FES Commissioning

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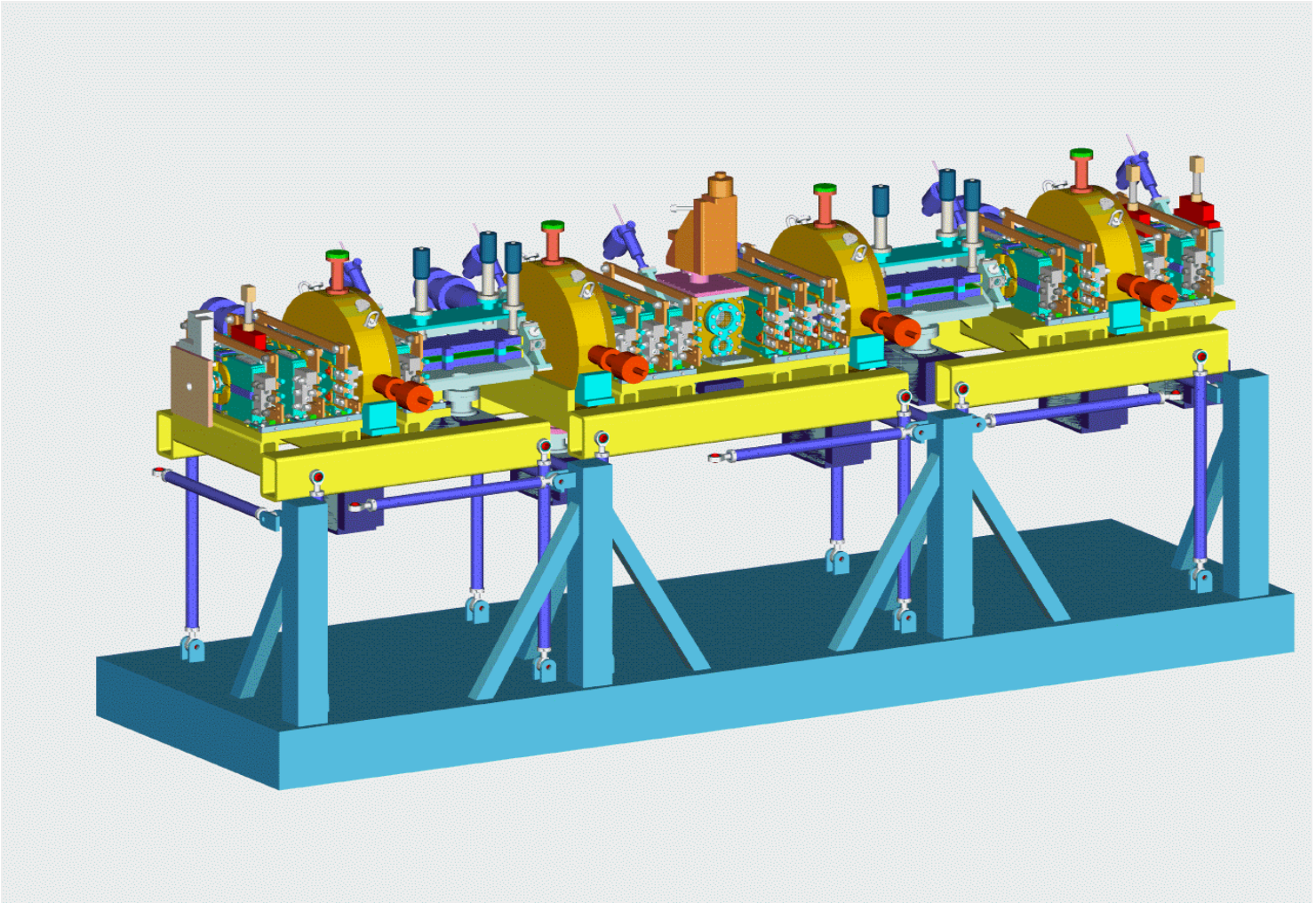
Overview

- FES Tuning
- Beam Parameter Range
- Diagnostic Plate
- Warmup
- Training and Safety
- Issues beyond FES

FES Tuning

- Knobs:
  - 11 quad (central 6 quads in 3 families
  - 8 rebuncher (4 amplitude, 4 phase)
  - 12 steering (6 x, 6 y steerers)
  - Chopper target position
- Diagnostics
  - 5 x, 5 y profile (wires, non-intercepting later)
  - 6 x, 6 y centroid from 6 BPMs
  - 6 phase monitors from same 6 BPMs
  - 2 toroids
  - Emittance device (very low power)

MEBT Layout



Beam properties in the front end:

About 60 mA out of the source

At least 52 mA (peak) out of the RFQ

645 ns on, 300 ns off during mini-pulse, "20 μs" ramp of the pulse width at leading edge of macropulse

Maximum power conditions: 1 ms macropulse length, 60 Hz

Power must be reduced when diagnostic devices are inserted, typical 10 to 100 μS pulse length, 2 to 10 Hz.

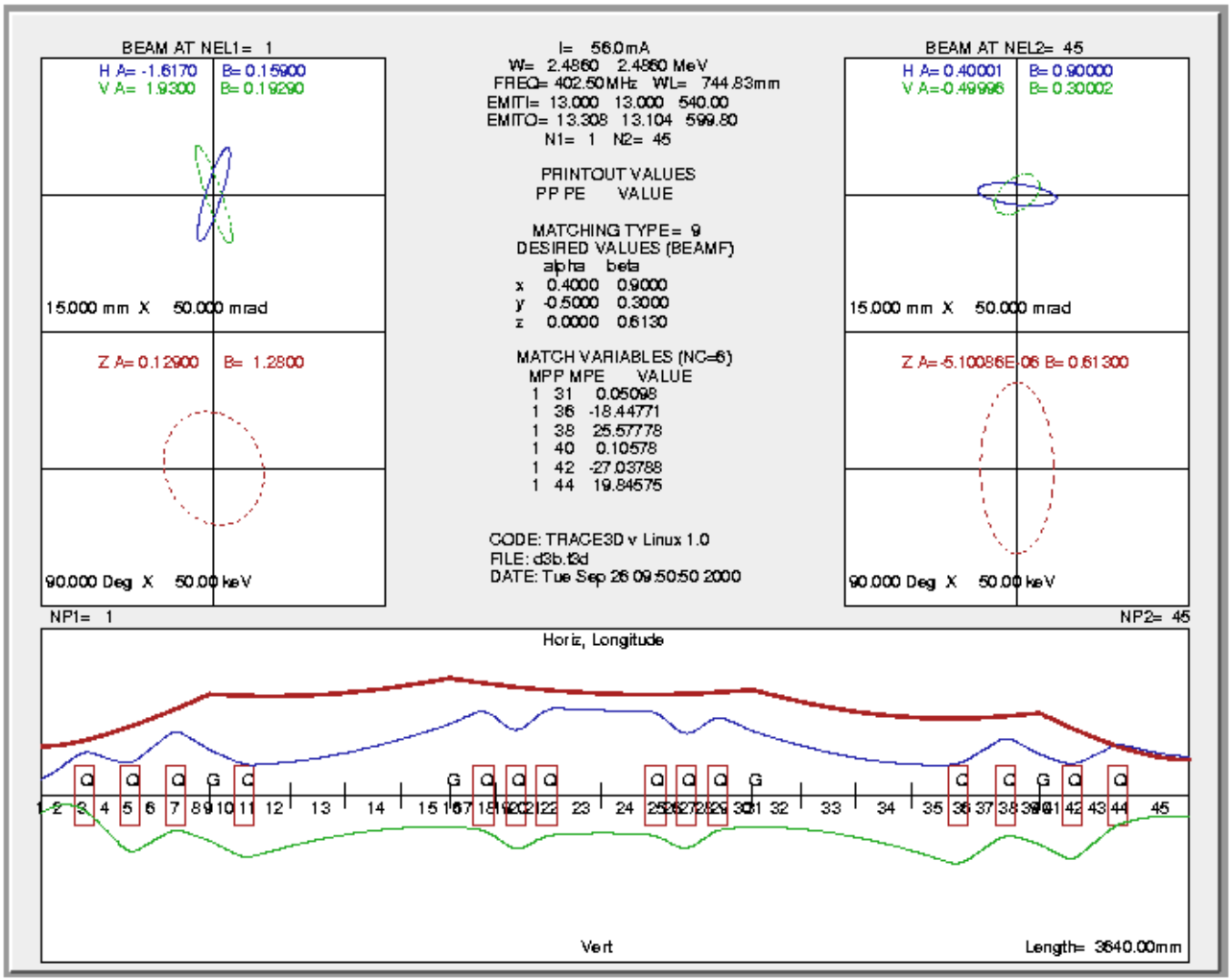
Can run "single turn injection" mode, only a single $\leq$645 ns pulse at up to 60 Hz.

Pulse-on-demand mode is inherently part of ALARA.

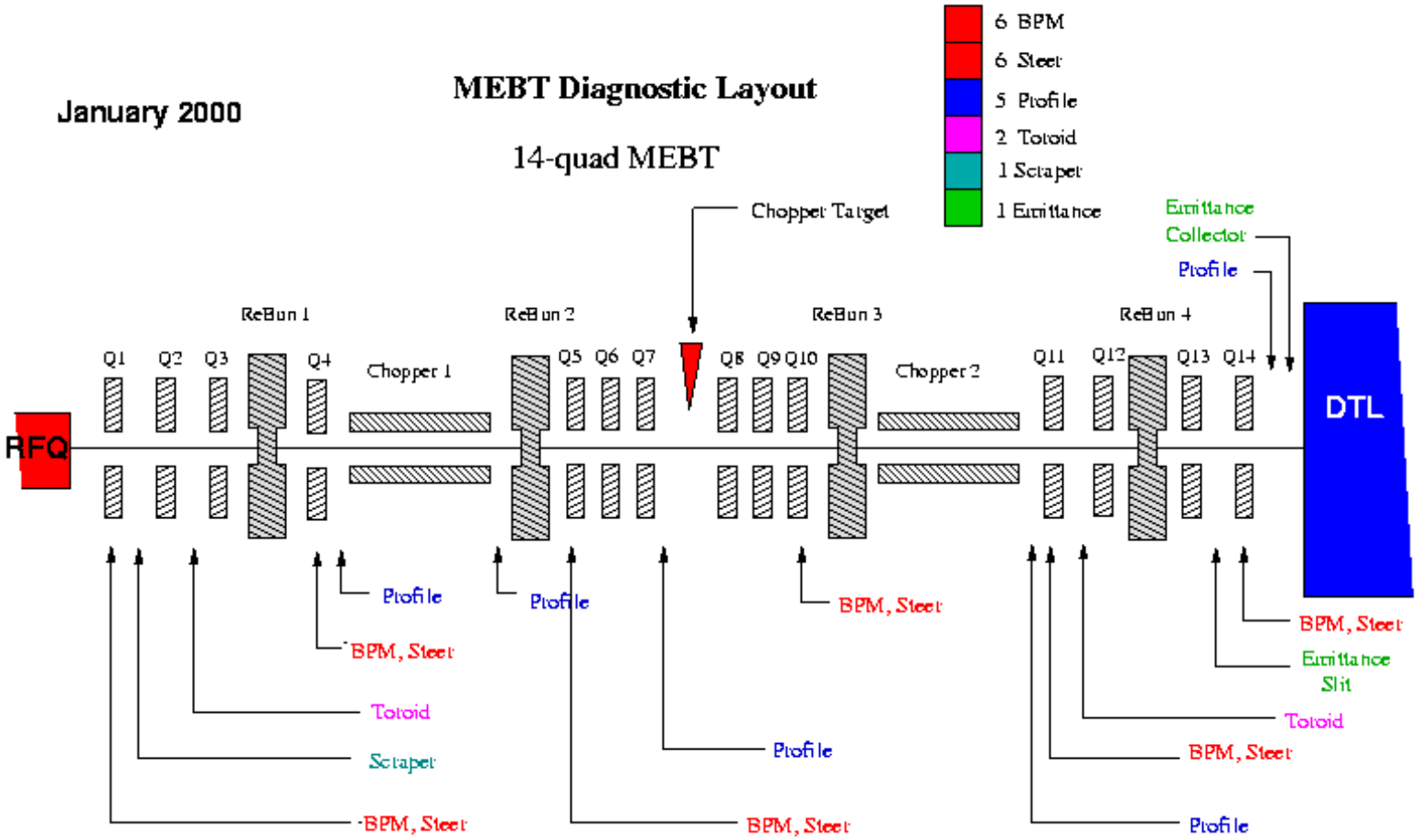
Because of thermal conditioning needs (e.g., plasma, accelerating cavities), in many of the reduced power modes, the high voltage and RF systems will cycle at a steady 6 to 60 Hz rate. Only the beam will be gated to lower (or even zero) rep rate with the LEBT chopper.

In MEBT (ignoring the 402.5 MHz RF microstructure):
52 mA $\cdot$ 2.5 MeV = 130 kW peak
52 mA $\cdot$ 2.5 MeV $\cdot$ 0.68 D.F. = 88 kW avg. over 1 ms
52 mA $\cdot$ 2.5 MeV $\cdot$ 0.68 D.F. $\cdot$ .06 D.F. = 5.3 kW thermal

MEBT Beam Envelope



MEBT Diagnostics



FES Tuning 2

- Diagnostics give slightly overdetermined set
- RFQ characteristics assumed known
  - fairly independent of ion source emittance
- Redundancy:
  - Quads: mag measurements + beam-based
  - Cavities: r.f. probes and TOF
- MEBT chopper power supply:
  - run at low or d.c. to set $M_{16}=M_{26}=0$

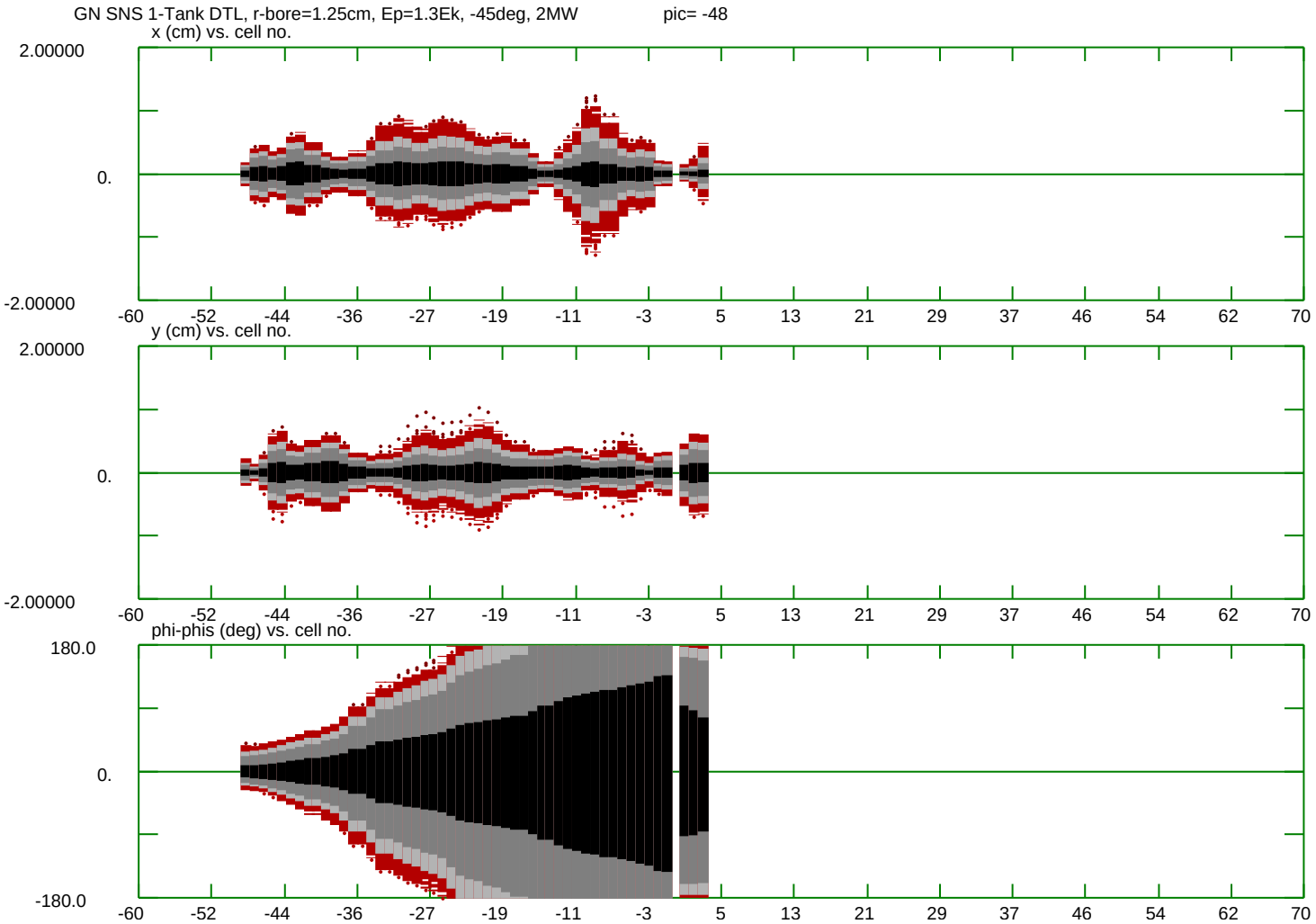
Beam Parameter Range

- Full 2 MW operation
- Enhanced, for 2-ring operation
  - implications of supercycle interaction
- Reduced Specs
  - single-turn for ring studies
  - low current
  - full current, low duty-factor
  - other special tuning/operation modes

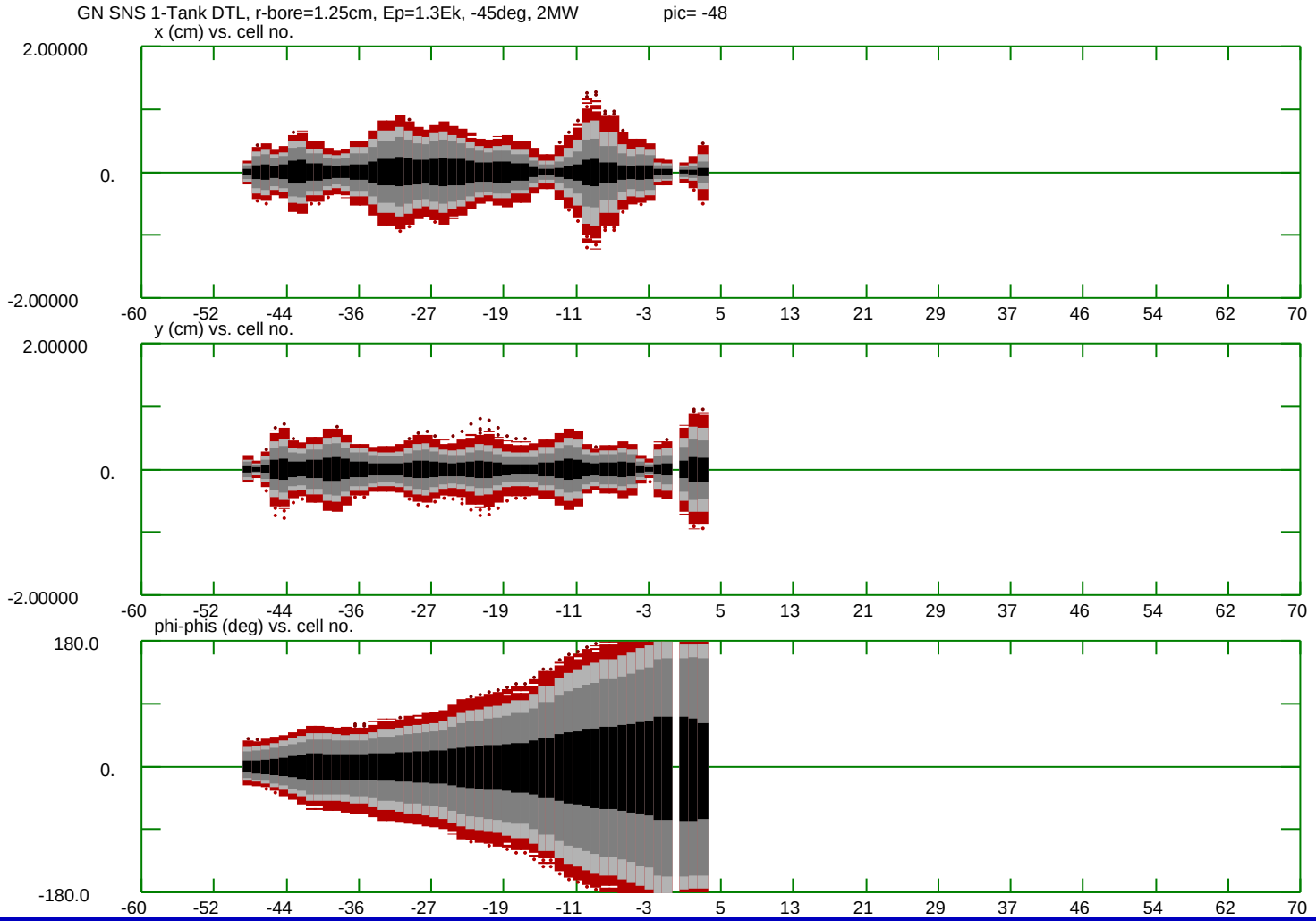
Rebuncher Cavity Tuning

- 4 Cavities, tune amplitude and phase of each
- Use TOF technique with BPMs
- Observe 805 MHz beam component
- Beam debunches fast: make sure that enough survives to do a TOF measurement
- Turn on rebuncher in sequence
- No pulse shape monitors in MEBT

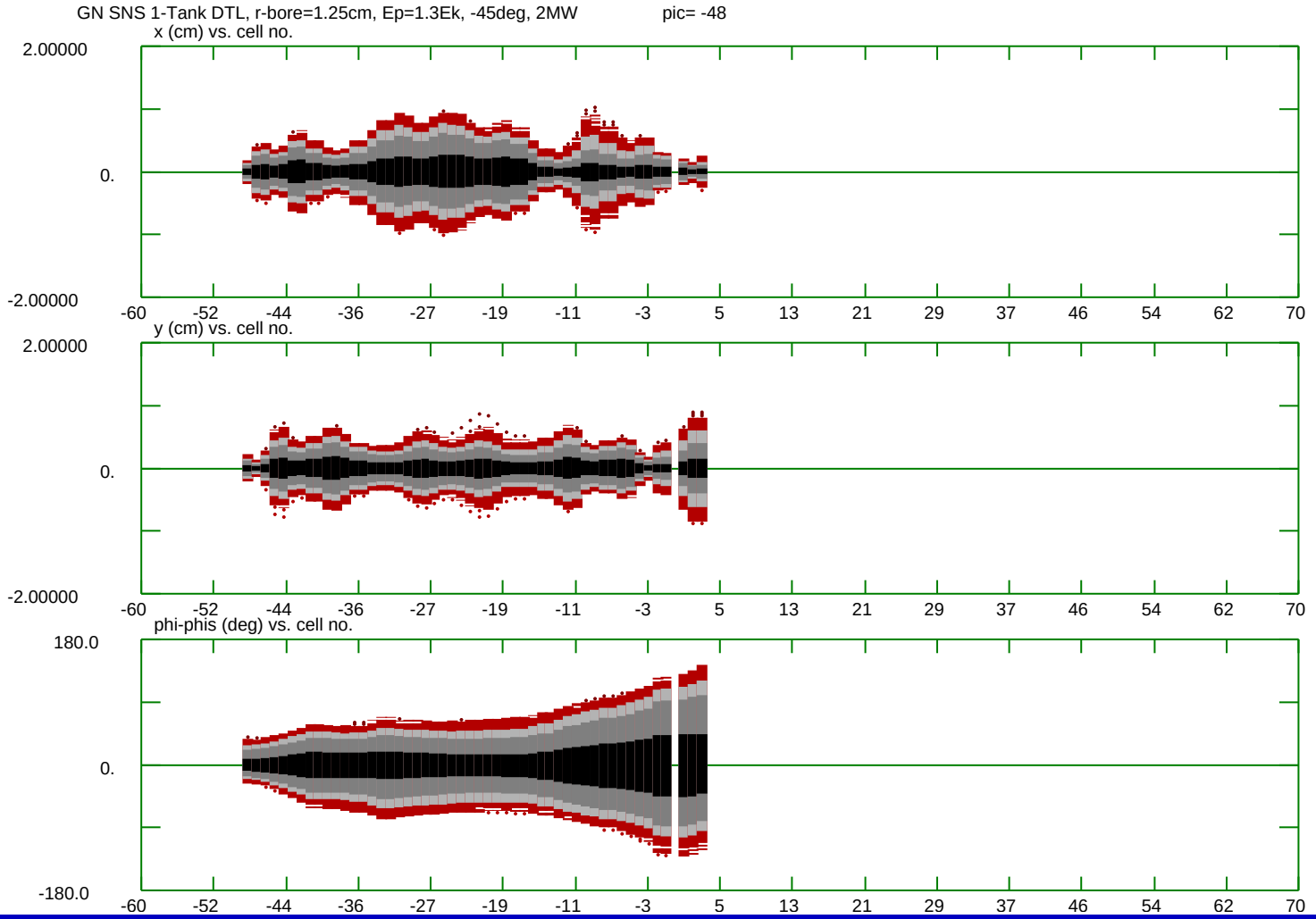
No rebunchers on



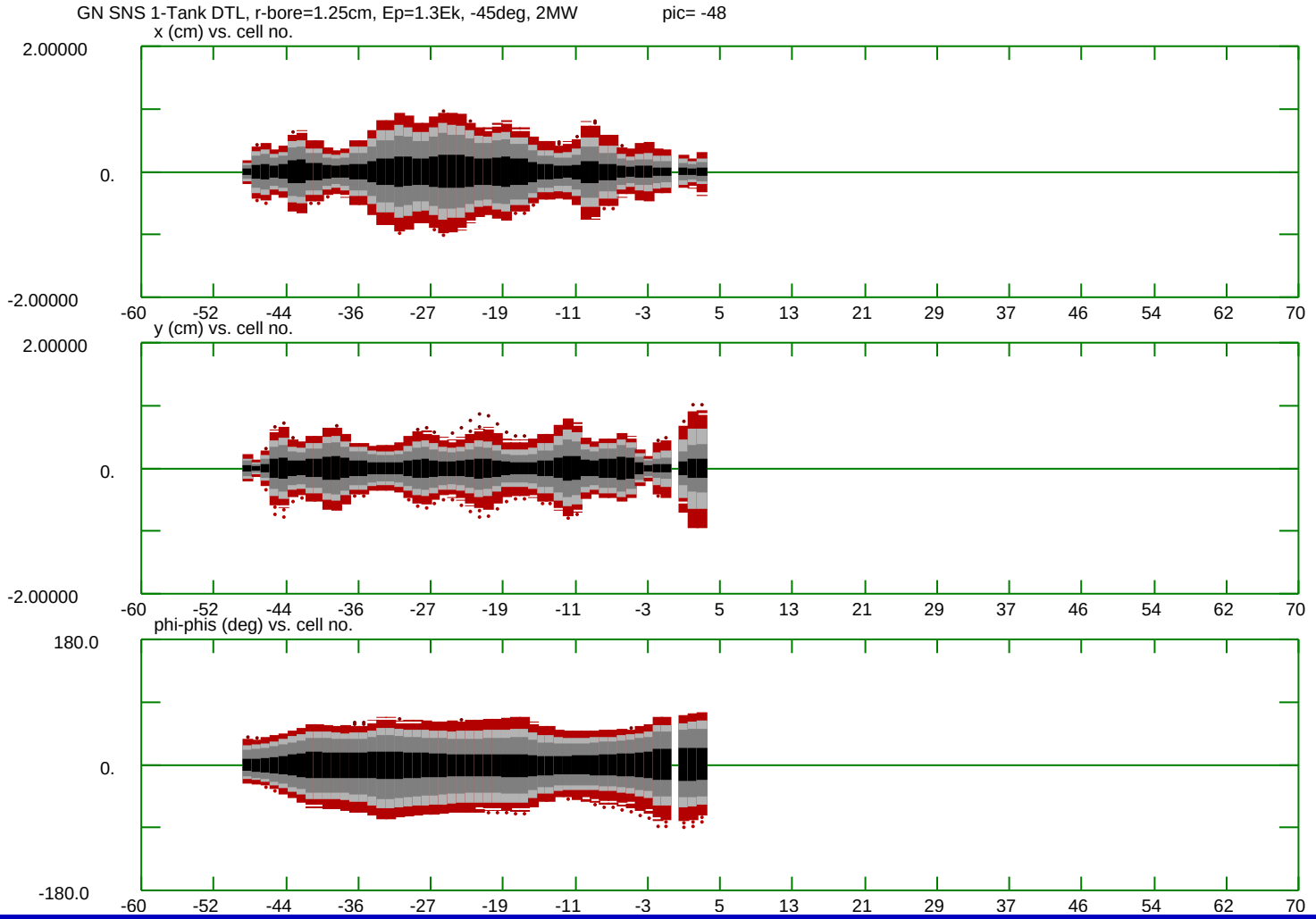
Rebuncher 1 on



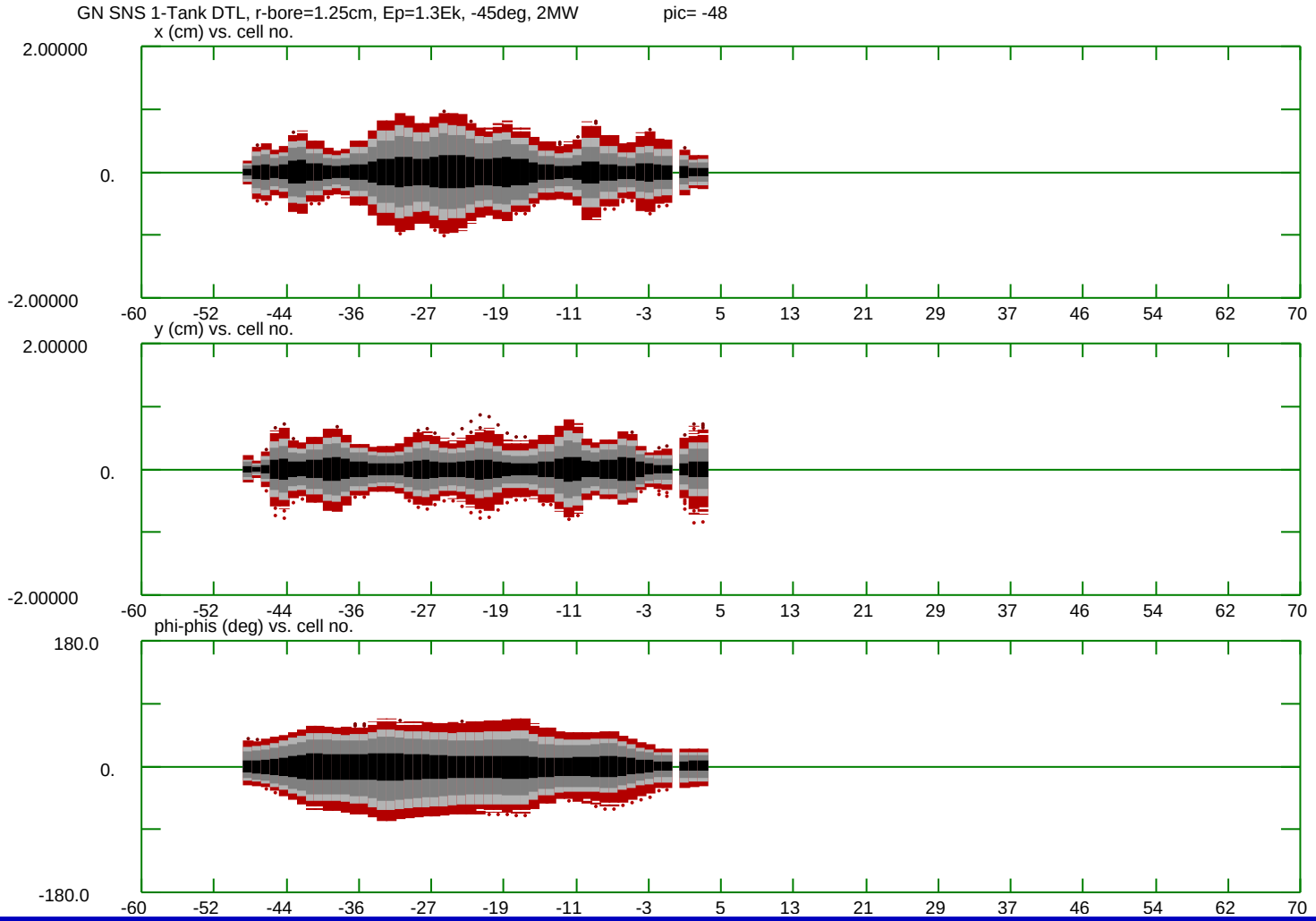
Rebunchers 1,2 on



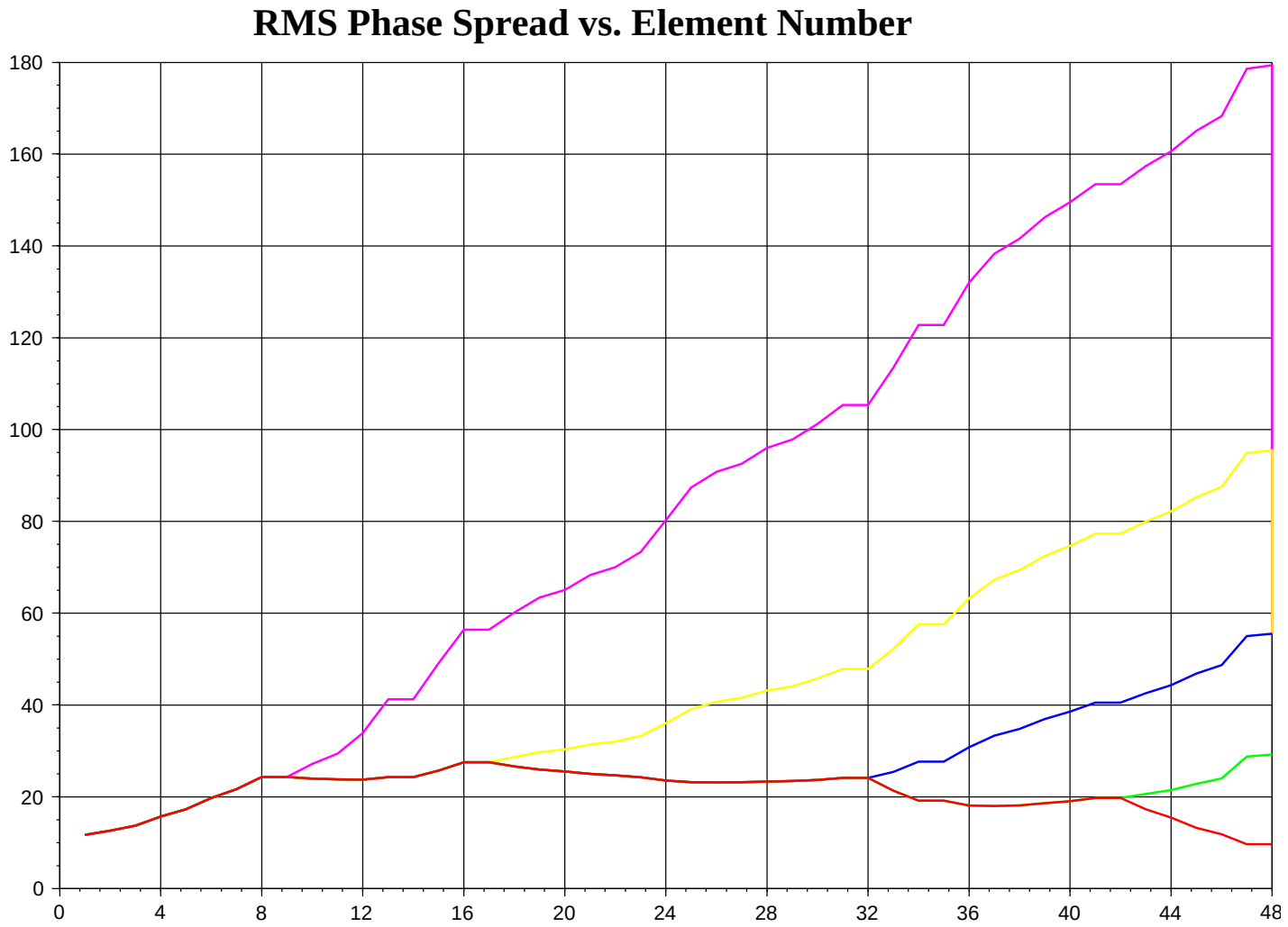
Rebunchers 1, 2, 3 on



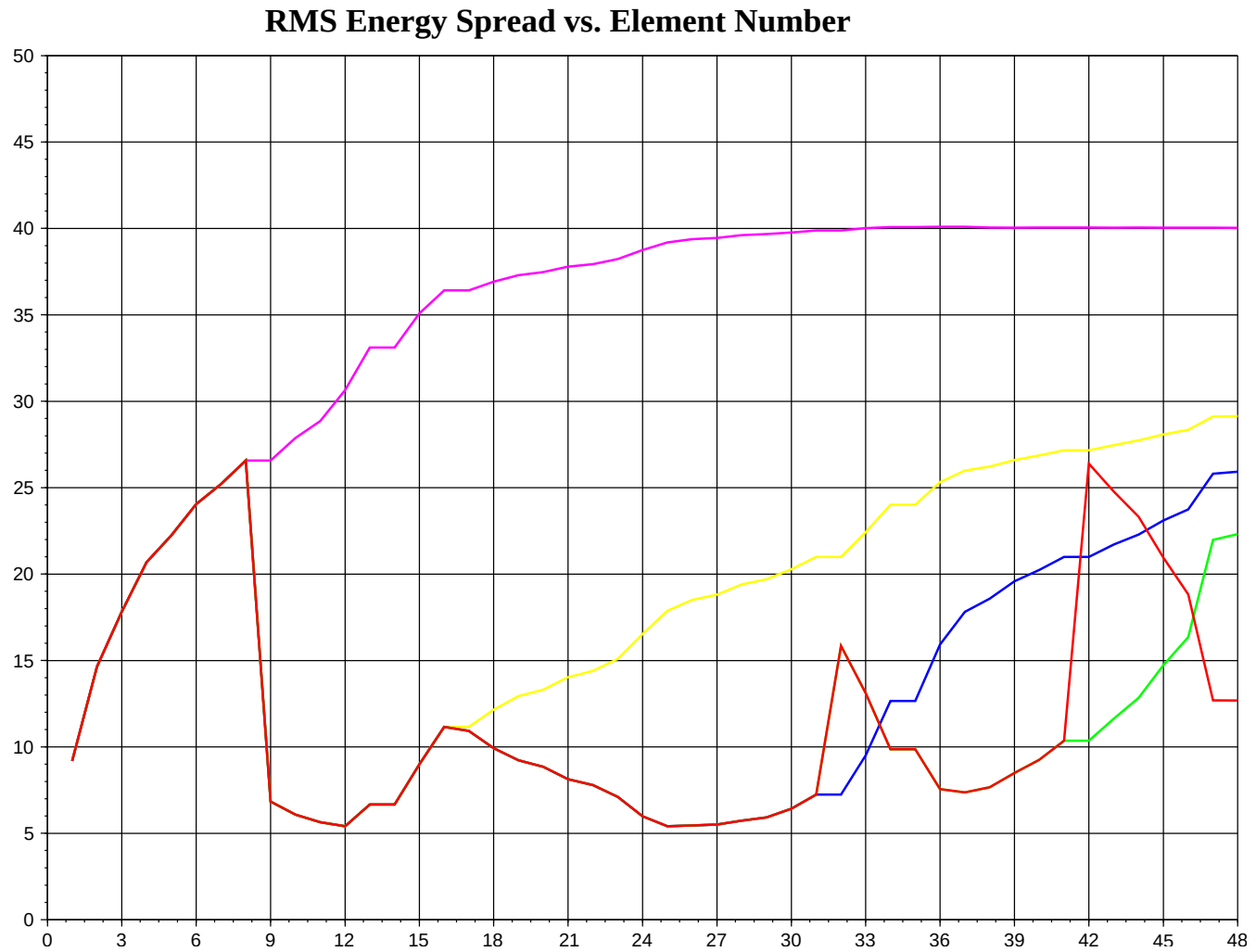
All Rebunchers on



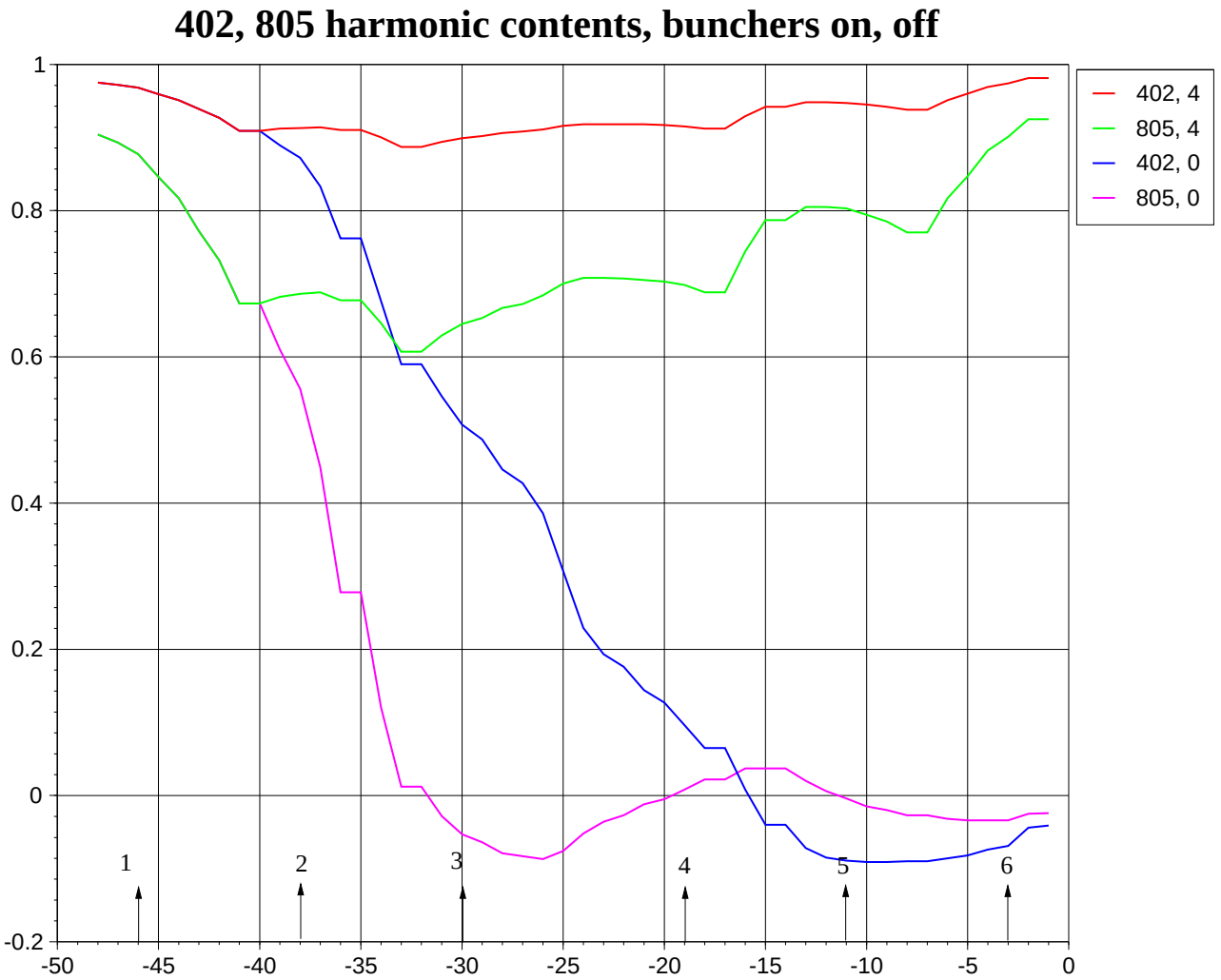
RMS Phase Spread



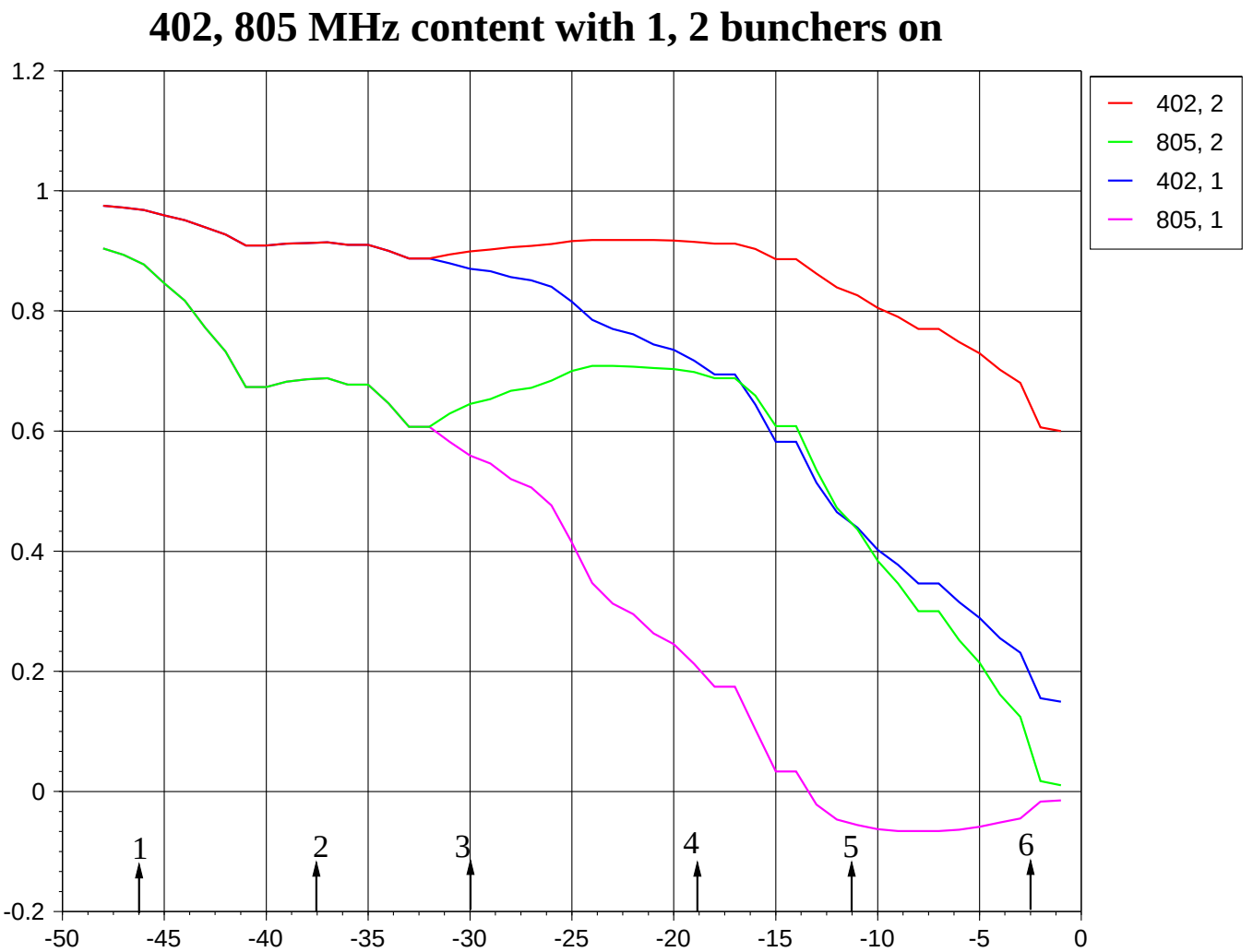
RMS Energy Spread



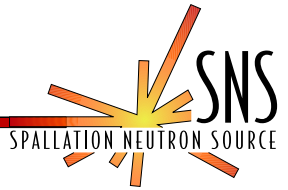
402,805 Harmonic Content



402, 805 Harmonic Content



Profile Monitors



- Measure x, y profile at 5 locations
- Needed to tune quads
- Non-intercepting desired
- Will use wires initially
- Power density significant
  - up to 500 kW/cm^2
  - independent of pulse length

Beam Power Density

	MEBT into 7.5 MeV DTL										energy =	2.5	MeV
	Beam size at profile monitors								beta =	0.073	current =	52	mA
Device	nc	Length (cm)	Location (cm)	alpha_x	beta_x (m)	emitt_x (cm-mrad)	alpha_y	beta_y (m)	emitt_y (cm-mrad)	sig(x) (cm)	sig(y) (cm)	Peak Pwr Density (kw/cm^2)	
	1		0.00	-1.607	0.160	0.0203	1.983	0.196	0.0206	0.067	0.074	4173	
	2	10.45	10.45	-5.446	0.860	0.0206	-0.602	0.069	0.0205	0.156	0.044	3019	
Q1, BPM, Steer	3	6.10	16.55	2.842	1.033	0.0210	-4.324	0.321	0.0205	0.172	0.095	1265	
Scraper	4	8.40	24.95	1.805	0.634	0.0214	-10.042	1.516	0.0206	0.136	0.207	734	
Q2	5	6.10	31.05	-5.172	0.802	0.0215	6.145	1.793	0.0207	0.154	0.225	597	
Toroid	6	8.40	39.45	-8.387	1.926	0.0217	4.107	0.922	0.0210	0.239	0.163	531	
Q3	7	6.10	45.55	6.525	2.045	0.0218	-2.339	0.825	0.0211	0.247	0.154	542	
	8	7.95	53.50	4.642	1.153	0.0219	-3.171	1.255	0.0212	0.186	0.191	583	
Reb 1	9	0.00	53.50	3.672	1.147	0.0220	-4.172	1.245	0.0214	0.186	0.191	583	
	10	7.95	61.45	2.542	0.654	0.0221	-5.614	2.014	0.0215	0.141	0.244	604	
Q4, BPM, Steer	11	6.10	67.55	-0.274	0.527	0.0220	3.323	2.162	0.0215	0.126	0.252	651	
Profile	**12**	11.45	79.00	**-0.741**	**0.645**	**0.0219**	**2.366**	**1.514**	**0.0215**	**0.139**	**0.211**	**705**	
Chop start	13	17.50	96.50	-1.674	1.066	0.0217	1.242	0.900	0.0214	0.178	0.162	716	
	14	0.00	96.50	-1.674	1.066	0.0217	1.242	0.899	0.0214	0.178	0.162	716	
Chop end	15	17.50	114.00	-2.932	1.859	0.0218	0.455	0.616	0.0212	0.236	0.134	657	
Profile	**16**	15.50	129.50	**-4.259**	**2.925**	**0.0222**	**-0.080**	**0.564**	**0.0211**	**0.298**	**0.128**	**544**	
Reb 2	17	0.00	129.50	-5.782	2.918	0.0222	-0.397	0.554	0.0215	0.298	0.128	544	
	18	7.70	137.20	-6.862	3.838	0.0226	-0.671	0.638	0.0214	0.345	0.137	439	
Q5, BPM, Steer	19	6.60	143.80	11.141	3.460	0.0229	-5.314	0.999	0.0213	0.329	0.171	368	
	20	3.40	147.20	9.747	2.724	0.0231	-6.381	1.398	0.0213	0.294	0.202	349	
Q6	21	6.60	153.80	-10.176	2.716	0.0234	4.877	1.515	0.0213	0.295	0.210	334	
	22	3.40	157.20	-11.494	3.427	0.0236	4.260	1.203	0.0213	0.333	0.187	332	
Q7	23	6.60	163.80	0.770	4.116	0.0241	0.299	0.921	0.0214	0.369	0.164	342	
Chop Stop, Profile	**24**	13.70	177.50	**0.279**	**3.837**	**0.0249**	**-0.071**	**0.890**	**0.0214**	**0.362**	**0.162**	**354**	

Beam Size, Continued

	25	13.70	191.20	-0.187	3.720	0.0256	-0.455	0.964	0.0213	0.361	0.168	342
Q8	26	6.60	197.80	10.382	2.956	0.0259	-4.677	1.282	0.0213	0.324	0.193	330
	27	3.40	201.20	9.009	2.285	0.0260	-5.357	1.623	0.0212	0.285	0.217	334
Q9	28	6.60	207.80	-7.419	2.188	0.0261	6.769	1.518	0.0210	0.280	0.209	354
	29	3.40	211.20	-8.374	2.720	0.0261	5.653	1.093	0.0210	0.312	0.177	374
Q10, BPM, Steer	30	6.60	217.80	5.542	2.912	0.0263	0.587	0.718	0.0211	0.324	0.144	444
	31	7.70	225.50	4.481	2.135	0.0264	0.316	0.650	0.0211	0.278	0.137	544
Reb 3	32	0.00	225.50	3.165	2.117	0.0266	-0.131	0.641	0.0213	0.278	0.137	545
	33	15.50	241.00	1.977	1.328	0.0266	-0.731	0.774	0.0213	0.220	0.150	626
Chop start	34	17.50	258.50	0.944	0.839	0.0262	-1.699	1.187	0.0213	0.174	0.186	641
	35	0.00	258.50	0.944	0.839	0.0262	-1.701	1.186	0.0213	0.174	0.186	641
Chop end	36	17.50	276.00	0.178	0.664	0.0257	-3.077	1.975	0.0218	0.153	0.243	557
Profile	**37**	11.95	287.95	**-0.265**	**0.682**	**0.0254**	**-4.172**	**2.749**	**0.0226**	**0.154**	**0.292**	**461**
Q11, BPM, Steer	38	6.10	294.05	-4.800	0.965	0.0253	8.319	2.393	0.0232	0.183	0.276	410
Toroid	39	8.90	302.95	-7.341	2.040	0.0253	5.364	1.130	0.0239	0.266	0.192	405
Q12	40	6.10	309.05	7.112	2.045	0.0255	-1.894	0.933	0.0242	0.267	0.176	440
	41	7.45	316.50	5.043	1.130	0.0257	-2.450	1.241	0.0246	0.199	0.204	508
Reb 4	42	0.00	316.50	3.771	1.134	0.0256	-3.867	1.244	0.0245	0.199	0.204	508
	43	7.45	323.95	2.626	0.654	0.0257	-5.054	1.884	0.0249	0.152	0.254	538
Q13	44	6.10	330.05	-1.941	0.615	0.0258	7.609	1.676	0.0252	0.147	0.241	584
Emitt slit	**45**	8.40	338.45	**-2.899**	**1.018**	**0.0258**	**4.439**	**0.658**	**0.0254**	**0.190**	**0.151**	**721**
Q14, BPM, Steer	46	6.10	344.55	1.803	1.095	0.0258	1.075	0.351	0.0255	0.197	0.111	950
Profile, Emitt collector	**47**	19.45	364.00	**0.246**	**0.728**	**0.0251**	**-0.496**	**0.249**	**0.0250**	**0.158**	**0.092**	**1417**
DTL Entrance	48	1.50	365.50	1.852	0.697	0.0251	-1.280	0.275	0.0250	0.155	0.097	1378

Power Density

- Power density typically 500 kW/cm^2
- Will restrict pulse length to a few microseconds
- No tuning beam stop possible in MEBT
- MEBT chopper protection will be critical

Profile Diagnostic

- Need rapid feedback to operator
- Need ability to do multi-dimensional display of beam size vs. multiple quad tunes
- Second moment problem: some embedded software may help sort it all out

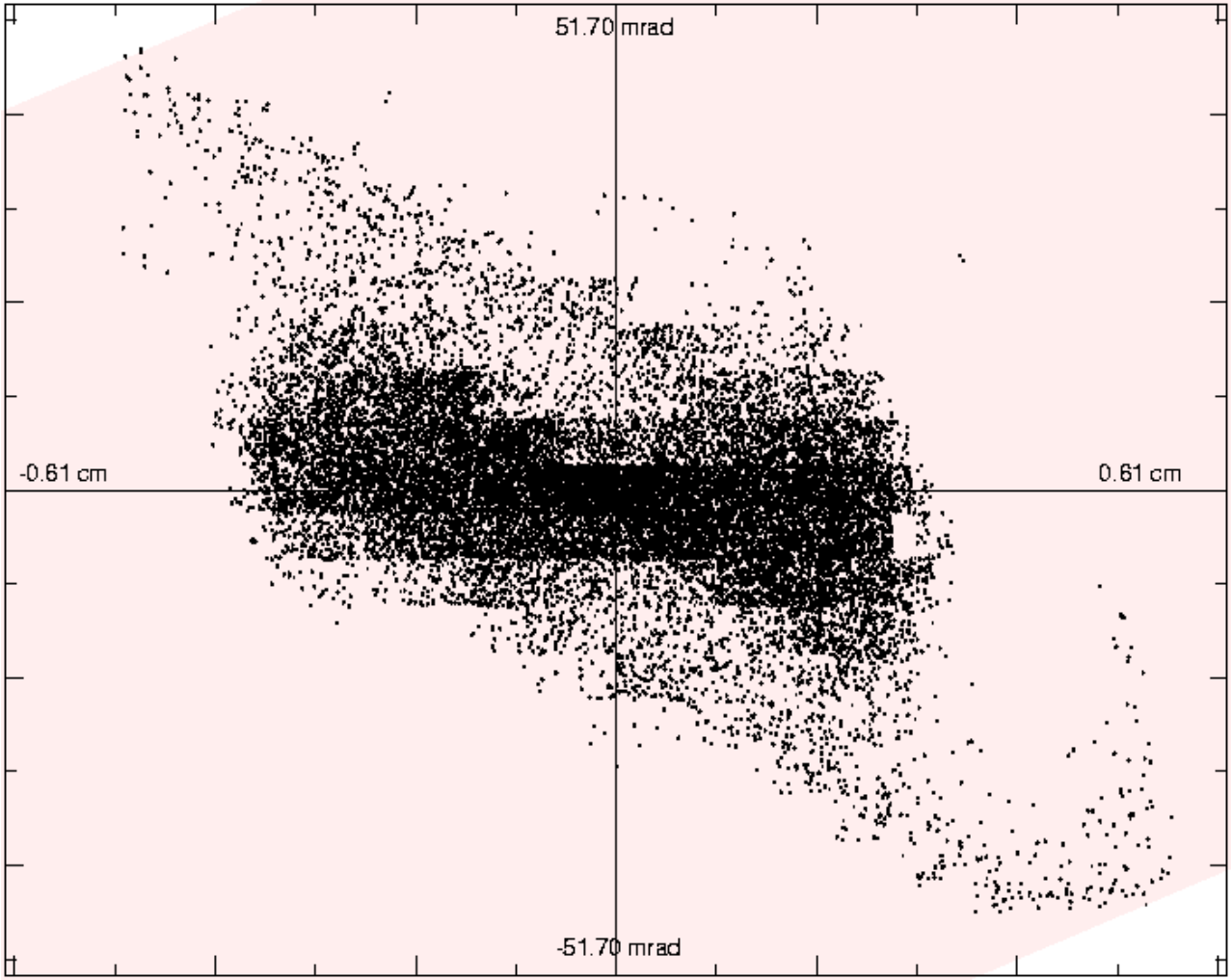
Beam Steering

- First run-thru: center in BPMs
- Check: check for quad steering
  - resolve differences
- Emittance growth reduced when steering invoked

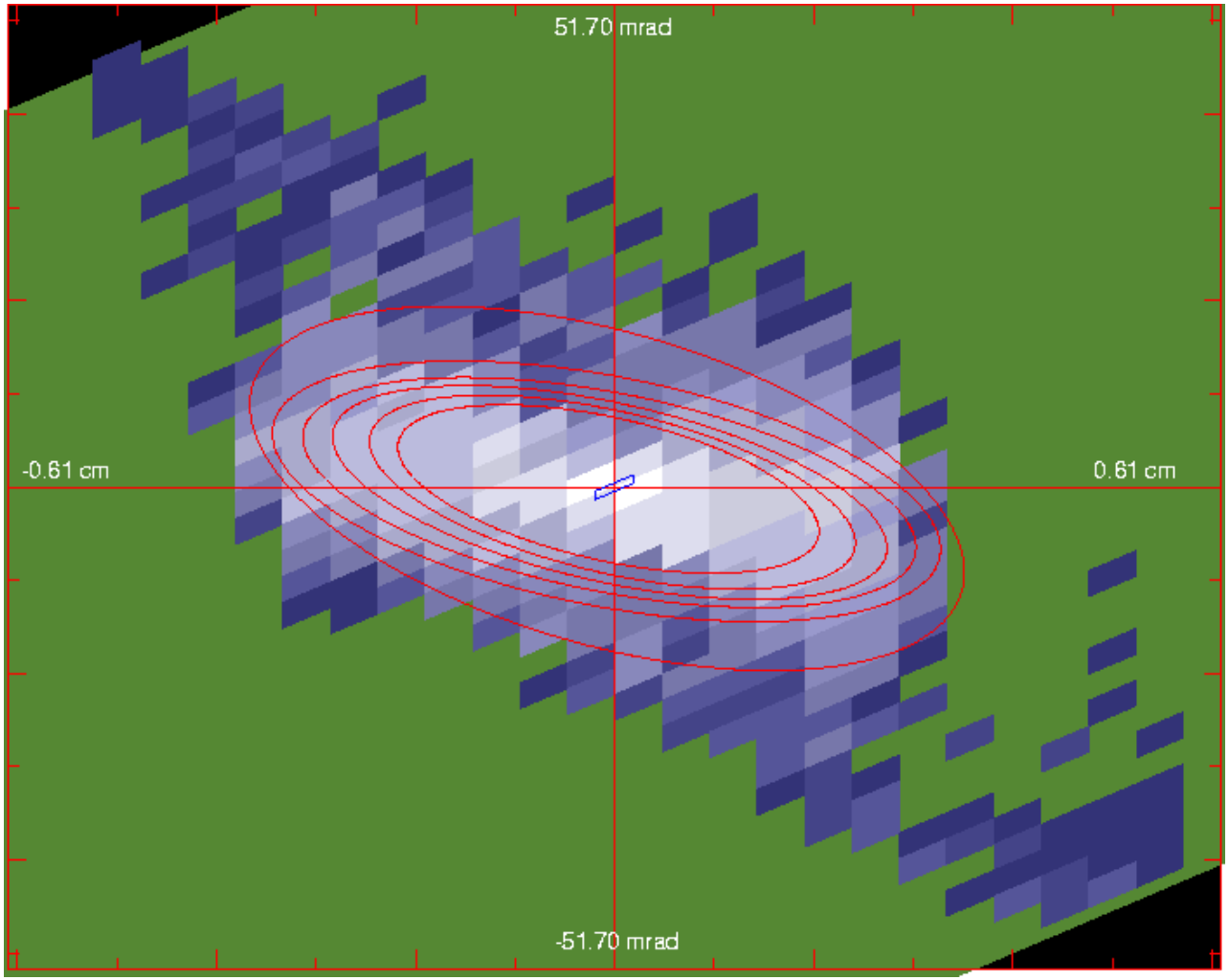
Emittance Device

- Slit, followed by collector stack
  - 50 slit positions
  - up to 64 collectors in stack
- Resolution modeled with simulator
- Power on slit must be kept very low
- Measurement in less than 10 seconds
- Short pulse, low duty factor

Sample Input Data



Emittance Resolution



Diagnostic Plate

- Temporary tuning device
- Used on RFQ and MEBT exit
- Requires 2 meter drift
- Equipment
  - fast faraday cup
    - expanded beam will debunch
  - emittance gear
    - low power only
  - 90 degree spectrometer

Warmup

- Voltage condition of
  - LEBT
  - RFQ
  - Rebuncher cavities
  - May require local 402.5 MHz clock
- Power condition plasma generator
- Beam tuning
  - with RFQ on, no convenient beam stop
  - may use LEBT chopper target

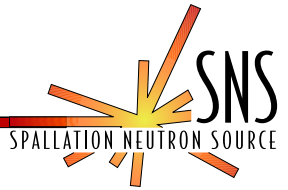
Issues Beyond FES

- Full FES commissioning will be carried out at LBNL:
  - Emittance device only at low power
  - We need sufficient time to carry this out
- At ORNL:
  - Recommission at 2.5 MeV
  - Carry beam through DTL tank 1
    - LANL tunes FES
    - What diagnostics, power limitation at 7.5 MeV?
  - Continued FES development necessary, especially on ion source

Issues 2

- Establish agreement on LANL beam acceptability and requirements for tuning and commissioning
- Identify differences between I&C HW and SW between LBNL and ORNL
- Establish trip limits for initial beam commissioning
  - protect chopper target, emittance box, etc.

Summary



- We have sufficient tools to commission FES at LBNL at full power.
- FES will provide wide range of beam parameters for downstream requirements
- Machine safety requirements must be carefully spelled out
- Continued FES development essential during installation phase of rest of accelerator components