The Start

Happy Birthday to Prach!

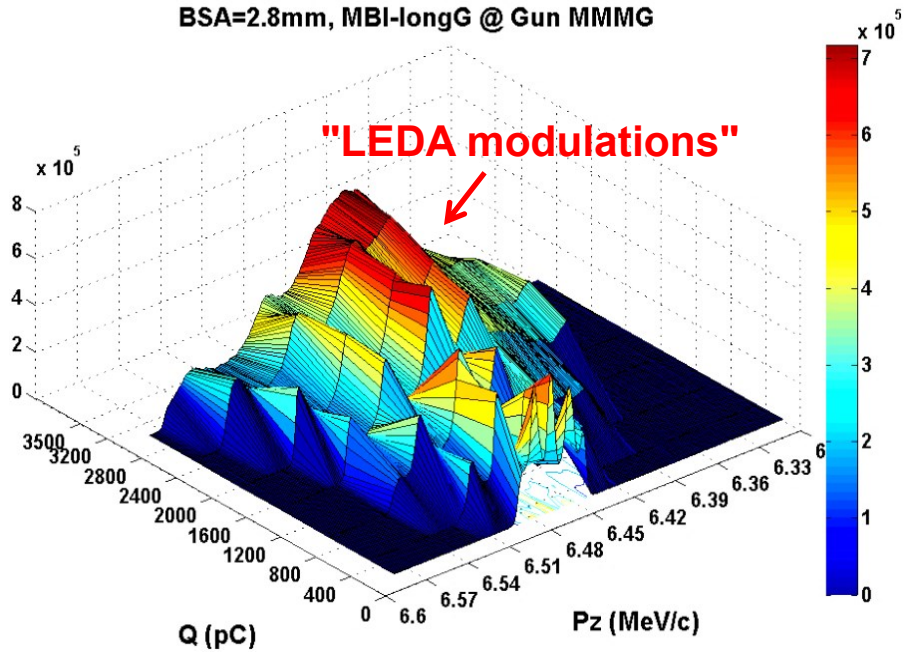
****First Transition Radiation Signal from the THz Detector, 08.08.2017***

Updates on Photoemission-related Studies

Y. Chen, PPS, DESY Zeuthen, 10.08.2017

Contents

- First emission measurements with Pharos laser
- E-bunch momentum spectrum modulation at LEDA
- Simulations of bunch compression in the gun

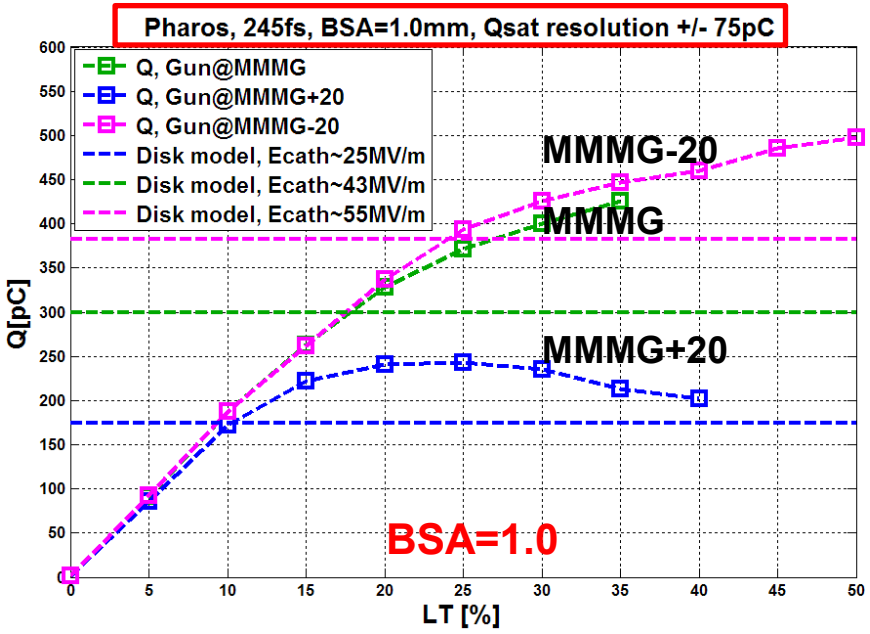


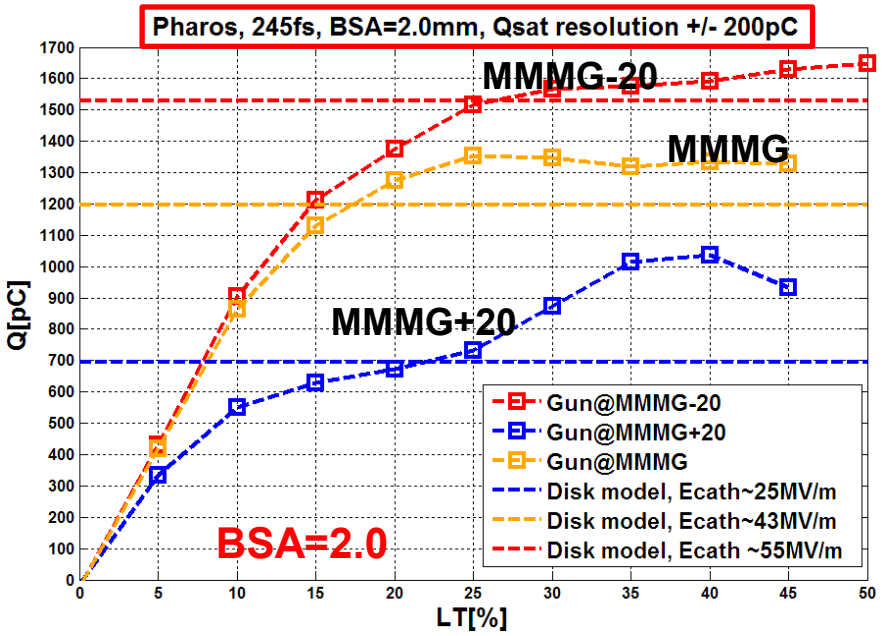
HELMHOLTZ ASSOCIATION

First emission measurements with Pharos laser

-> 1. First emission curves with PL = 245 fs

25-26.07.2017, raw data taken by Yves and Quantang





- **BSA=1.0 case fits the charge disk model -> not so bad**
- **BSA=2.0 case does not fit the disk model -> transverse inhomogeneity plays**
- Resolution of LT scan shall be improved for Qsat measurements

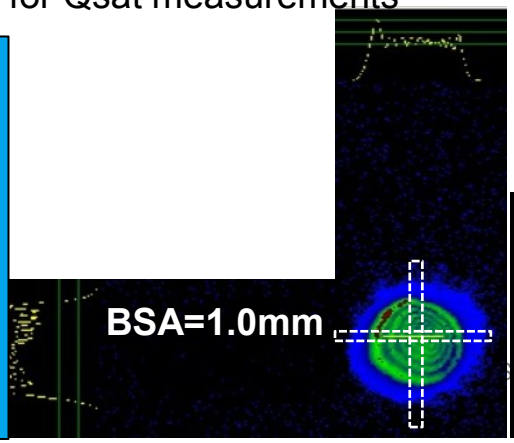
Why saturation charge?

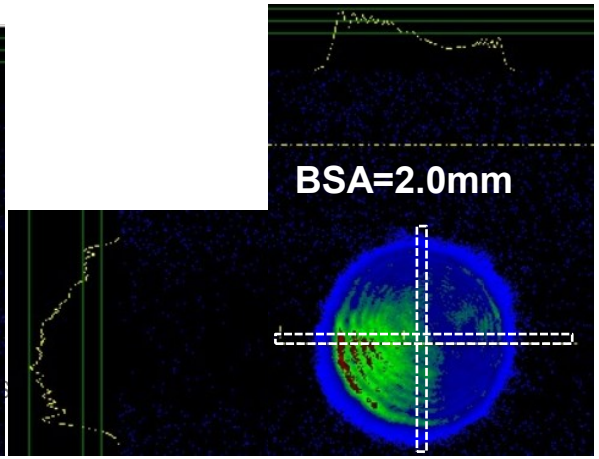
"Defining" optimum working conditions for

- ✓ **Best emittance measurement at PITZ**
- ✓ **Studying beam transverse brightness**

e.g., $B_{\perp} \propto \frac{E^{1.5}\Delta t^{1}}{R^{0.5}\sigma_p{}^{2}}$, ε_{th} needed

- ✓ **Modeling charge extraction dynamics with different beam aspect ratios**



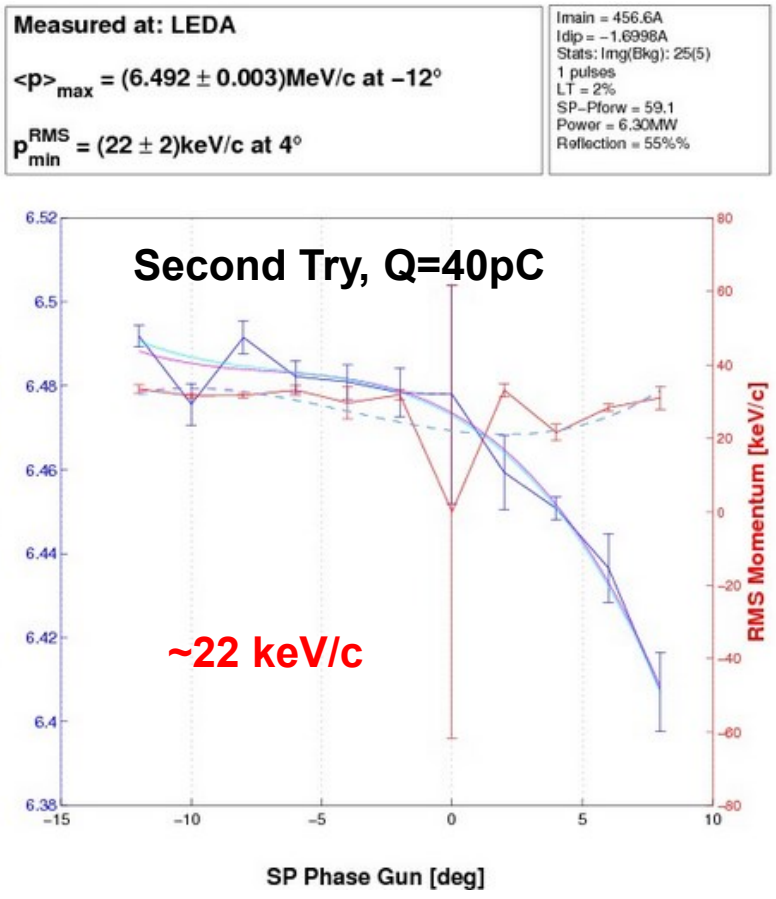


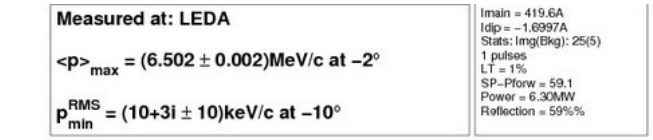
First emission measurements with Pharos laser

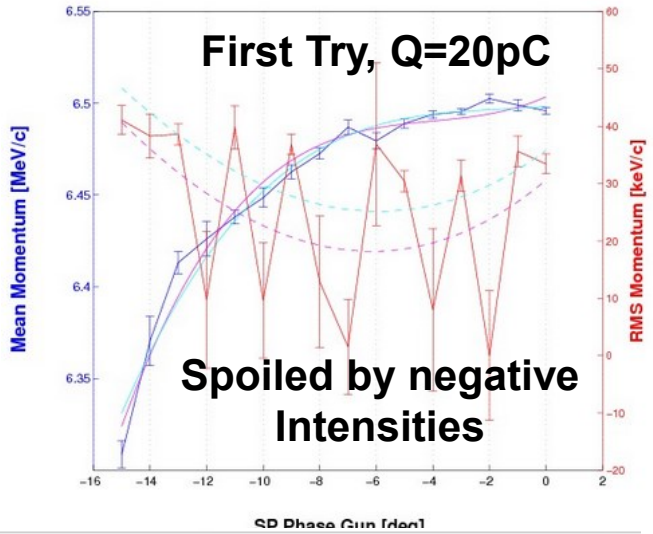
-> 2. Testing smallest momentum spread with PL ≈ 245 fs

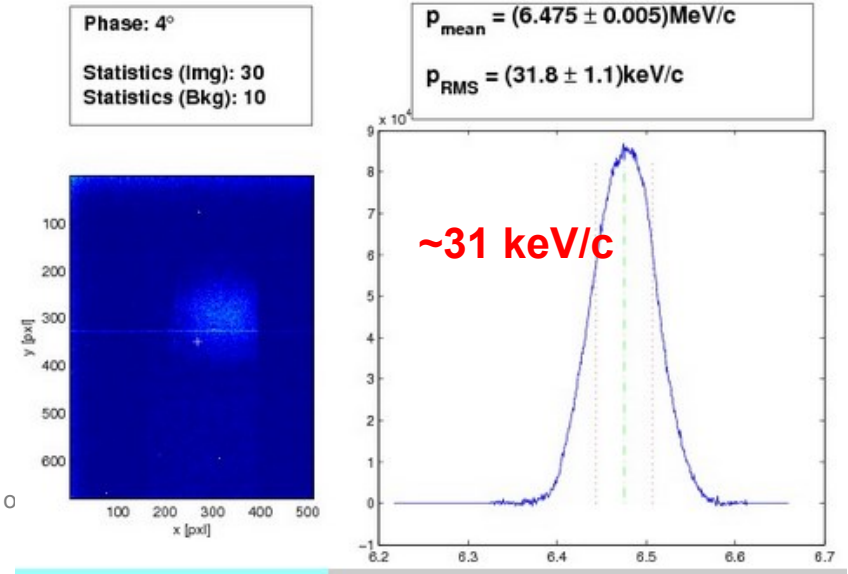
25.07.2017, raw data taken by Yves

Conditions: 245fs, Q=20pC/40pC, 60 pulses, BSA=1.0mm







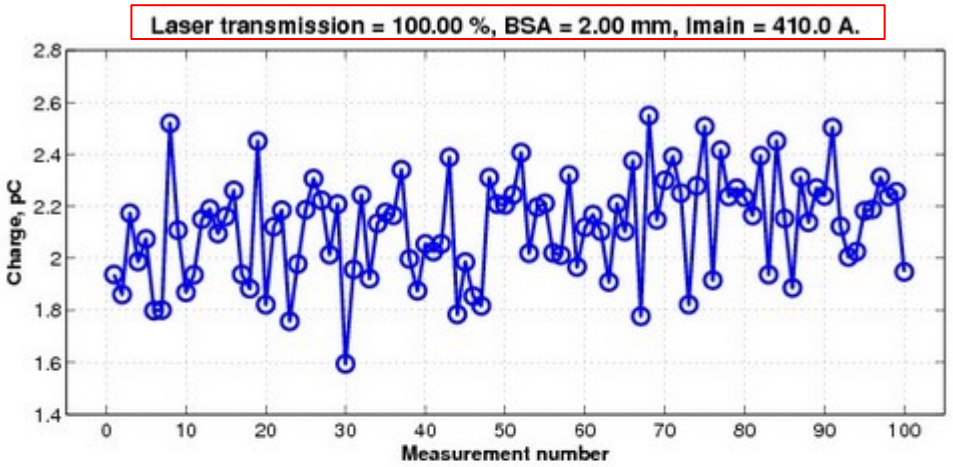


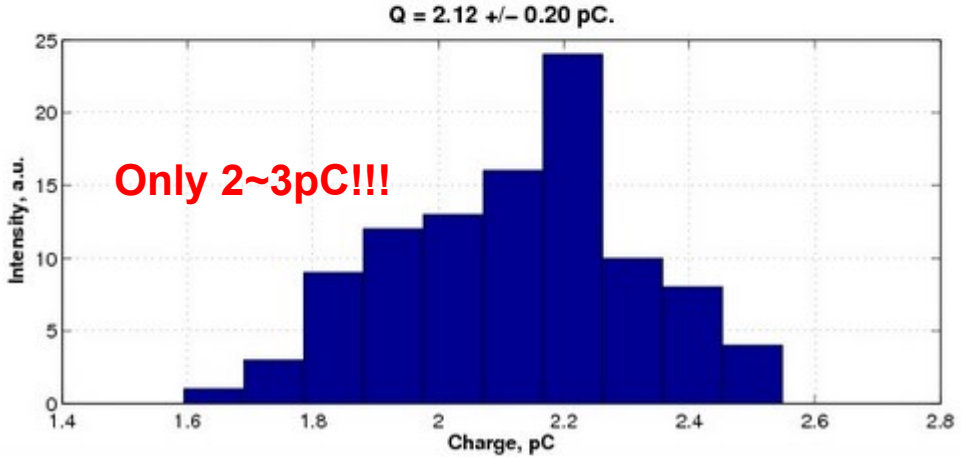
- ❑ No satisfying results observed yet
- ❑ Charge not low enough?
- ❑ LEDA resolution limiting?

First emission measurements with Pharos laser
-> 3. Testing "LEDA modulation" with PL ≈ 10 ps

27.07.2017, raw data taken by Yves and James

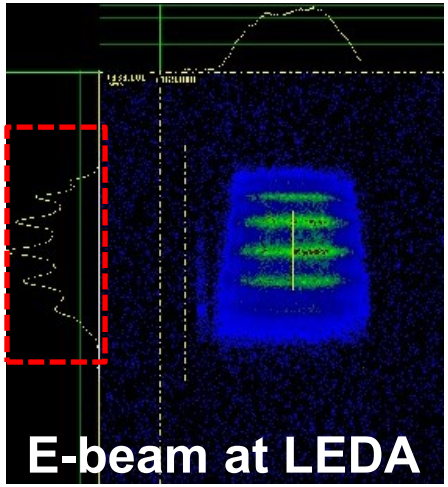
BSA=2.0mm, Pharos 10ps, charge way too low!!!

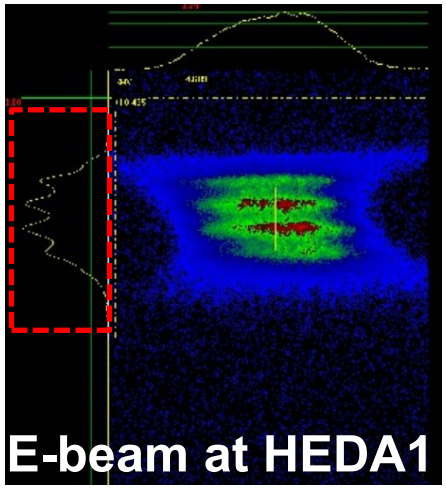




1. -> With MBI (11~11.5ps), BSA= 2.0, Q ≥ 100pC, pronounced modulations at LEDA
2. With ELLA (~10ps after adjustments?), no modulations at LEDA observed
3. With Pharos (10~11ps), impossible to extract >100pC at BSA=2.0; PL needs to be adjusted to << 10ps

E-bunch momentum spectrum modulation at LEDA (+Anna Sledneva)

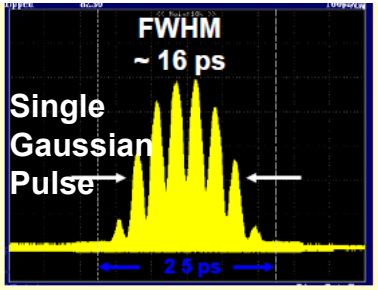




Facts:

1.
   - Pronounced modulation **at LEDA**
   - Weaker modulation **at HEDA1**
   - No obvious modulation **at PST.SCR1**
2.
   - Observed with **MBI** laser
   - No modulation observed with **ELLA** laser
   - Hard to compare with **Pharos** laser (too low charge @ ~10ps)

Pulse shape variation by using a single Lyot filter without pulse shaper

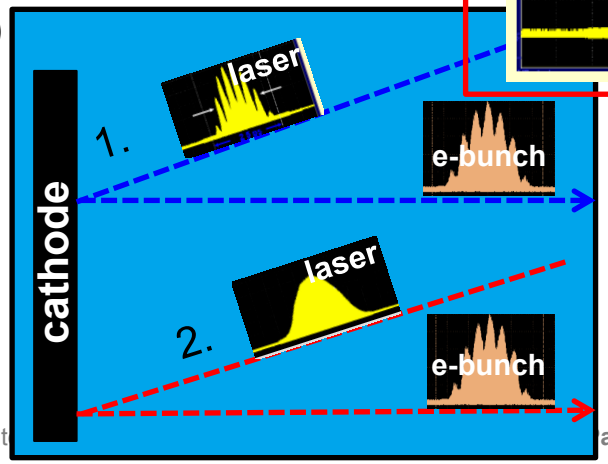


Possible source(s) of the modulation:

1. Laser (photon):
Slight misalignment in regenerative amplifier (RA) (e.g., position and/or angle of Lyot filter)

Just some suggestions from Ingo, the source is not clear yet !!!

2. Emission (photon->electron):
Cathode related effect(s) (e.g., band bending)

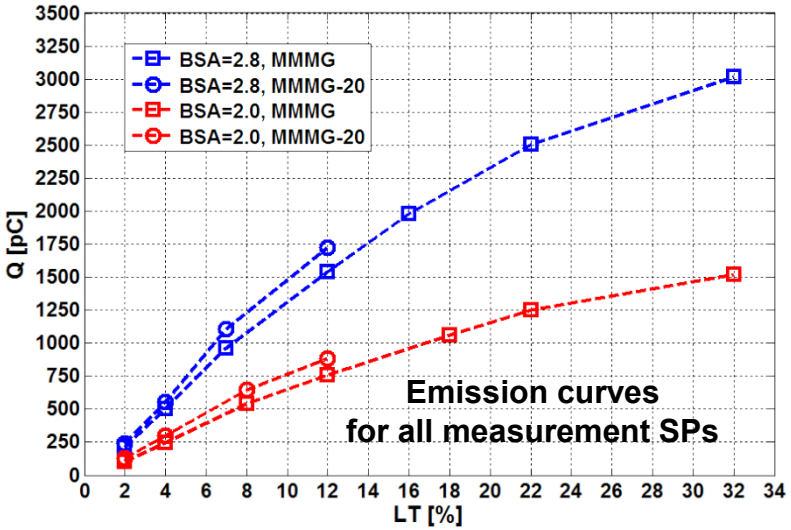


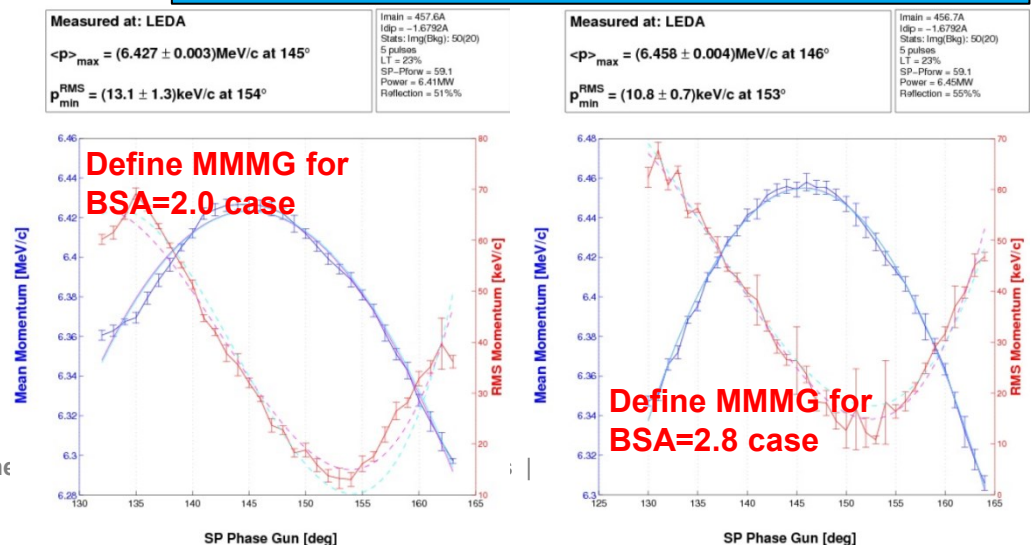
E-bunch momentum spectrum modulation at LEDA

> Experiments

- ✓ MBI LongG (11~11.5 ps)
- ✓ BSA = 2.0 / 2.8 mm
- ✓ 6.5MeV/c, Gun @MMMG / MMMG-20 deg
- ✓ Charge =100~3000 pC
- ✓ Adjusted parameters:
  - LT, NoP
  - Imain
  - Camera gain and exposure time

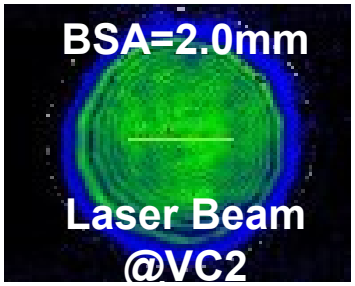
w.r.t. MMMG	BSA	LT	NoP	Imain	LOW.ICT1, pC
MMMG	2.8	2	10	437	216
MMMG	2.8	4	7	447	501
MMMG	2.8	7	9	455	963
MMMG	2.8	12	10	455	1540
MMMG	2.8	16	10	455	1980
MMMG	2.8	22	10	456	2506
MMMG	2.8	32	9	457	3019
MMMG-20deg	2.8	2	20	431	240
MMMG-20deg	2.8	4	20	439	558
MMMG-20deg	2.8	7	20	442	1105
MMMG-20deg	2.8	12	20	443	1725
MMMG	2	2	15	440	104
MMMG	2	4	12	452	243
MMMG	2	8	12	457	544
MMMG	2	12	15	457	757
MMMG	2	18	15	458	1063
MMMG	2	22	13	458	1254
MMMG	2	32	12	459	1522
MMMG-20deg	2	2	50	424	127
MMMG-20deg	2	4	50	436	299
MMMG-20deg	2	8	50	445	645
MMMG-20deg	2	12	50	440	885

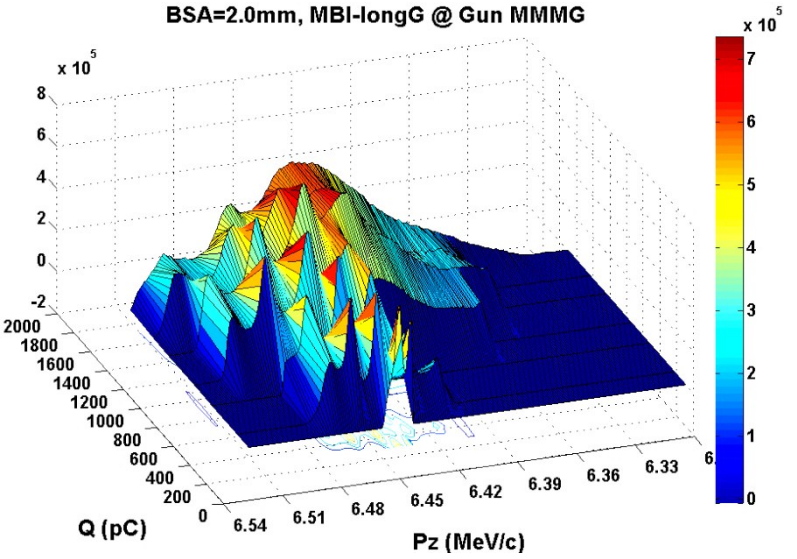


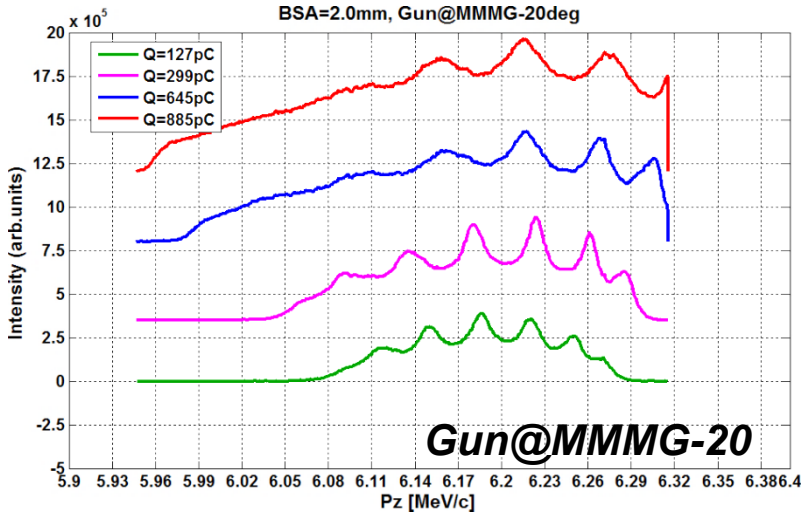


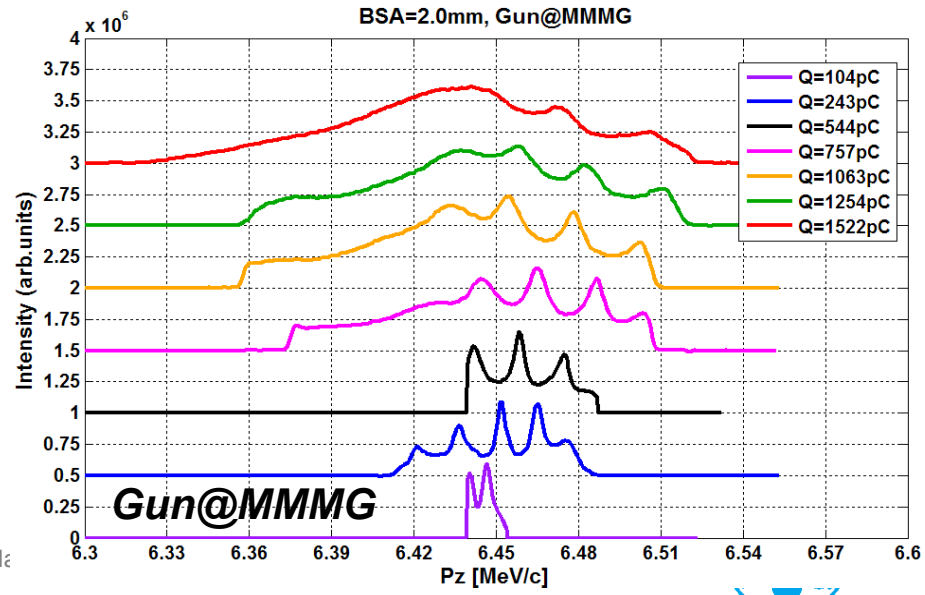
E-bunch momentum spectrum modulation at LEDA

> Experimental results









E-bunch momentum spectrum modulation at LEDA

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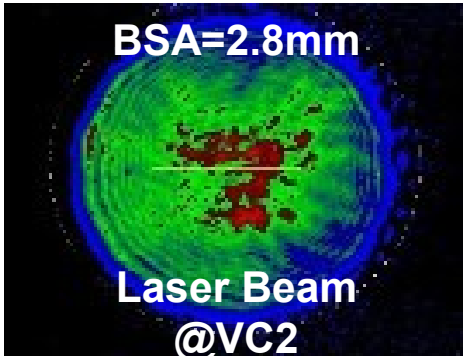
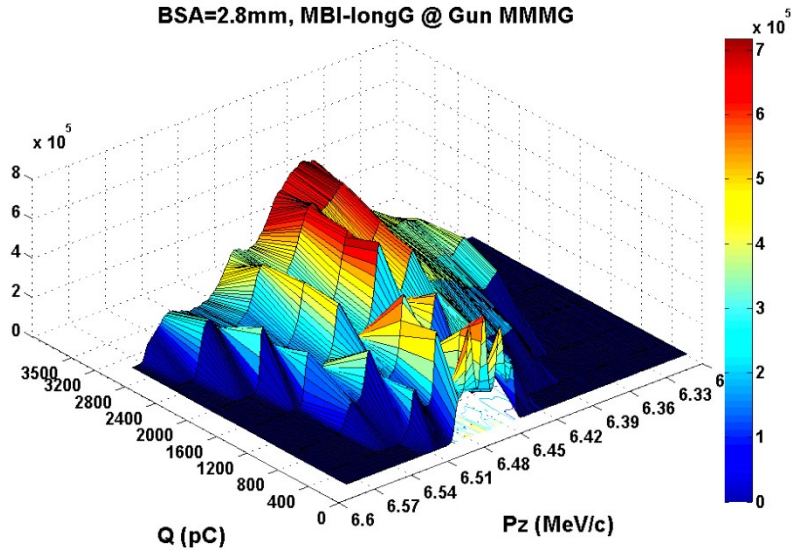
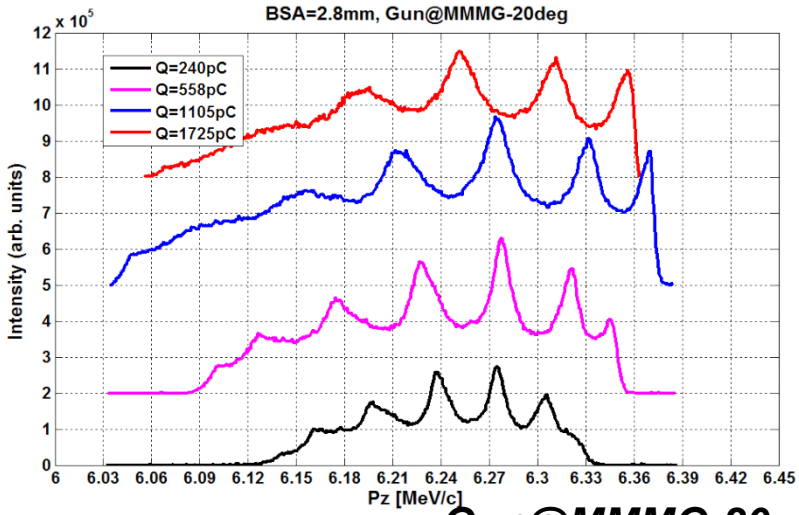
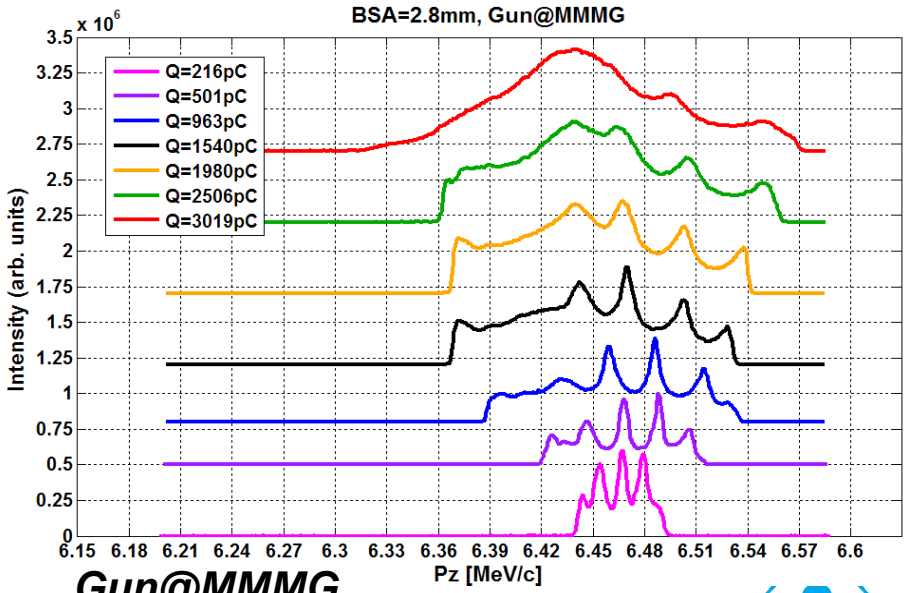






Gun@MMMG-20

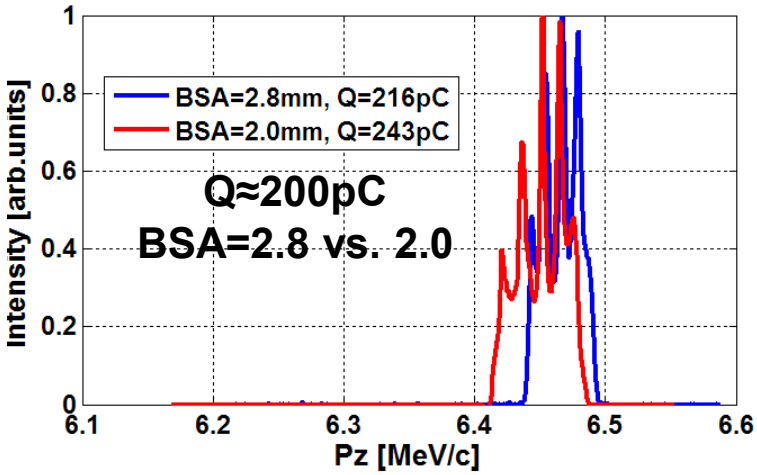


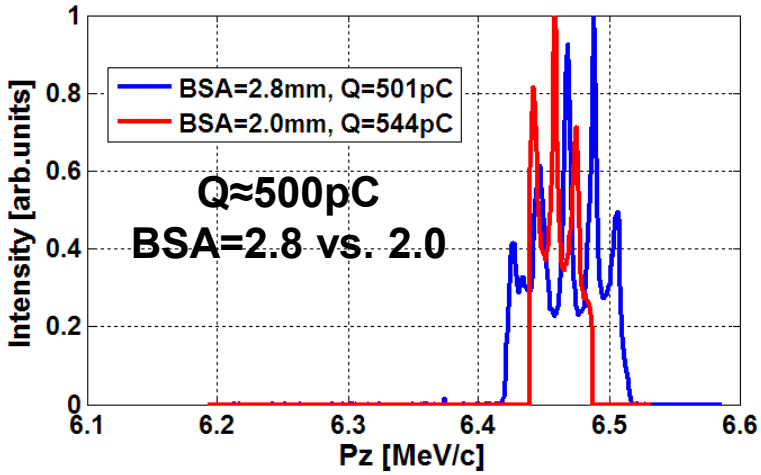
Gun@MMMG

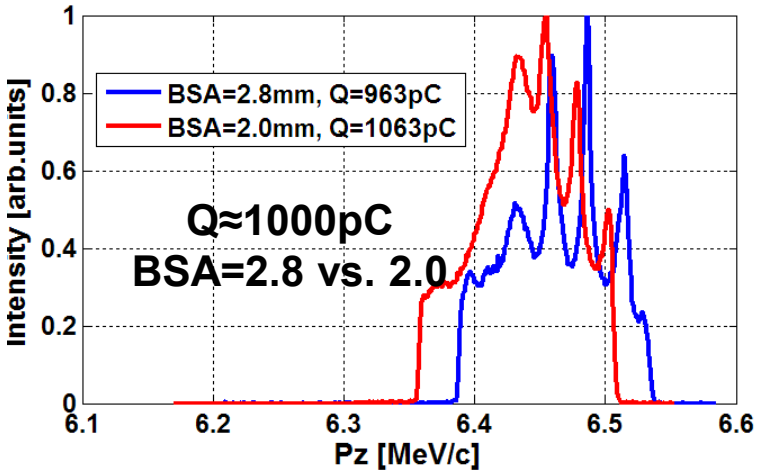
E-bunch momentum spectrum modulation at LEDA

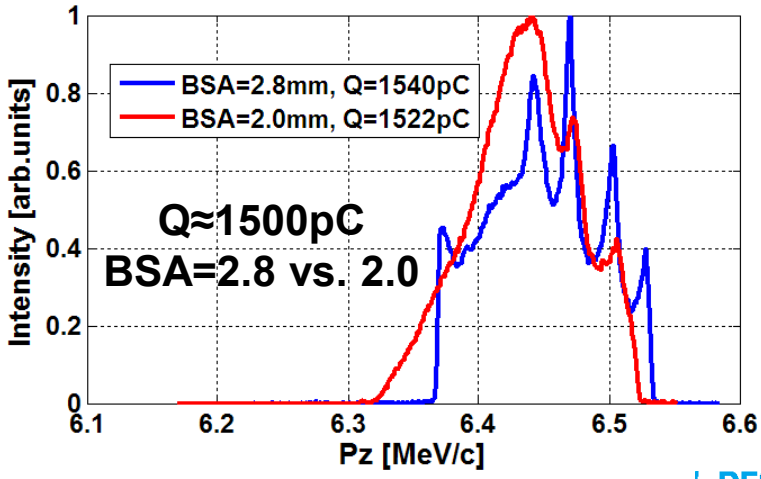
> Experimental results

Gun@MMMG



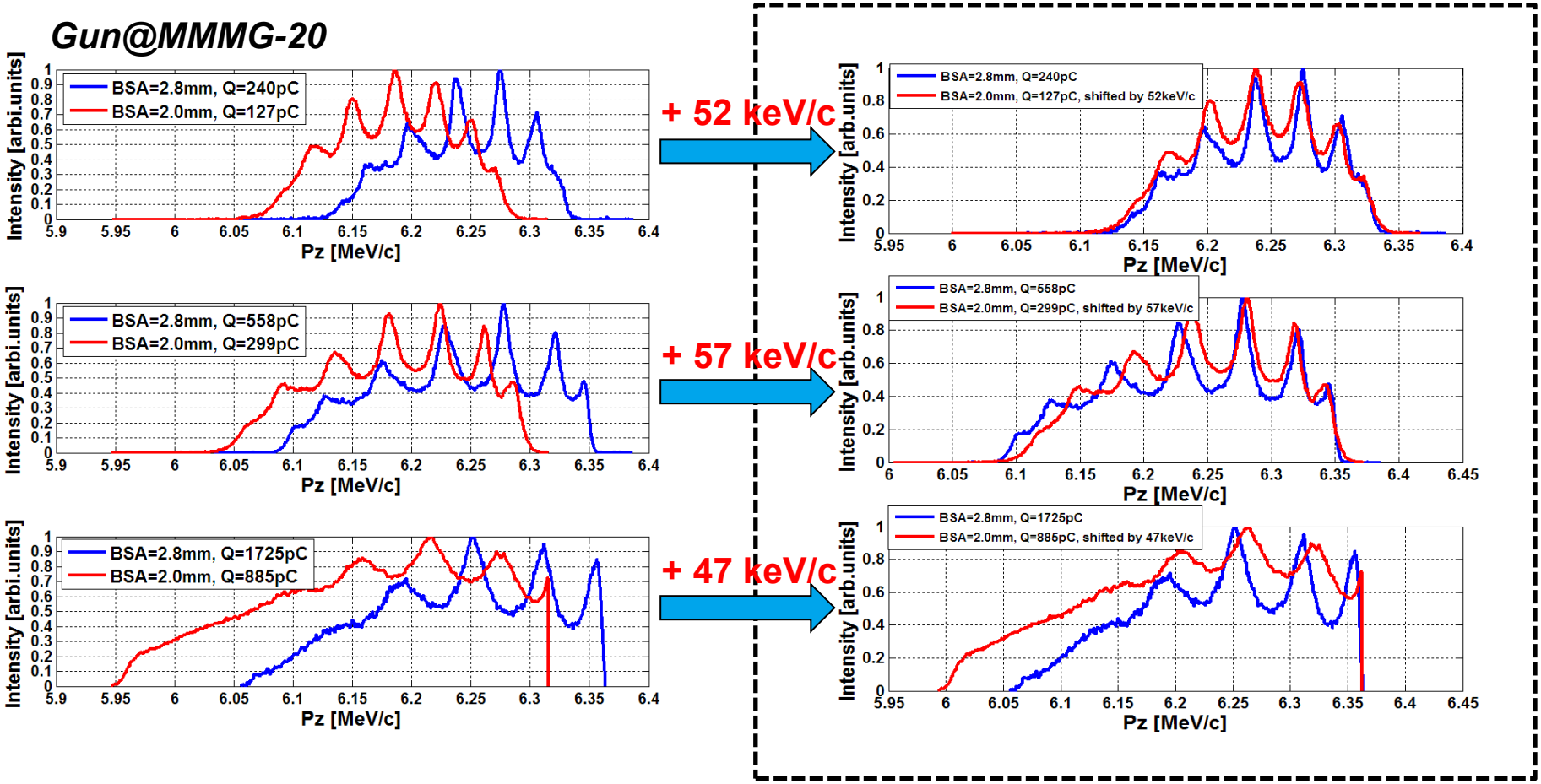






E-bunch momentum spectrum modulation at LEDA

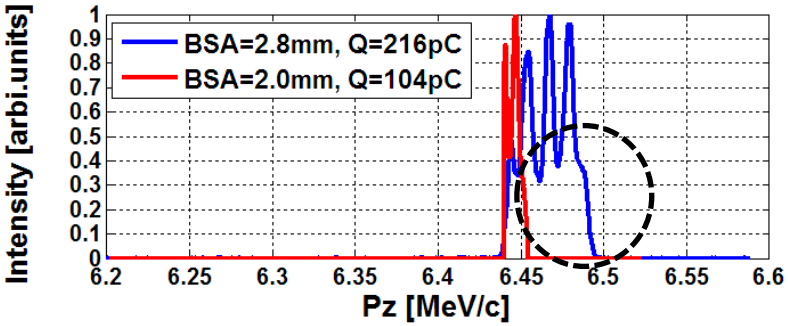
> Experimental results

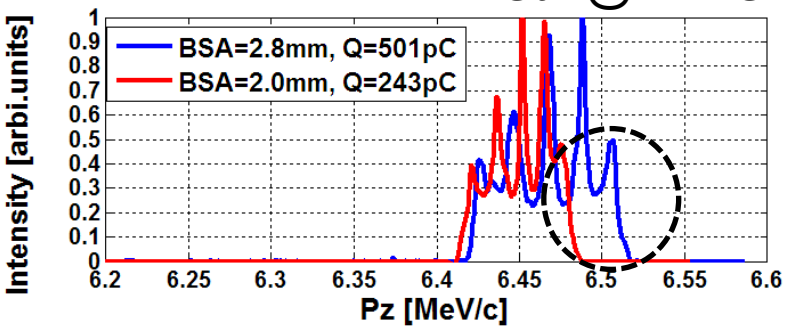


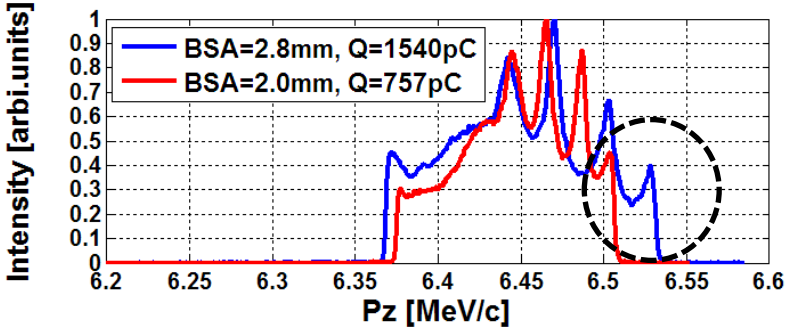
E-bunch momentum spectrum modulation at LEDA

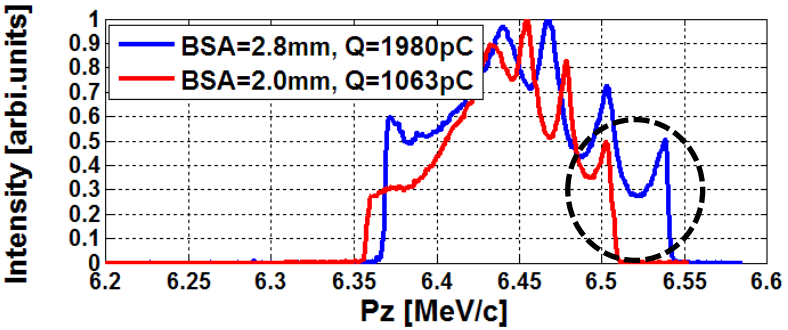
> Experimental results

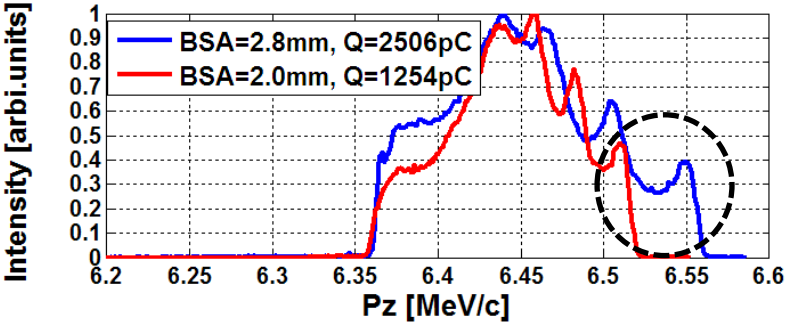
Gun@MMMG

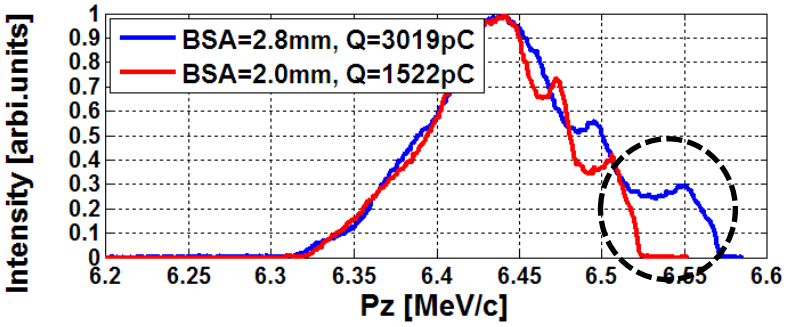












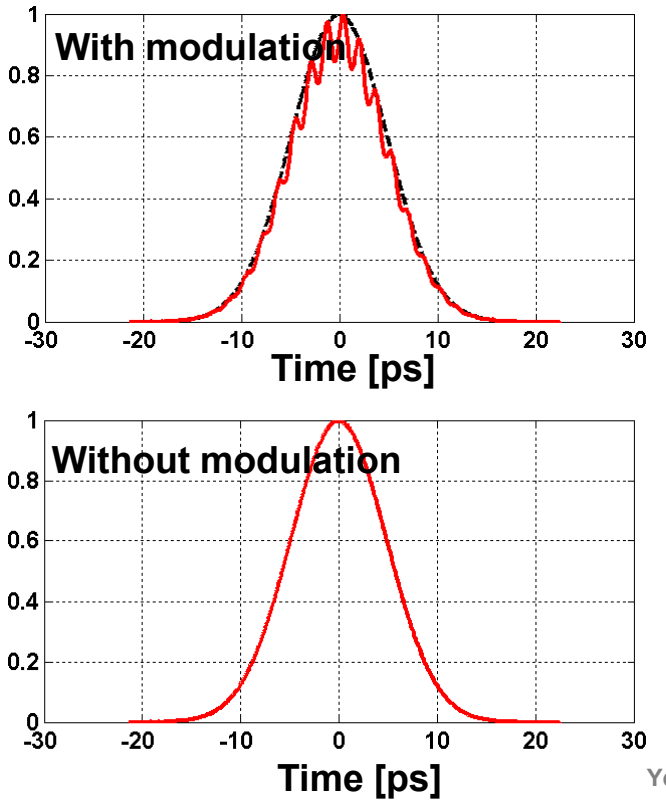
E-bunch momentum spectrum modulation at LEDA

> First simulation with modulated temporal beam profile @cathode

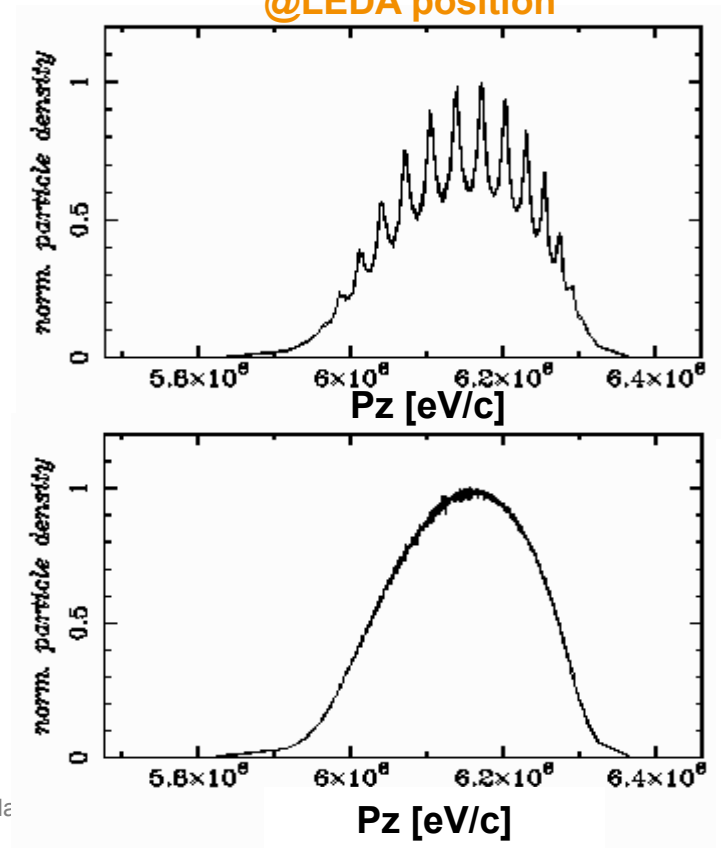
Simulation settings in ASTRA:

- BSA=2.0mm, Q≈250pC, Gun phase @ MMMG+20
- Temporally long Gaussian profile with slight modulations (11.5ps in FWHM)
- Transversely uniform distribution

E-beam temporal profile @cathode

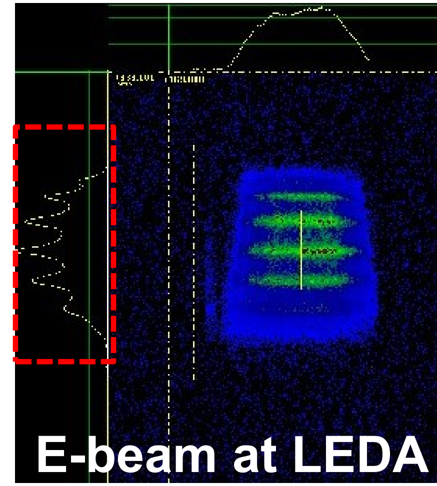


E-beam momentum spectrum @LEDA position



E-bunch momentum spectrum modulation at LEDA

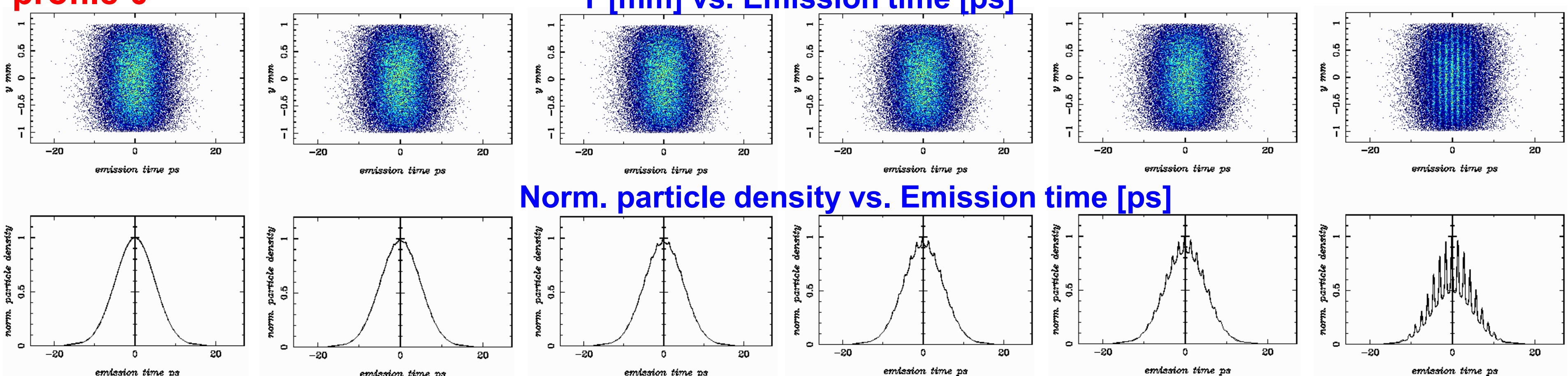
- **Parametric studies**
  - **Producing modulated temporal beam profiles @cathode**
  - **Using these modulated bunch distributions for investigations on**
    - ✓ modulations of e-bunch momentum spectrum
    - ✓ space charge density impacts on the modulations



Cath temporal profile 0	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5

Y [mm] vs. Emission time [ps]

Norm. particle density vs. Emission time [ps]



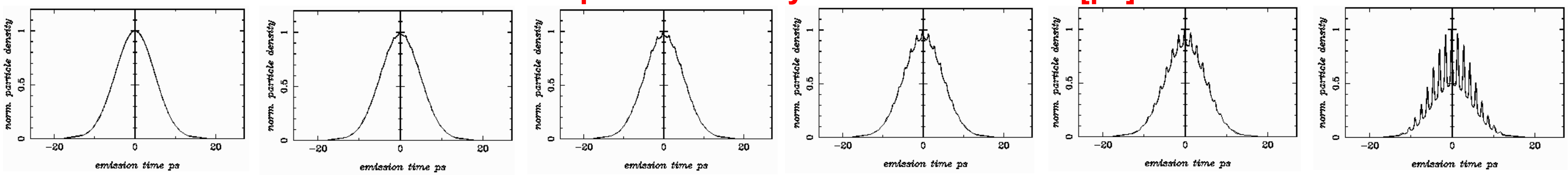
No modulation	Modulation P2Pmax~4%	Modulation P2Pmax~7%	Modulation P2Pmax~11%	Modulation P2Pmax=16%	Modulation P2Pmax~53%

E-bunch momentum spectrum modulation at LEDA

BSA=2.0, Space Charge Excluded, Gun @MMMG

Cath Profile 0 | Profile 1 | Profile 2 | Profile 3 | Profile 4 | Profile 5

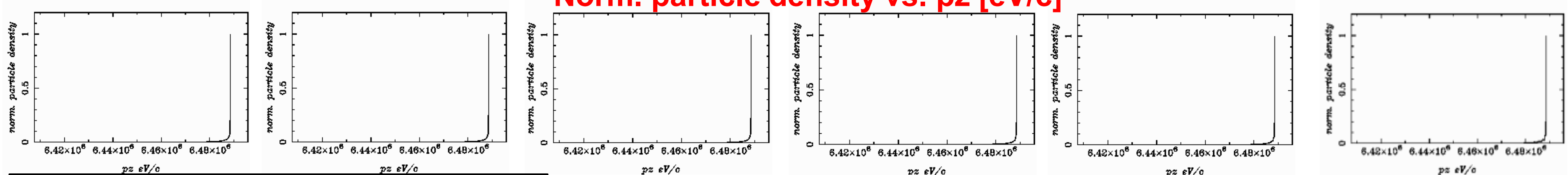
Norm. particle density vs. Emission time [ps]

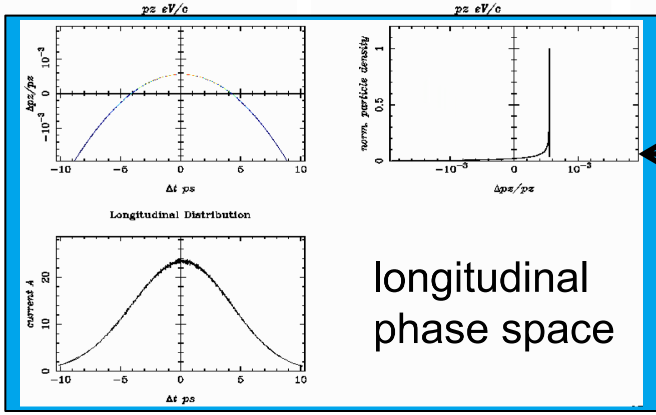


No modulation | Modulation P2Pmax~4% | Modulation P2Pmax~7% | Modulation P2Pmax~11% | Modulation P2Pmax=16% | Modulation P2Pmax~53%

LEDA Spectrum 0 | Spectrum 1 | Spectrum 2 | Spectrum 3 | Spectrum 4 | Spectrum 5

Norm. particle density vs. pz [eV/c]

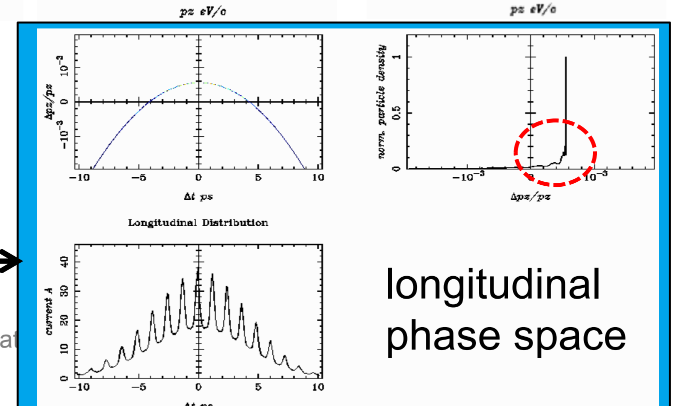




longitudinal phase space

Cath temporal Profile 0

Cath temporal profile 5



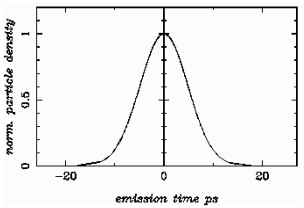
longitudinal phase space

E-bunch momentum spectrum modulation at LEDA

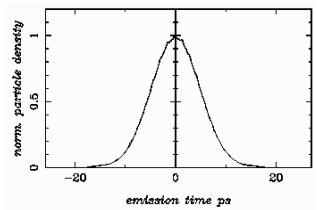
BSA=2.0, Space Charge Excluded, Gun @MMMG+20 (in ASTRA)

Cath Profile 0	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5

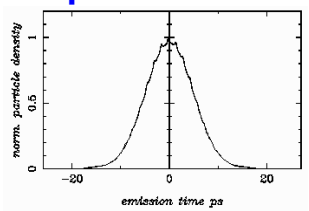
Norm. particle density vs. Emission time [ps]



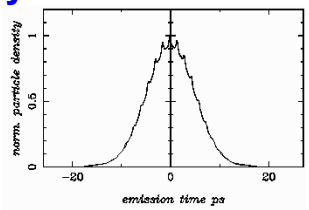
No modulation



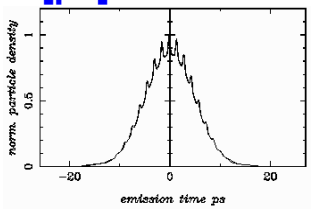
Modulation P2Pmax~4%



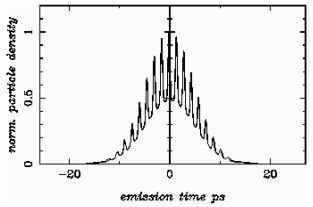
Modulation P2Pmax~7%



Modulation P2Pmax~11%



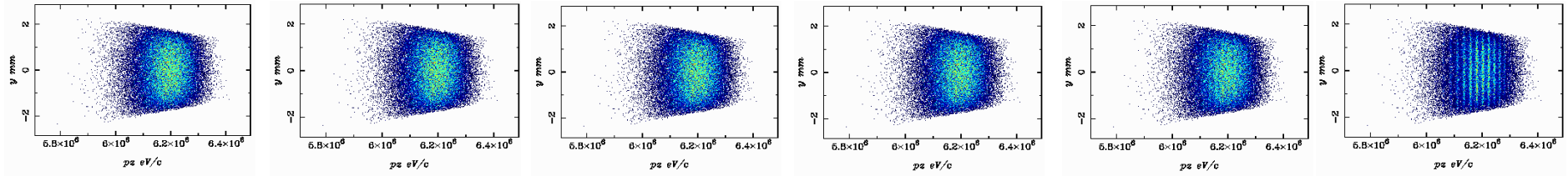
Modulation P2Pmax=16%



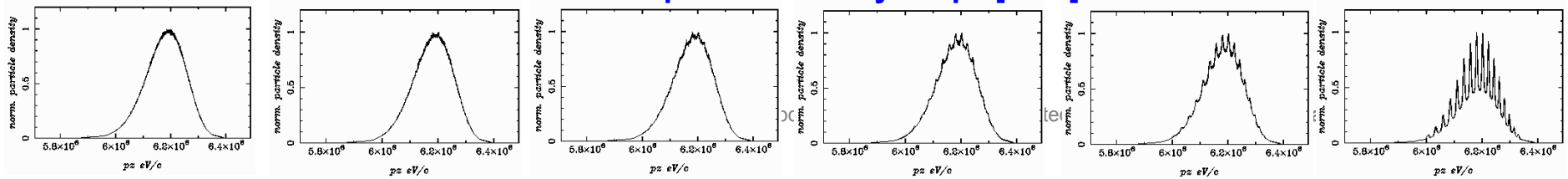
Modulation P2Pmax~53%

LEDA Spectrum 0	Spectrum 1	Spectrum 2	Spectrum 3	Spectrum 4	Spectrum 5

Y [mm] vs. pz [eV/c]



Norm. particle density vs. pz [eV/c]

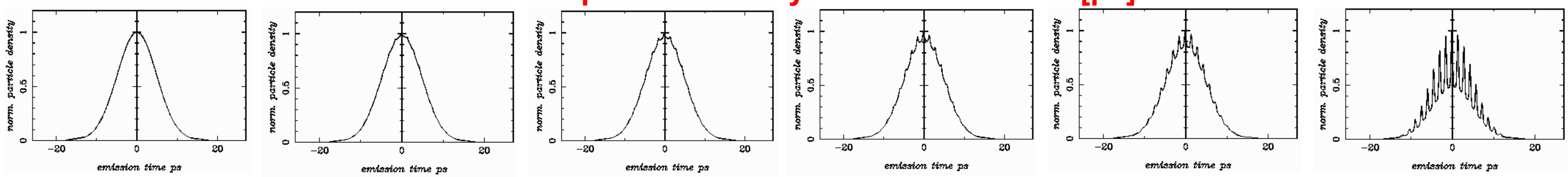


E-bunch momentum spectrum modulation at LEDA

BSA=2.0, Q=243pC, Space Charge Included, Gun @MMMG

Cath Profile 0	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5

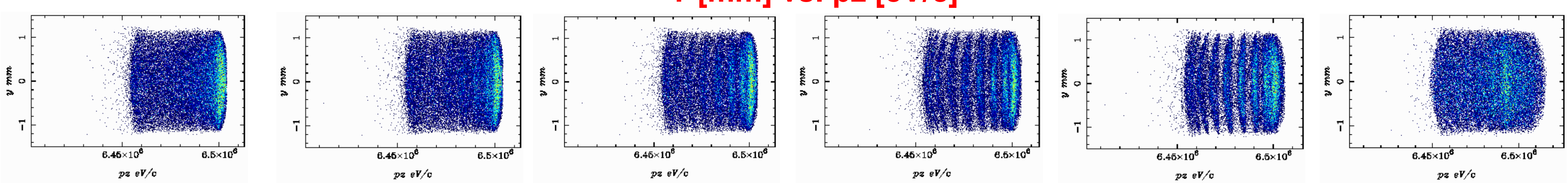
Norm. particle density vs. Emission time [ps]



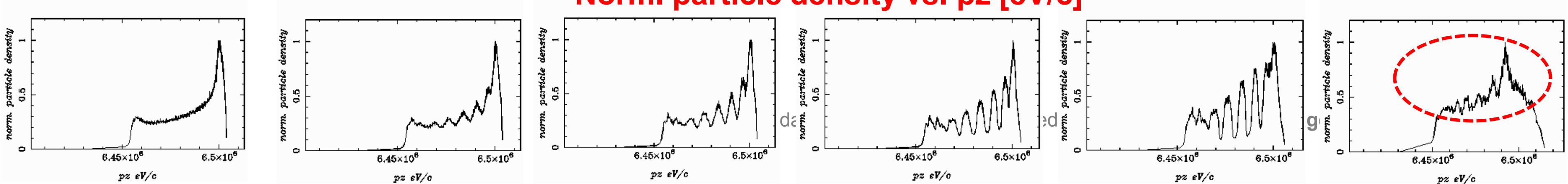
No modulation	Modulation P2Pmax~4%	Modulation P2Pmax~7%	Modulation P2Pmax~11%	Modulation P2Pmax=16%	Modulation P2Pmax~53%

LEDA Spectrum 0	Spectrum 1	Spectrum 2	Spectrum 3	Spectrum 4	Spectrum 5

Y [mm] vs. pz [eV/c]



Norm. particle density vs. pz [eV/c]

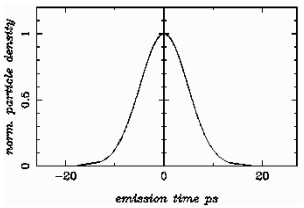


E-bunch momentum spectrum modulation at LEDA

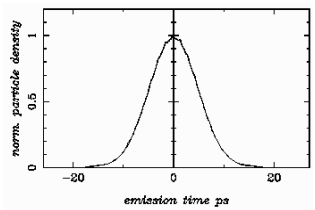
BSA=2.0, Q=299pC, Space Charge Included, Gun @MMMG+20 (in ASTRA)

Cath Profile 0	Profile 1	Profile 2	Profile 3	Profile 4	Profile 5

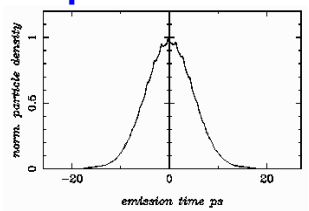
Norm. particle density vs. Emission time [ps]



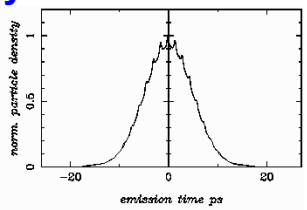
No modulation



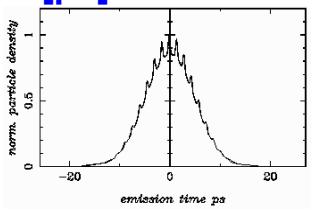
Modulation P2Pmax~4%



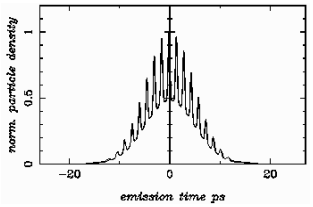
Modulation P2Pmax~7%



Modulation P2Pmax~11%



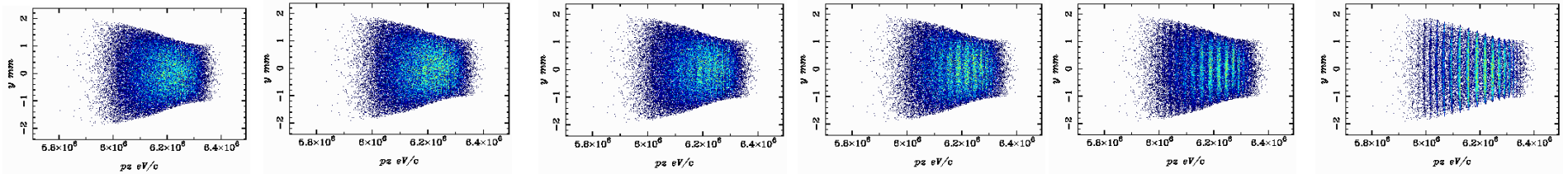
Modulation P2Pmax=16%



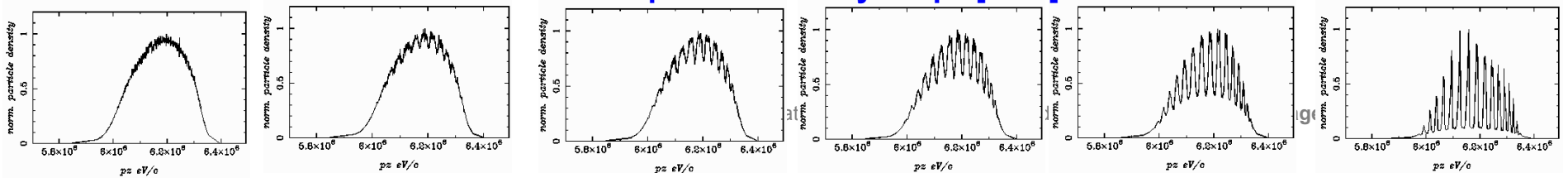
Modulation P2Pmax~53%

LEDA Spectrum 0	Spectrum 1	Spectrum 2	Spectrum 3	Spectrum 4	Spectrum 5

Y [mm] vs. pz [eV/c]



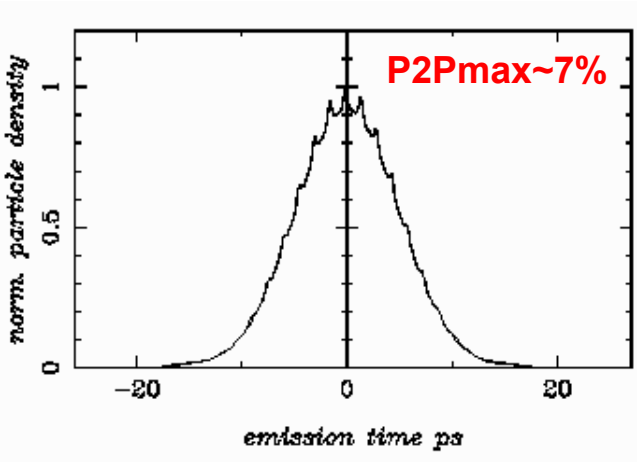
Norm. particle density vs. pz [eV/c]



E-bunch momentum spectrum modulation at LEDA

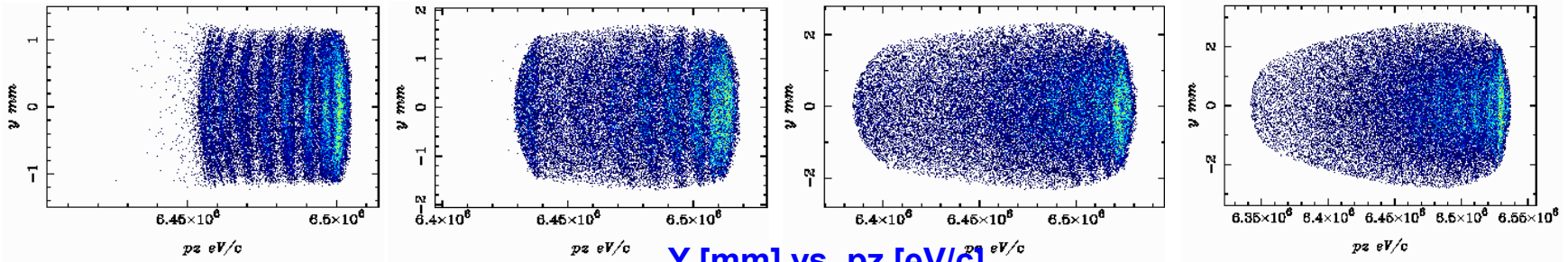
Using cathode laser temporal profile 3

- BSA=2.0
- Q=243 / 544 / 1063 / 1522 pC
- Gun @MMMG

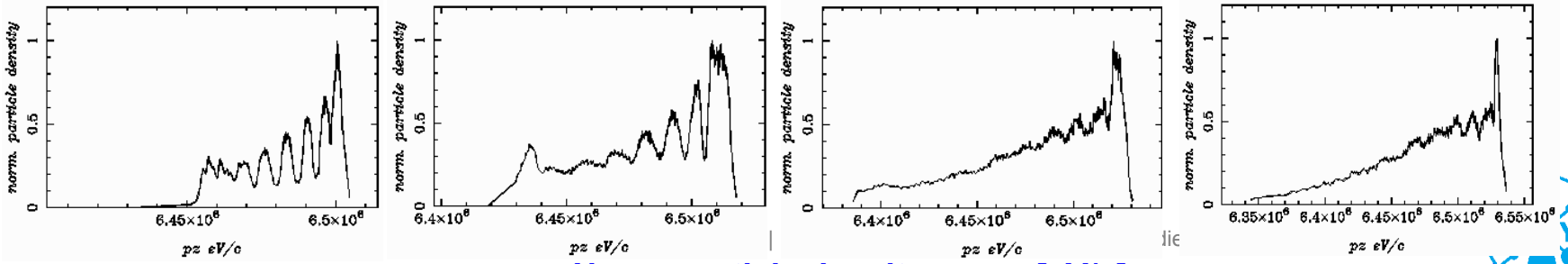


LEDA Spectrum:

243pC 544pC 1063pC 1522pC

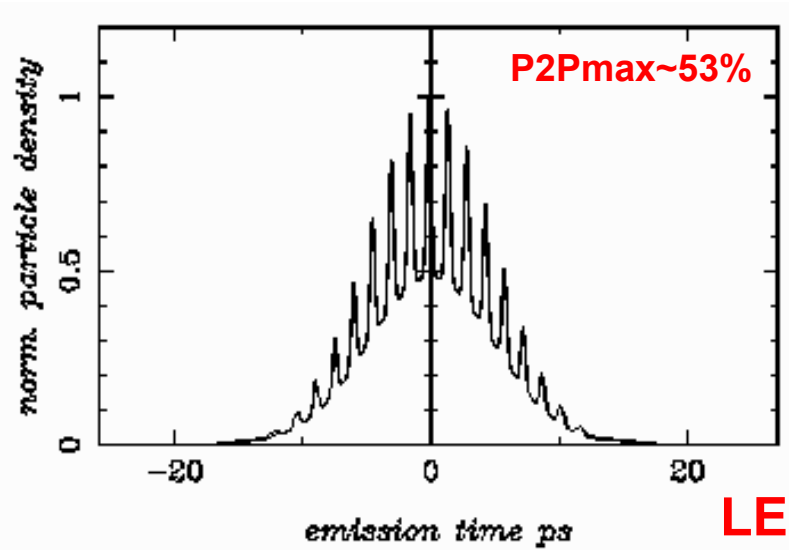


Y [mm] vs. pz [eV/c]



Norm. particle density vs. pz [eV/c]

E-bunch momentum spectrum modulation at LEDA

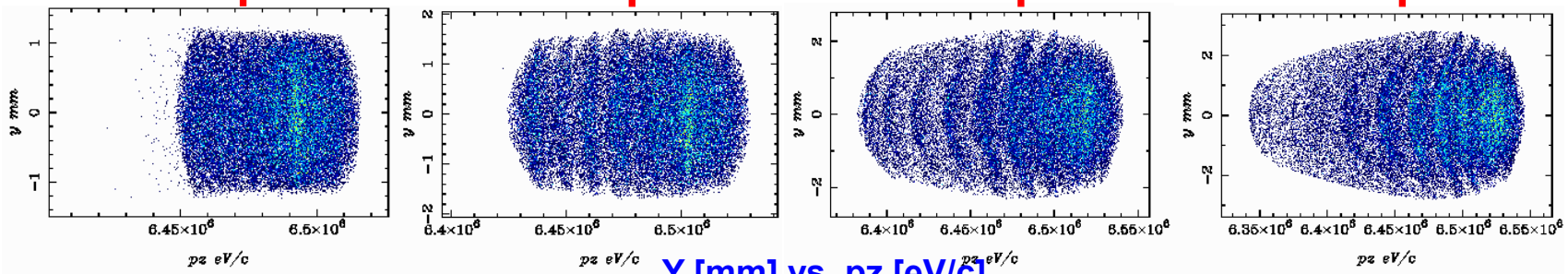


Using cathode laser profile 5

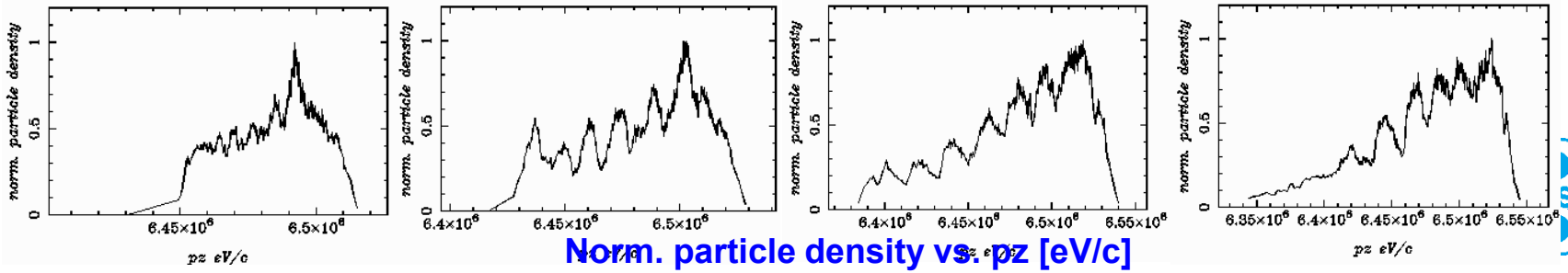
- BSA=2.0
- Q=243 / 544 / 1063 / 1522 pC
- Gun @MMMG

LEDA Spectrum

243pC | 544pC | 1063pC | 1522pC



Y [mm] vs. pz [eV/c]

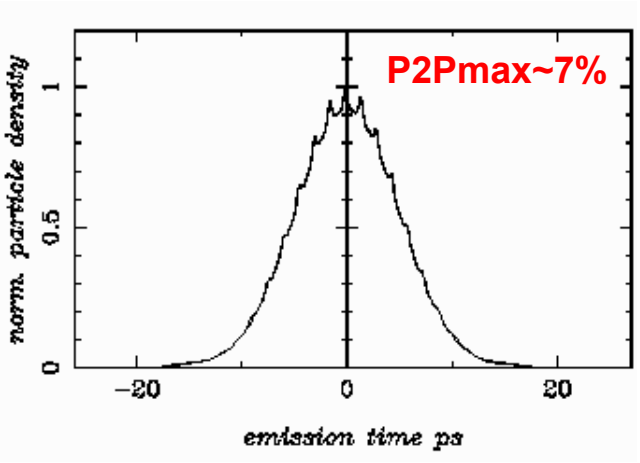


Norm. particle density vs. pz [eV/c]

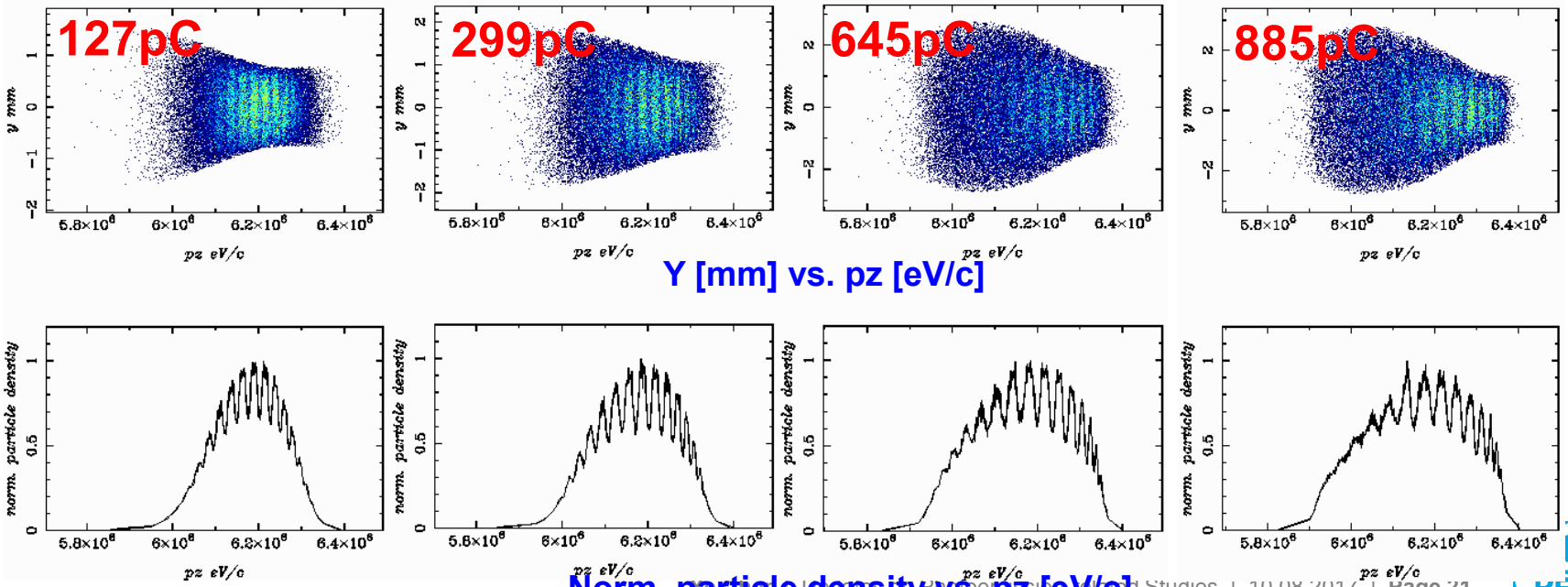
E-bunch momentum spectrum modulation at LEDA

Using cathode laser temporal profile 3

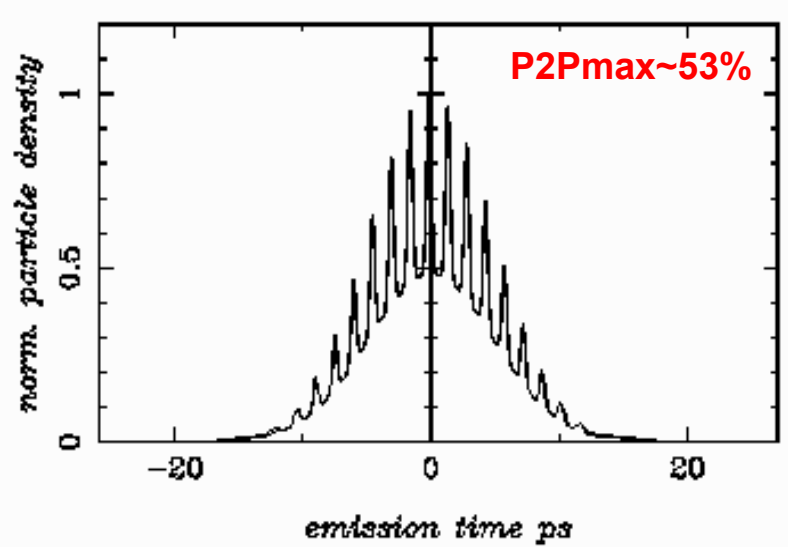
- BSA=2.0
- Q=243 / 544 / 1063 / 1522 pC
- Gun @MMMG+20



LEDA Spectrum:



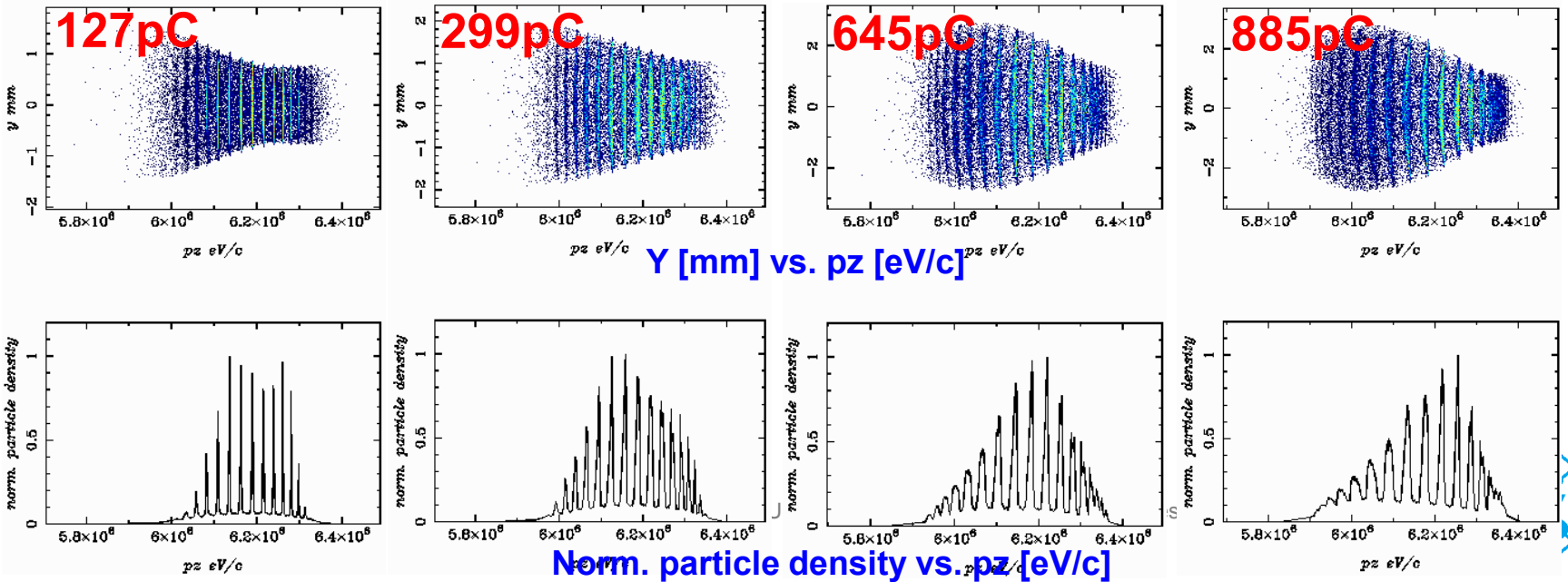
E-bunch momentum spectrum modulation at LEDA



Using cathode laser profile 5

- BSA=2.0
- Q=243 / 544 / 1063 / 1522 pC
- Gun @MMMG+20

LEDA Spectrum



E-bunch momentum spectrum modulation at LEDA

- Measure **laser spectrum** after RA using James's spectrograph during shut down?
- Since MBI oscillator and possibly other sections have been re-adjusted, shall we find some time to quickly check if we still have such modulations at LEDA? (now different cathodes as well)
- Simulate beam momentum measurements with dipole field?

Simulations of bunch compression (BC) in the gun

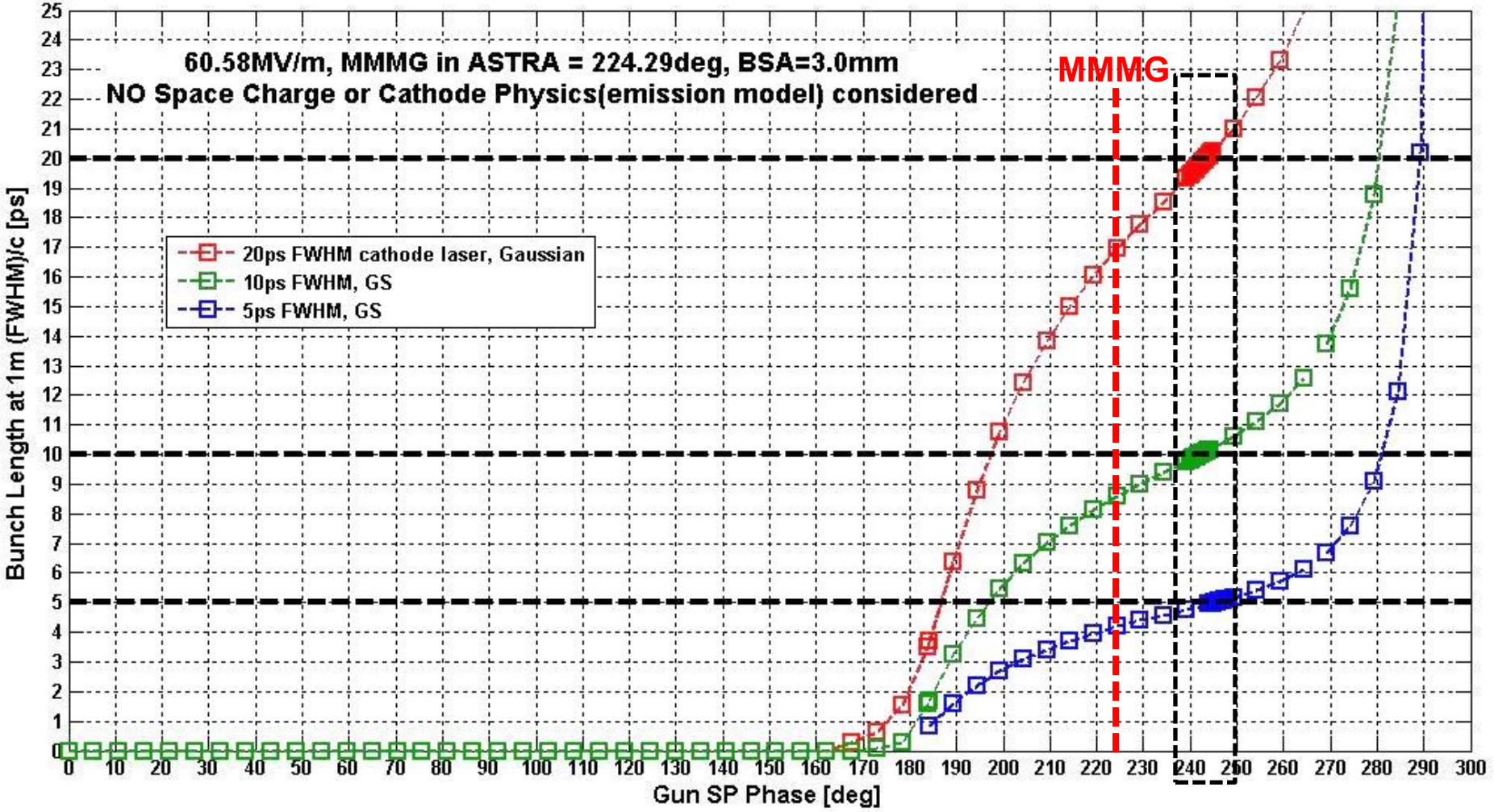
- **Correlate bunch length at TDS with cathode laser pulse length for emission studies**
- **Providing more precise RF field info for the emission process**
- **Compare with analytical solution of bunch compression factor in [1]**
- **Compare the bunch length in ASTRA with other codes (or models) to find the discrepancy source**
- **Simulations of bunch length**
  - No space charge first, then with BSA=3.0mm, Q<100pC

Cath laser pulse (GS, FWHM in ps)	Gun Phase w.r.t. MMMG	Bunch length at 1m in ps	Boo Phase w.r.t. MMMG	Bunch length at 10m in ps
5				
10				
20				

[1] K. Floettmann, PRST-AB 18, 064801 (2015)

Simulations of bunch compression (BC) in the gun

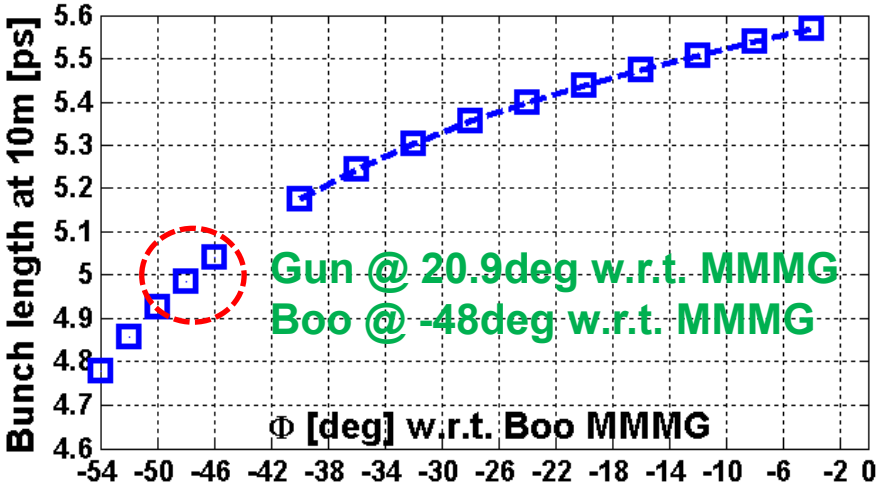
Bunch Length at 1 m vs. Gun SP Phase



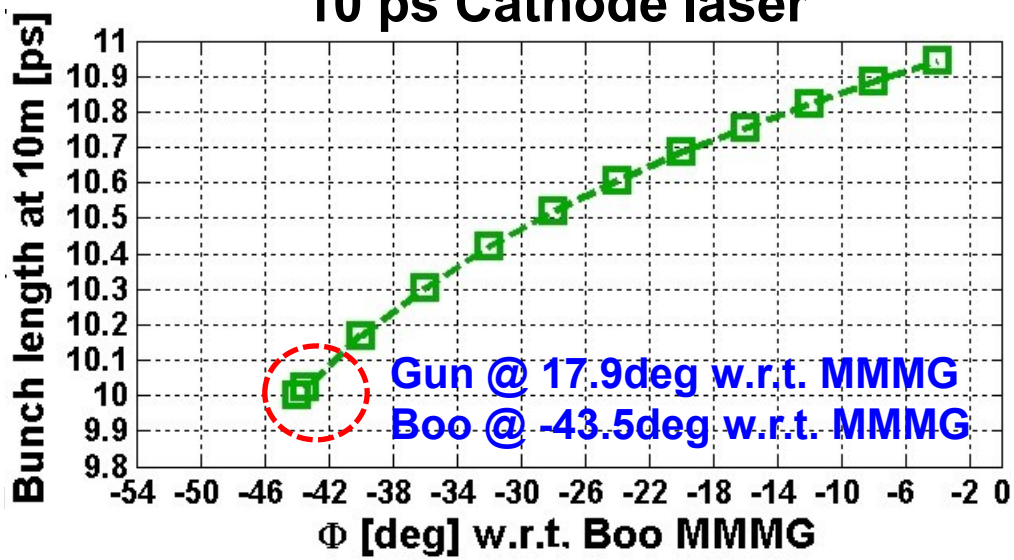
Simulations of bunch compression (BC) in the gun

Bunch Length at 10 m vs. Booster SP Phase (Gun @ BC=1 phase)

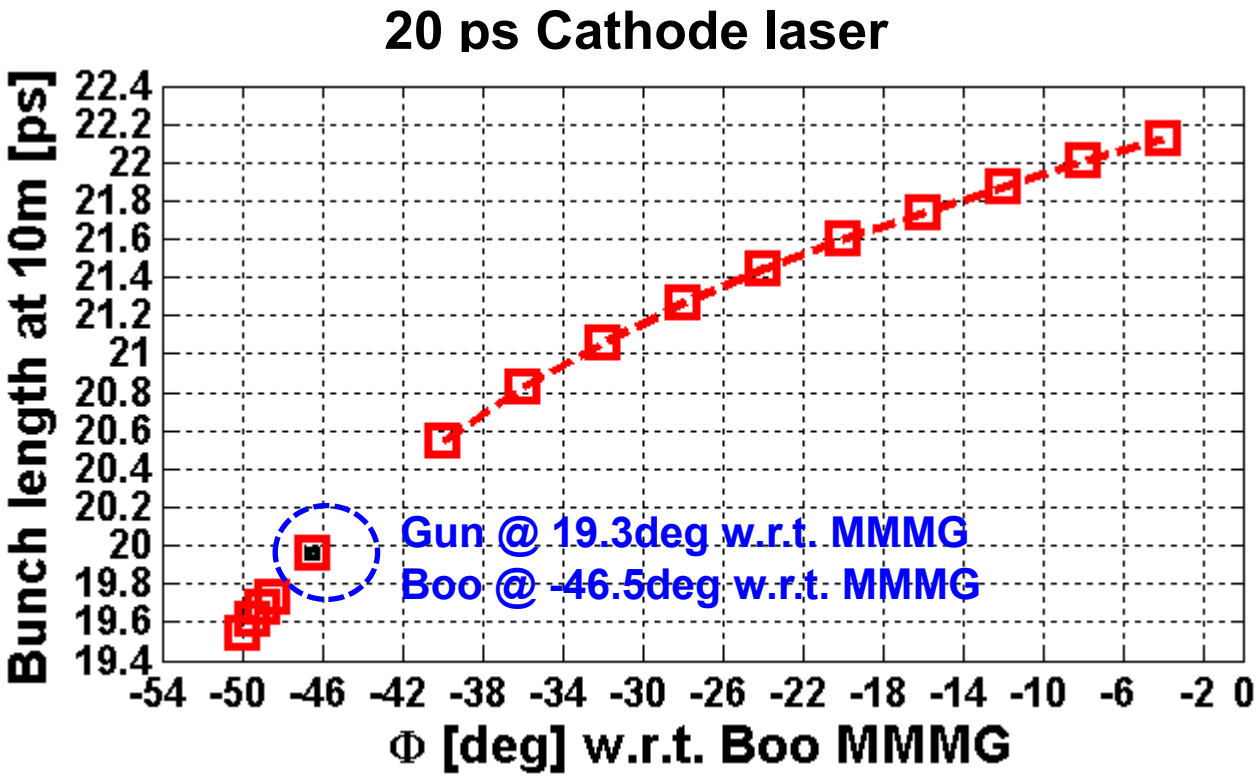
5 ps Cathode laser



10 ps Cathode laser



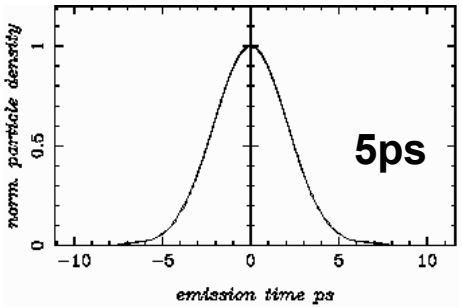
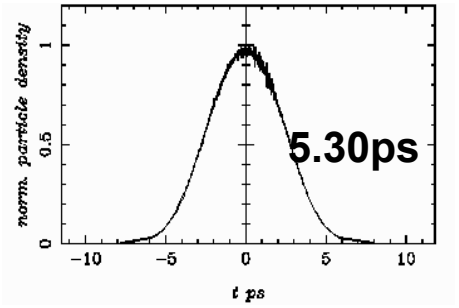
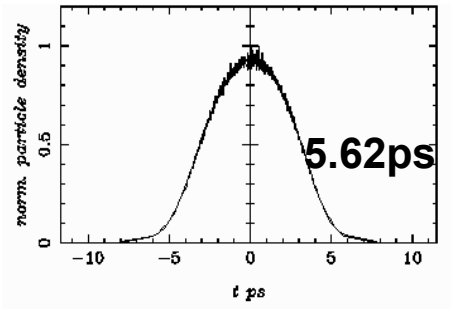
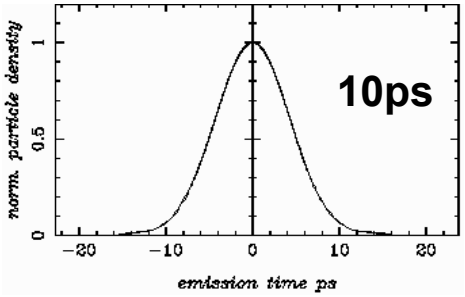
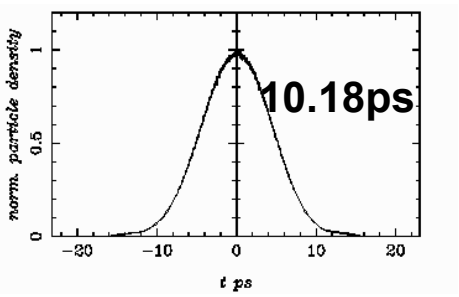
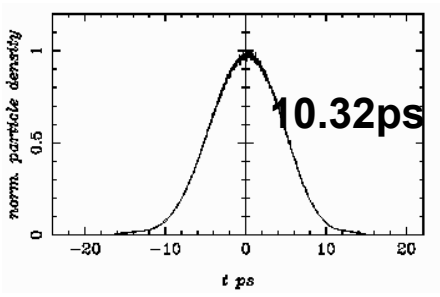
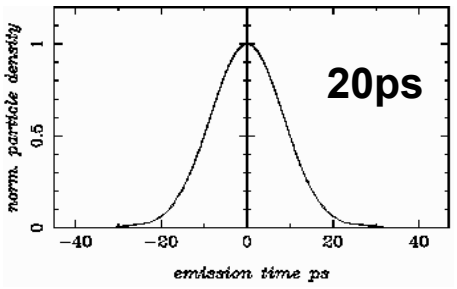
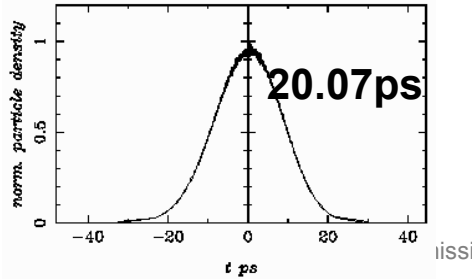
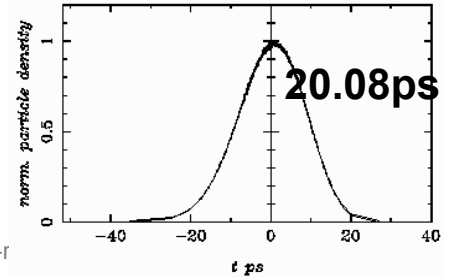
Simulations of bunch compression (BC) in the gun



Cath laser pulse (GS, FWHM in ps)	Gun Phase w.r.t. MMMG	Bunch length at 1m in ps	Boo Phase w.r.t. MMMG	Bunch length at 10m in ps
5	20.9	5.01	-48.0	**4.99**
10	17.9	10.04	-43.5	**10.02**
20	19.3	20.01	-46.5	**19.96**

Simulations of bunch compression (BC) in the gun

Bunch Length Simulation using Gun & Booster at (BC=1) SP Phase with Space Charge ON, BSA=3.0, Q=100pC

Z=0, Cath	Z=1m, after gun	Z=10m, after Boo, at ~TDS
		
		
		

Simulations of bunch compression (BC) in the gun

> Summary

Space charge excluded

Cath laser pulse (GS, FWHM in ps)	Gun Phase w.r.t. MMMG	Bunch length at 1m in ps	Boo Phase w.r.t. MMMG	Bunch length at 10m in ps
5	20.9	**5.01**	-48.0	**4.99**
10	17.9	**10.04**	-43.5	**10.02**
20	19.3	**20.01**	-46.5	**19.96**

Space charge included (BSA=3.0mm, Q=100pC)

Cath laser pulse (GS, FWHM in ps)	Gun Phase w.r.t. MMMG	Bunch length at 1m in ps	Boo Phase w.r.t. MMMG	Bunch length at 10m in ps
5	20.9	**5.30**	-48.0	**5.62**
10	17.9	**10.18**	-43.5	**10.32**
20	19.3	**20.07**	-46.5	**20.08**

Thank you very much!