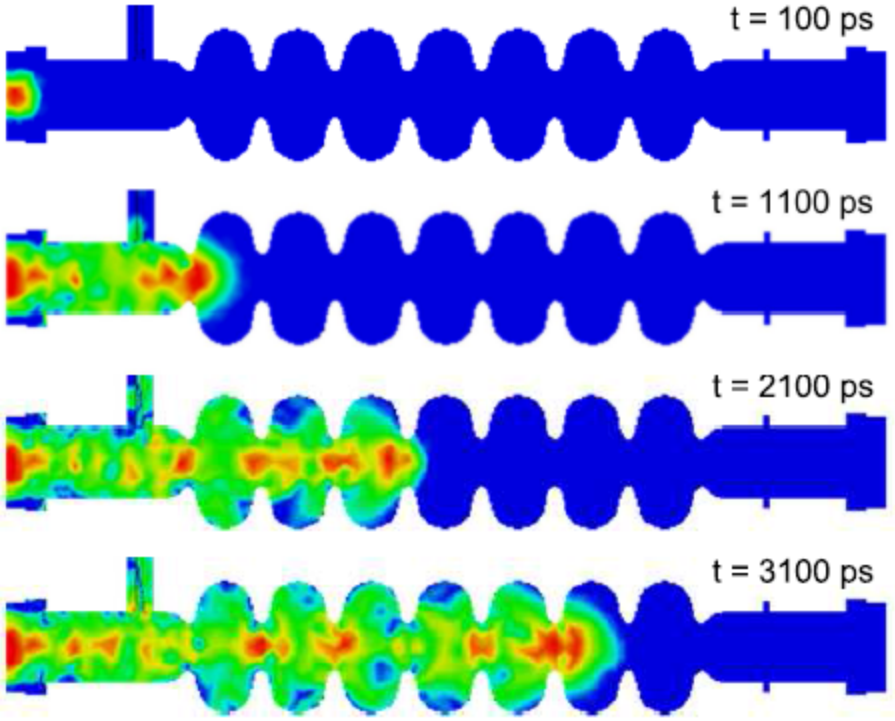
BBU simulation



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Beam breakup Instability (BBU)

- Higher Order Modes (HOM) in the cavities give undesired kick.
- Off-orbit bunch returns to the cavities and excite more HOMs…

- BBU limits the maximum achievable current in an ERL ⟹ threshold current I_{th}

- I_{th} decreases with # recirculation turns.

Design current of CBETA

Design current (mA)	KPP	UPP
1-pass	1	100
4-pass	1	40

BBU simulation on Bmad

- Given a complete lattice with multi-pass cavities and HOMs assigned…

- Starts with a test current…

1. tracks off-orbit bunches through lattice
2. computes bunch-HOM momentum exchanges
3. determines stability of all HOM voltages

- Attempts different test currents to pin down I_{th}

Nick Valles simulation for 1-cavity dipole HOMs

	Frequency (Hz)	R/Q Ohm/m^(2n)	Q	mode	Polarization_Angle (Radians/2pi)
&long_range_modes					
lr(1) =	8.8302e9	7765.5	606830.	1	0.
lr(2) =	3.0751e9	3901.5	310240.	1	0.
lr(3) =	2.549e9	81610.	6229.9	1	0.
lr(4) =	1.7041e9	51754.	1654.5	1	0.
lr(5) =	1.7381e9	42511.	1755.8	1	0.
lr(6) =	1.8702e9	39137.	1610.	1	0.
lr(7) =	1.8558e9	25852.	1598.9	1	0.
lr(8) =	1.8711e9	42890.	789.99	1	0.
lr(9) =	1.872e9	40762.	653.48	1	0.
lr(10) =	1.6766e9	11687.	707.34	1	0.
/					

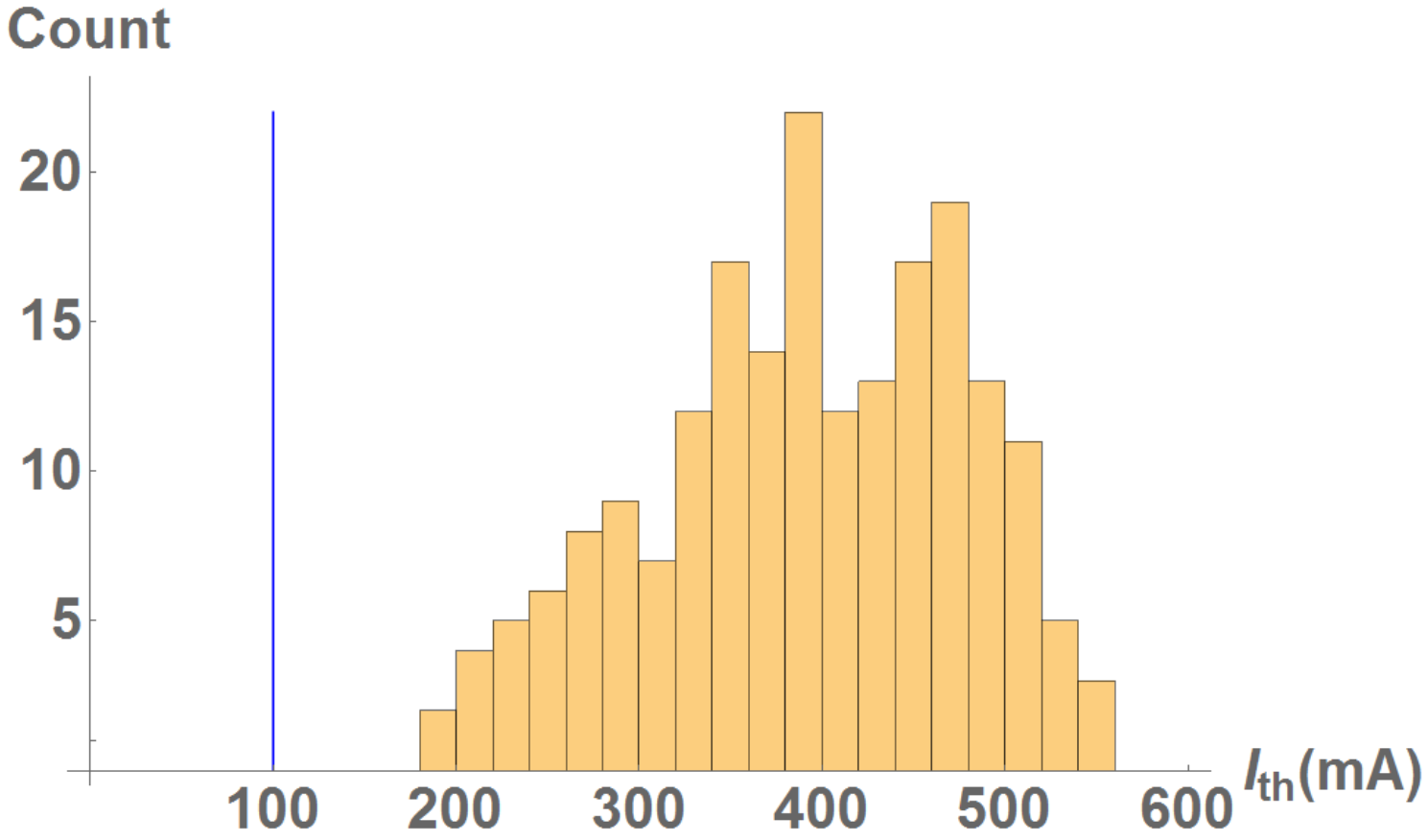
- Cavity construction error: ± 125 μm, 250 μm…
- 400 unique cavities provided per error case.

The "10 worst dipole HOMs" (large figure of merit) provided per cavity.

$$\xi_\lambda = (R/Q)_\lambda \frac{\sqrt{(Q_L)_\lambda}}{f_\lambda}$$

CBETA 1-pass

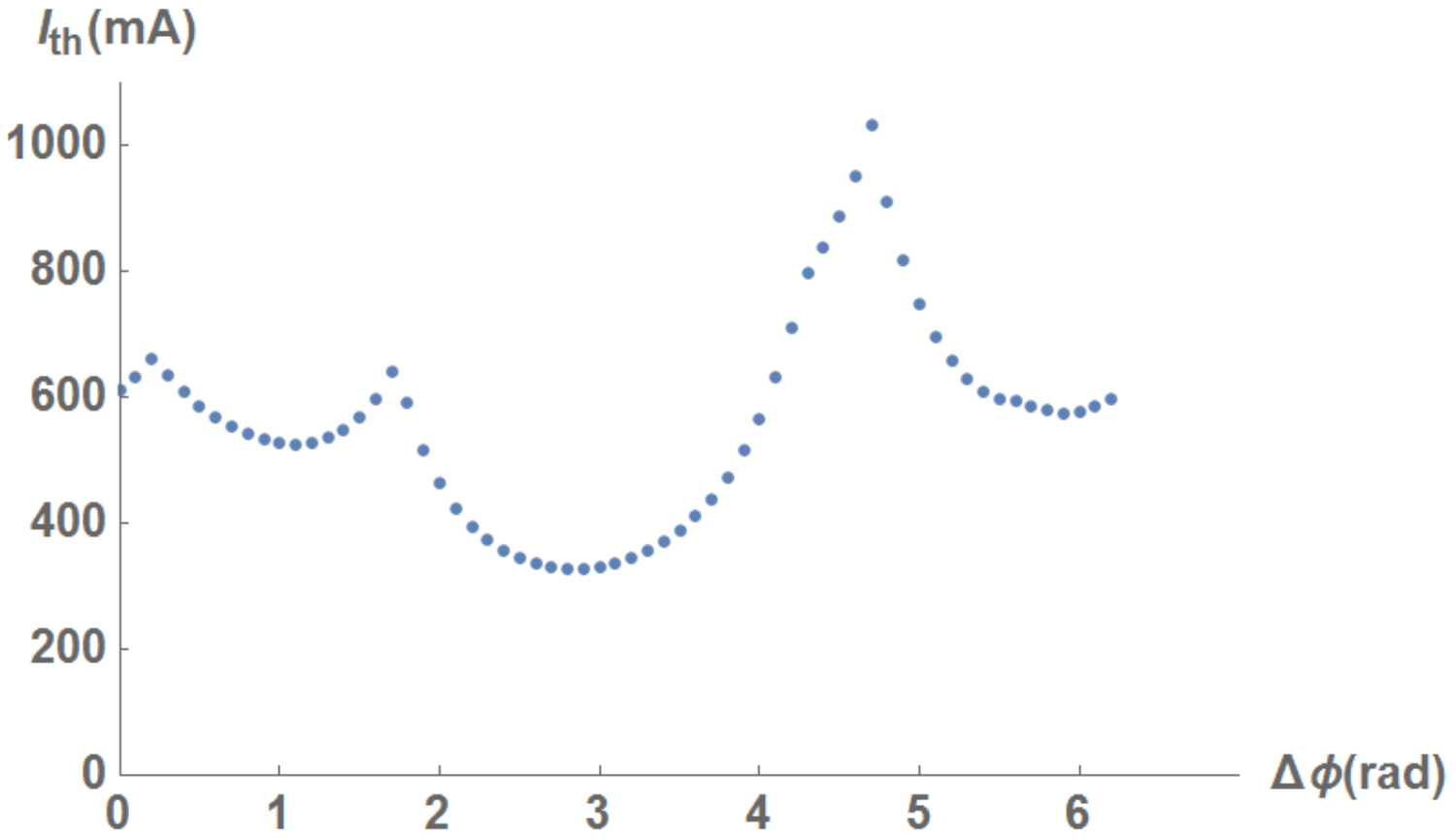
Cavity shape error: 125 μm
HOM assignment: random (10 dipole/cavity)



All 200 I_{th} results > UPP (100mA)

CBETA 1-pass

I_{th} v.s phase advance Δϕ

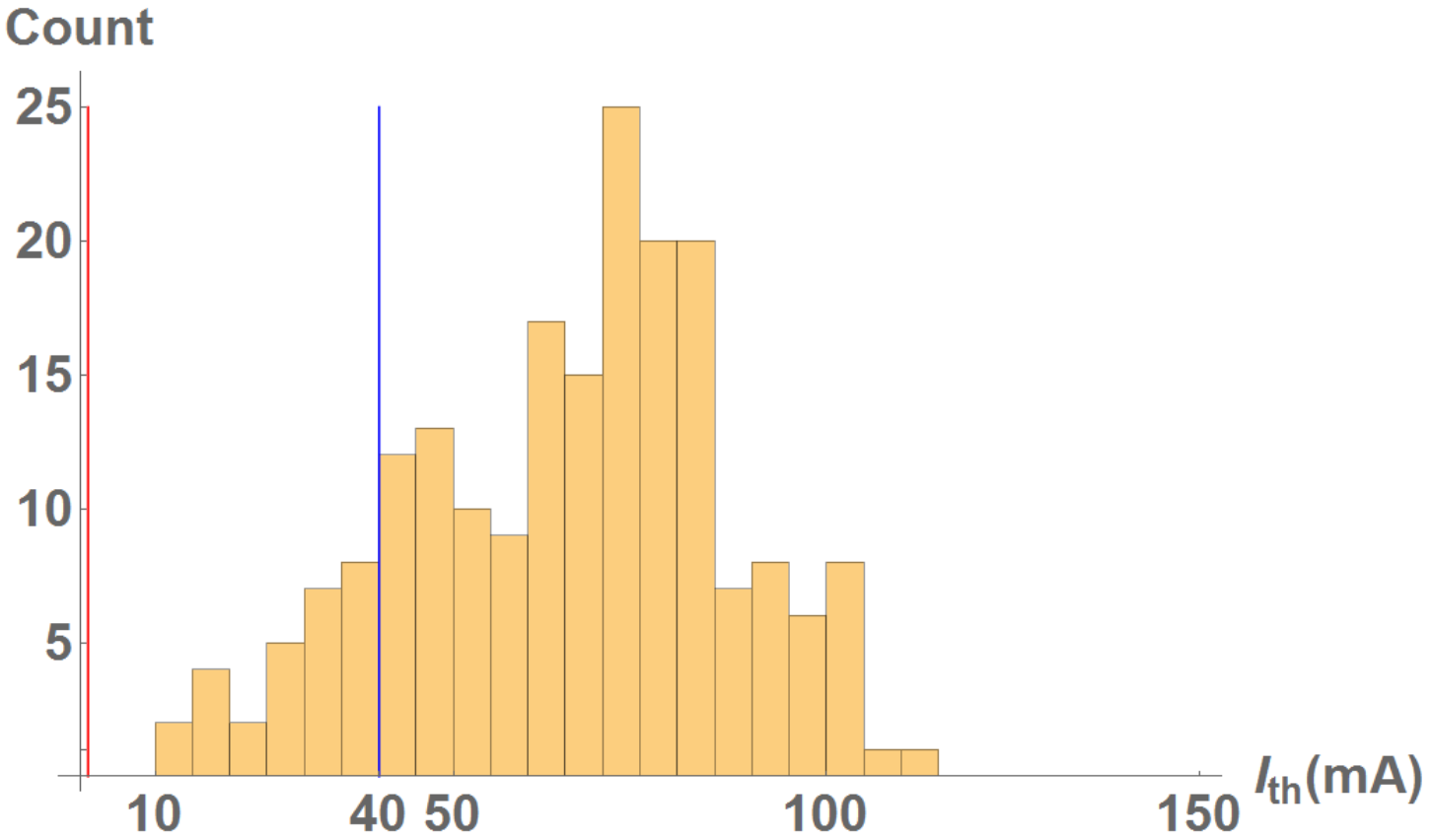


I_{th} results can vary significantly

CBETA 4-pass

Cavity shape error: 125 μm

HOM assignment: random (10 dipole/cavity)



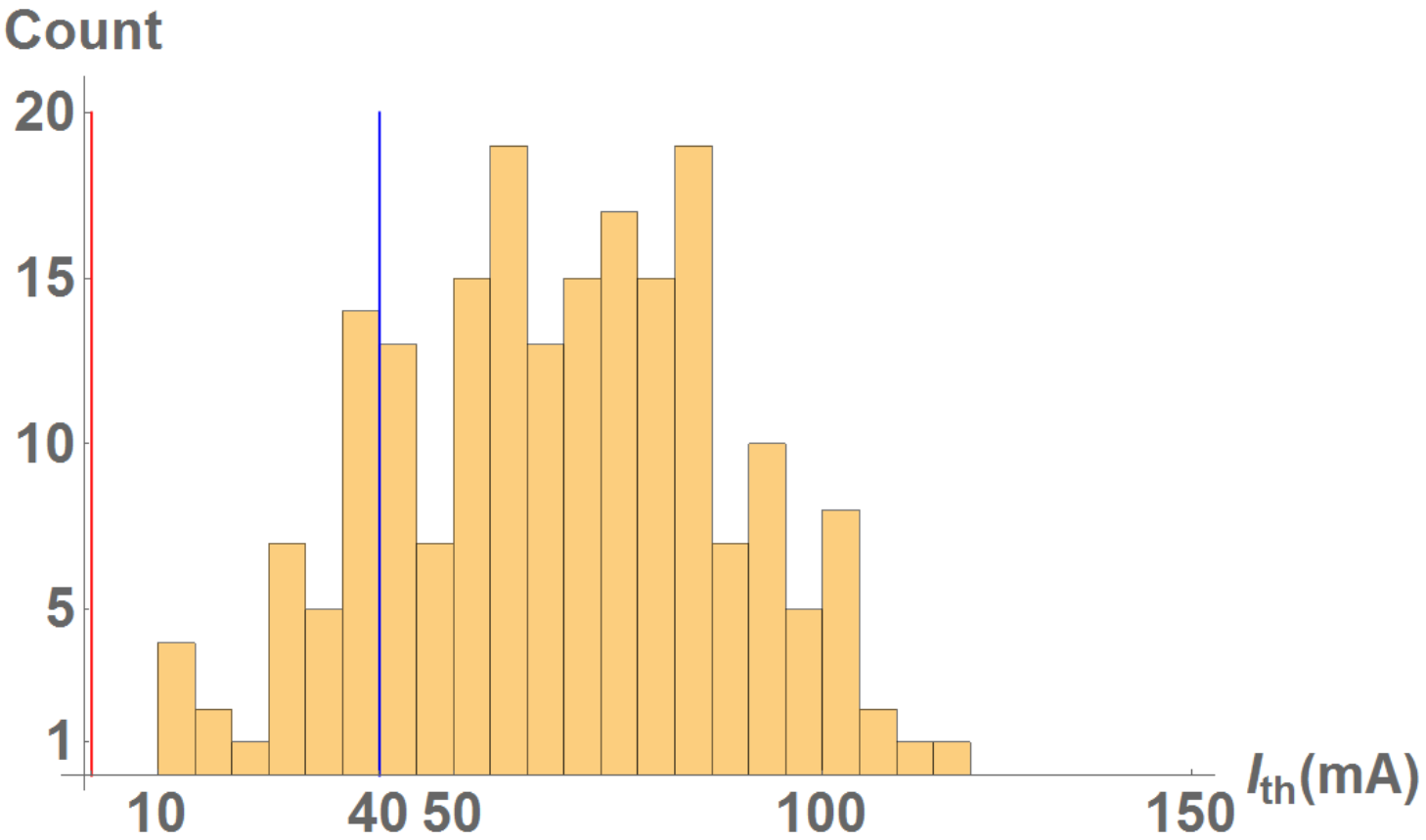
All I_{th} results above KPP (1mA)

28 out of 200 below UPP (40mA)

CBETA 4-pass

Cavity shape error: 250 μm

HOM assignment: random (10 dipole/cavity)



All I_{th} results above KPP (1mA)

33 out of 200 below UPP (40mA)

Aim for better I_{th}

Potential ways to improve I_{th} :

1) Change bunch frequency
2) Vary phase advance
3) x-y coupling of beam optics

Does I_{th} vary with bunch frequency?

fb / (1.3 GHz)	4-pass I_{th} (mA)
1	40.0
1/2	48.8
1/4	49.5
1/8	46.0
1/16	45.8

Future…

- Vary phase-advance for CBETA 4-pass
- Check if x-y coupling affects I_{th}
- Improve simulation accuracy
  (Use actual measured HOM data)

References

- BBU paper by Georg and Ivan
- Bmad manual
- Nick Valles's dissertation

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THE END

RFC cavity HOMs from Nick Valles

Shape variations in the optimized 7-cell cavity geometry were simulated by adding random errors to each ellipse parameter from a uniform distribution for the error cases of ±1/8, ±1/4, ±1/2 and ±1 mm. These resulting cavity shapes were tuned cell by cell to 1.3 GHz to ensure field flatness. Subsequently the dipole mode spectrum was calculated up to 10 GHz, using 4 boundary conditions at the at the center plane of the HOM beamline absorbers at the ends of the cavity beamtubes (electric-electric, magnetic-magnetic, electric-magnetic and magnetic-electric) to simulate the superposition of HOMs that are possible for a cavity in a long cavity string.