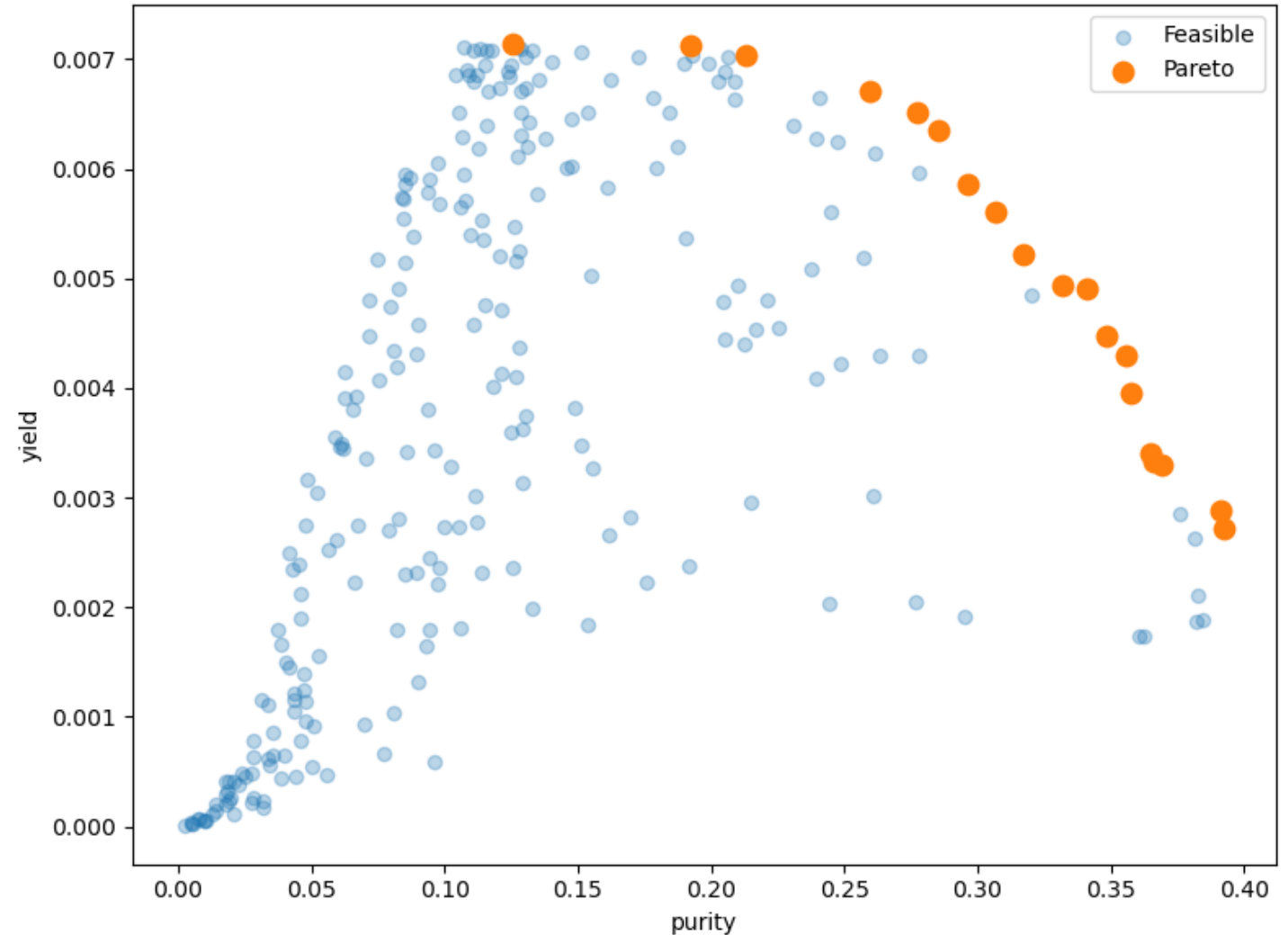
1 hr 44 min – 12 Core Machine

19 Point Pareto Front

- No linear collapse of the in-band yield above 0.9 MV now that GL3 can be co-tuned
- Prominent trade-off curve

Needed Constraint

- Any point with an in-band yield lower than the primary beam should be discarded.



MOB0 Finer Search Constrained

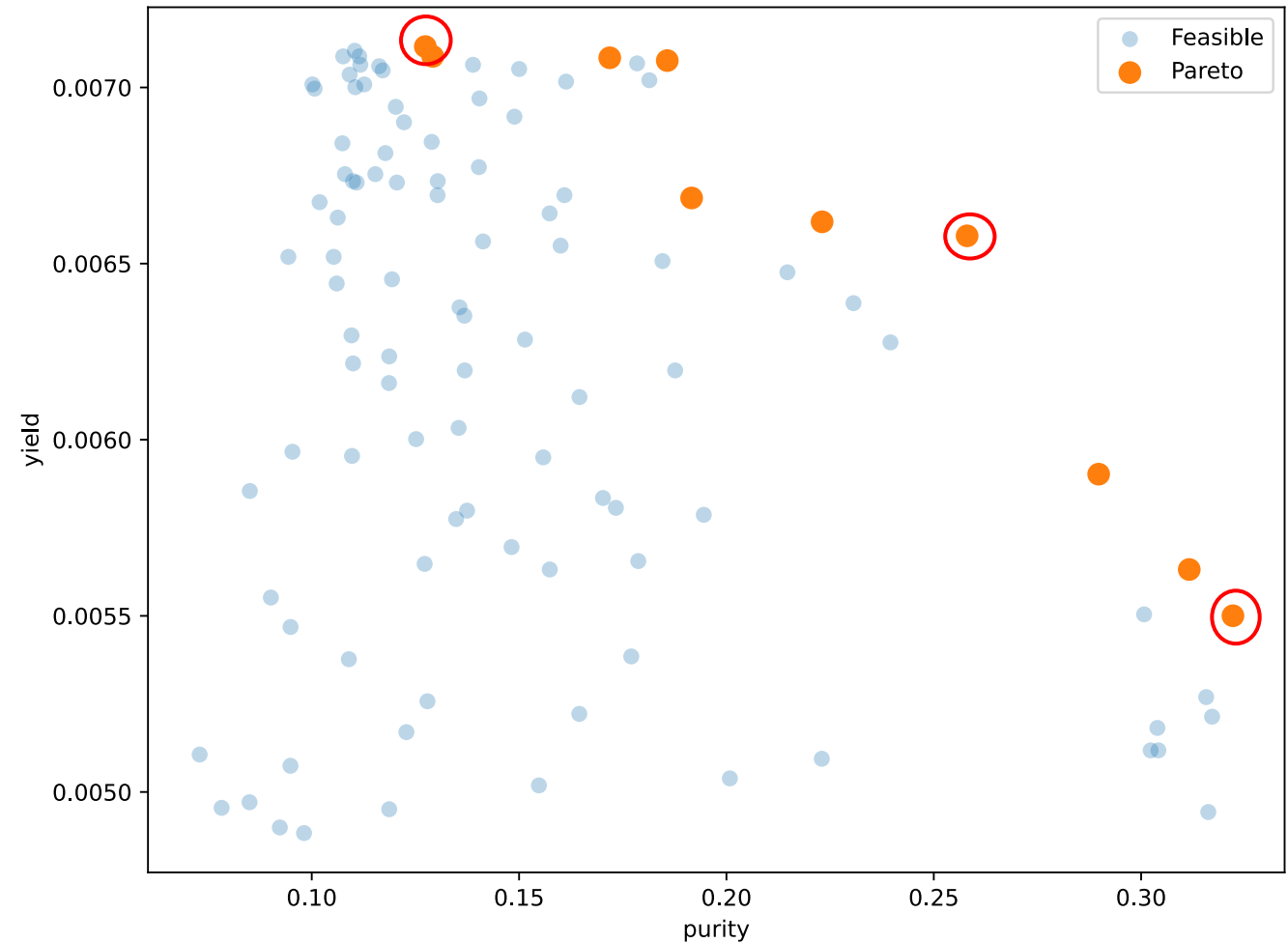
Same Tight Bounds

- RF Voltage – {0.65, 1.05} MV
- GL3B – {0.75, 0.92}
- COL Aper. – {0.3, 4} mm

10 Point Front - 3 Highlights

- Purity Favoured
 - 32% purity, 12% yield increase
 - 0.978 MV, 0.8420 T, 1.02 mm
- Balanced
 - 26% purity, 34% yield increase
 - 0.70 MV, 0.835 T, 1.57 mm
- Yield Favoured
 - 13% purity, 45% yield increase
 - 0.975 MV, 0.853 T, 3.3 mm

GL3 Field converges to 0.83 – 0.86 T equiv.
across all trade-offs



Thank You

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Phase Space at Col Entrance - X-Y, X-KE

Cavity Parameters

- Frequency – 50 MHz
- Gap Length – 0.26 m
- Voltage – 0.9 MV

Gabor Lens 3 Parameters

- Length – 0.857 m
- Field – 0.84 T equivalent

Collimator Parameters

- Length – 1 cm
- Radial aperture – 2.0 mm

