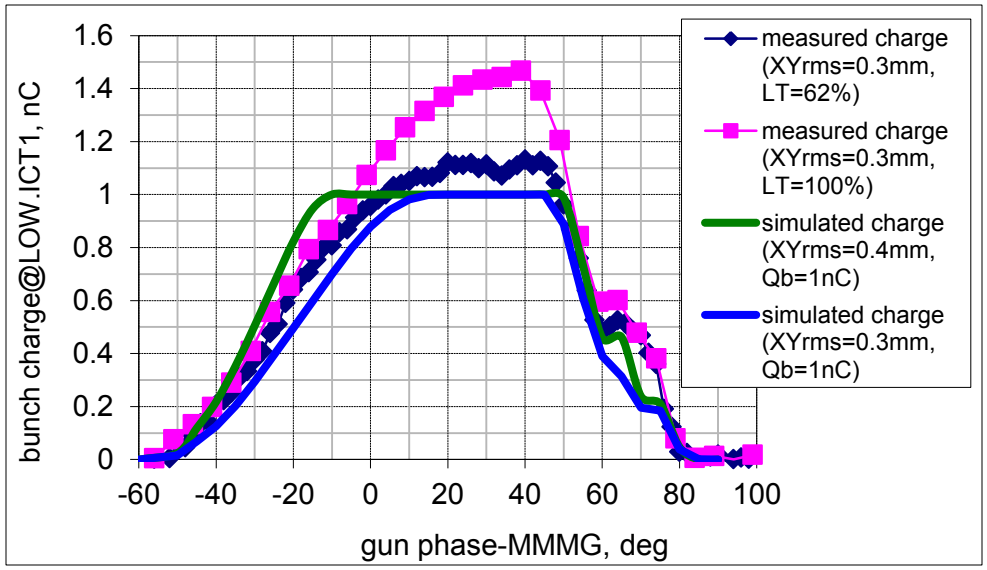
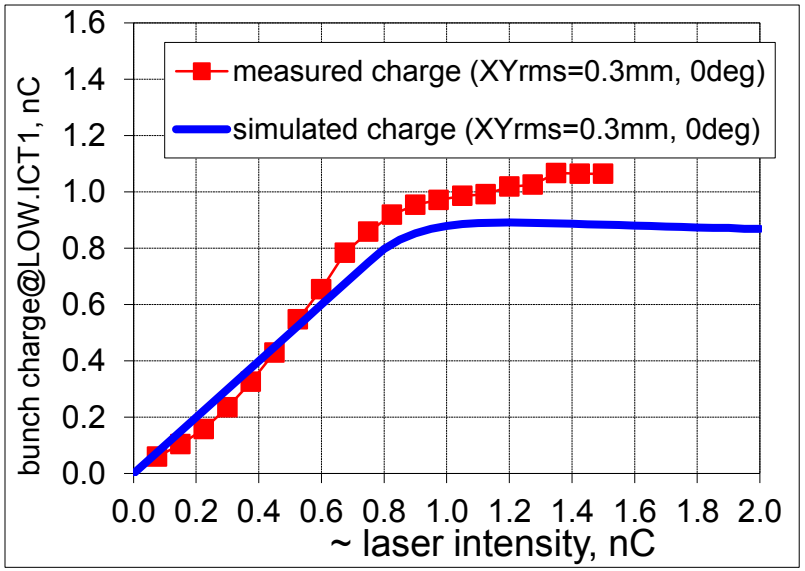
Simulations of the measured longitudinal momentum at PITZ-1.8

M.Krasilnikov, PPS, 04.04.2012

Motivation: Measurements ←→ simulations for the "PITZ-1.8 paper"

- **Experiment**:
  - Best 1 nC emittance for LaserXYrms=0.3 mm
  - Optimum gun phase is +6 deg w.r.t. MMMG phase
- **Simulations**:
  - Best emittance for LaserXYrms=0.4 mm
  - Optimum gun phase is +0.2 deg w.r.t. MMMG phase
  - Direct plug-in of the experimental machine parameters: LaserXYrms=0.3 mm at MMMG gun phase ➔ no 1 nC due to space charge limited emission



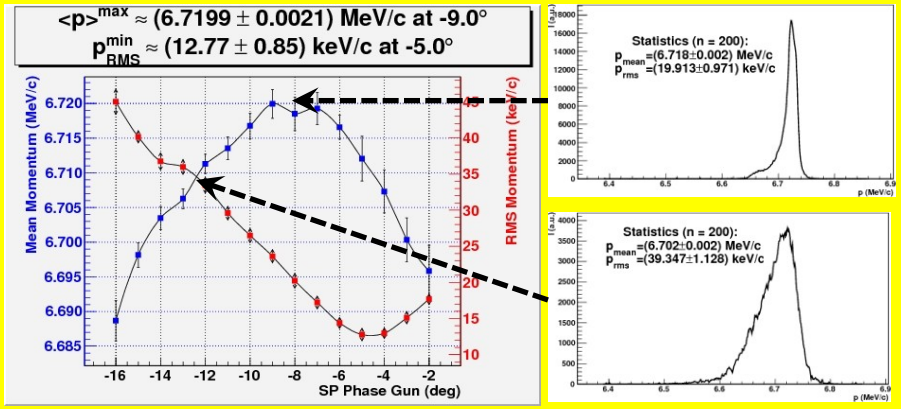


Motivation: what is with Longitudinal Phase Space (LPS)?

- ??? Due to the space charge assisted photo emission electron bunches in experiment are significantly longer than those expected in the optimum simulations???
- Unfortunately there were no bunch length (LPS) measurements were done at PITZ-1.8 (2009-2011)
- Only electron beam momentum are available (e.g. 05.05.2011N):

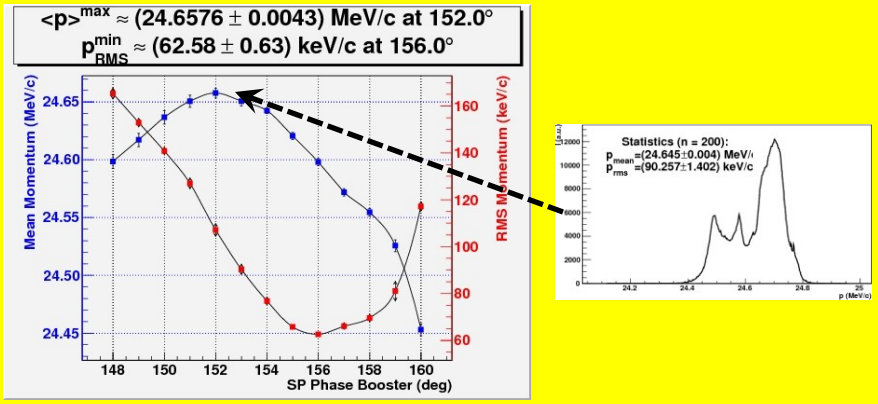
LEDA scan:

Imain = 475 A; IDipole = -1.75A; LT = 100.0 % (~1 nC);
NoP = 3; 50 statistics



HEDA scan :

Imain = 390 A; IDipole = -91.2A; LT = 100.0 % (~1 nC);
NoP = 1; 30 statistics



Simulation Setup

- Cathode laser:
  - Temporal → flat-top: 2 / 21.5 \ 2 ps
  - Transverse → radial homogen:
    - XYrms=0.4mm ➔ **"simulations400"** (Qbunch=1nC → 1nC electron bunch)
    - XYrms=0.32mm ➔ **"simulations320"** (Qbunch=1nC → 0.97nC electron bunch)
- Gun:
  - Gun-4.1 field profile (smoothed)
  - Ecath tuned in order ➔ <Pz>(MMMG)
  - Phase scans -10deg:0.5deg:+10deg (AUTOPHASE=.T, but the cubic polynomial fit for MMMG)
- Solenoid:
  - Calibration |Bz(z=0.276m),A|=0.00058930*Imain(SP)+0.00007102
  - Bucking → compensating Bz(z=0)
- Booster
  - CDS field profile (smoothed)
  - Max(Ez) tuned in order ➔ <Pz>(MMMG)
- Pz-Measurements:
  - LEDA ➔ Z=0.9 m (before LEDA dipole)
  - HEDA ➔ Z=7.0 m (before HEDA1 dipole)

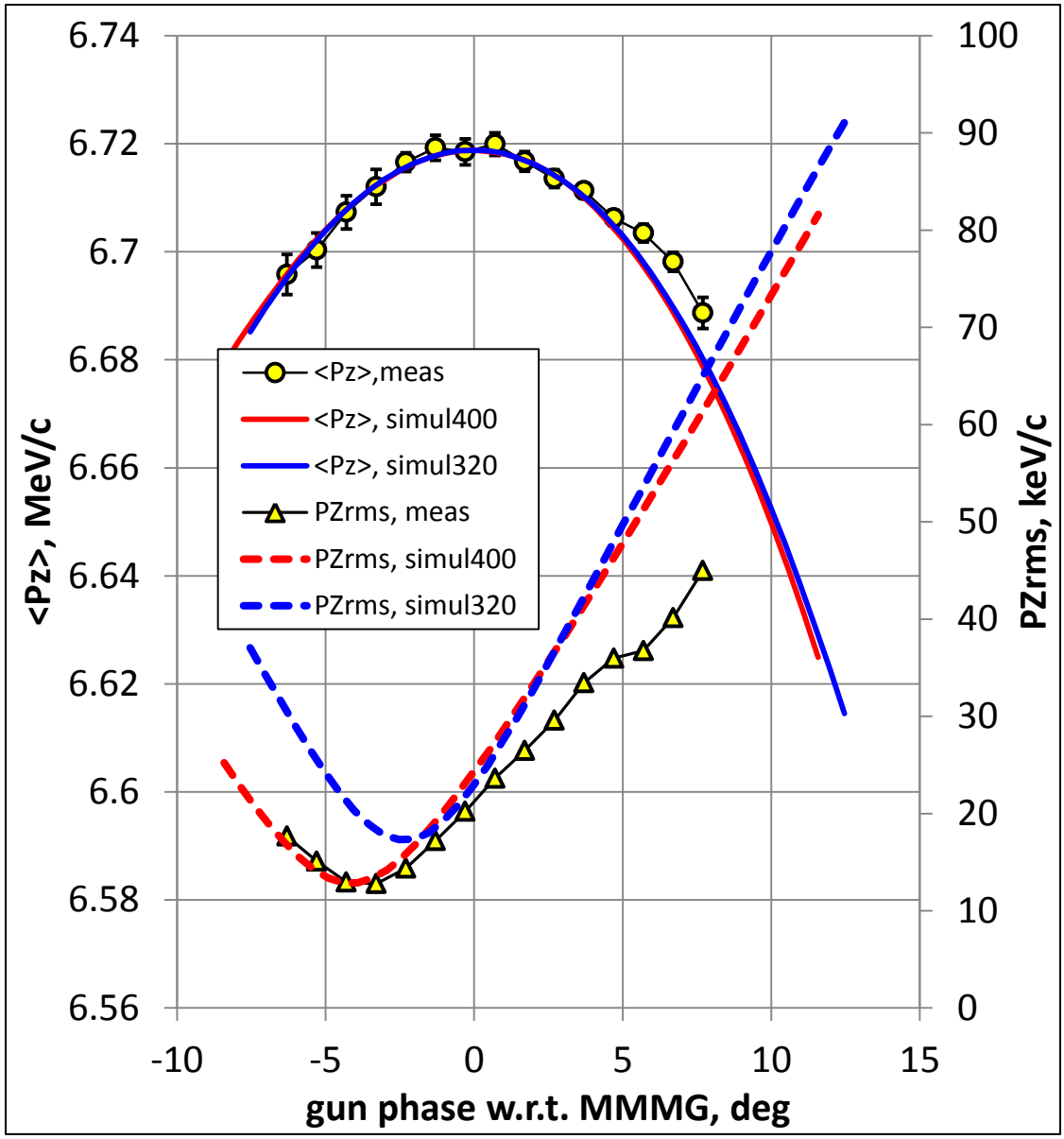
LEDA Scan: M ← → S

Measured data (phase20110506_030309)

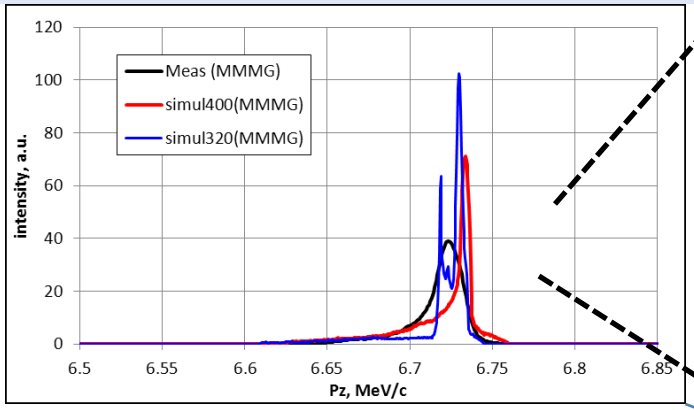
SPPhase	phase	<Pz>, MeV/c	error	PZrms, keV/c	error
-16	7.7	6.689	0.0029	44.988	0.0017
-15	6.7	6.698	0.0018	40.138	0.0008
-14	5.7	6.703	0.0017	36.739	0.0012
-13	4.7	6.706	0.0014	35.968	0.0010
-12	3.7	6.711	0.0014	33.445	0.0011
-11	2.7	6.714	0.0017	29.571	0.0009
-10	1.7	6.717	0.0018	26.463	0.0010
-9	0.7	6.720	0.0021	23.612	0.0009
-8	-0.3	6.719	0.0024	20.210	0.0010
-7	-1.3	6.719	0.0023	17.203	0.0009
-6	-2.3	6.717	0.0017	14.366	0.0007
-5	-3.3	6.712	0.0032	12.769	0.0009
-4	-4.3	6.707	0.0031	12.947	0.0007
-3	-5.3	6.700	0.0032	15.100	0.0008
-2	-6.3	6.696	0.0037	17.659	0.0007

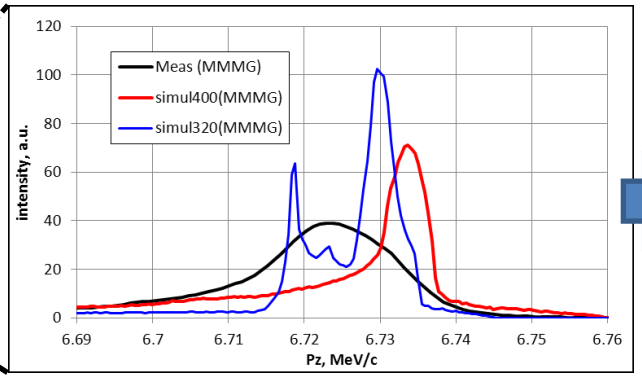
Simulation fit

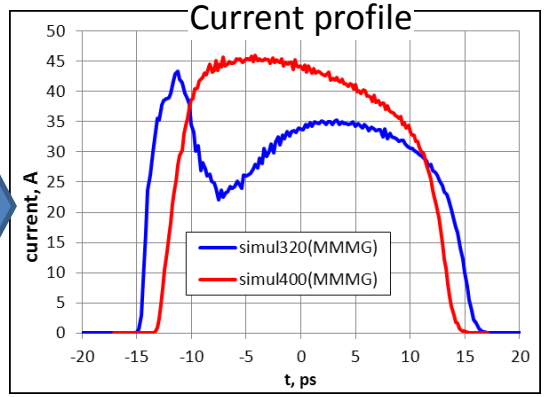
- Simul400:
  Ecath=60.889MV/m
  DeltaPhi1(AUTOPHASE)=-1.58deg
- Simul320:
  Ecath=60.932MV/m
  DeltaPhi1(AUTOPHASE)=-2.46deg

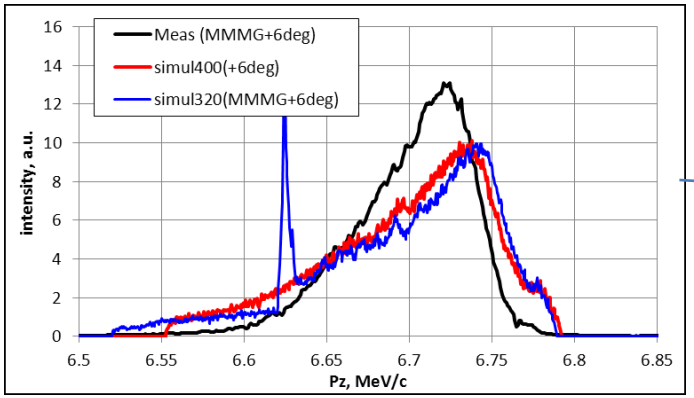


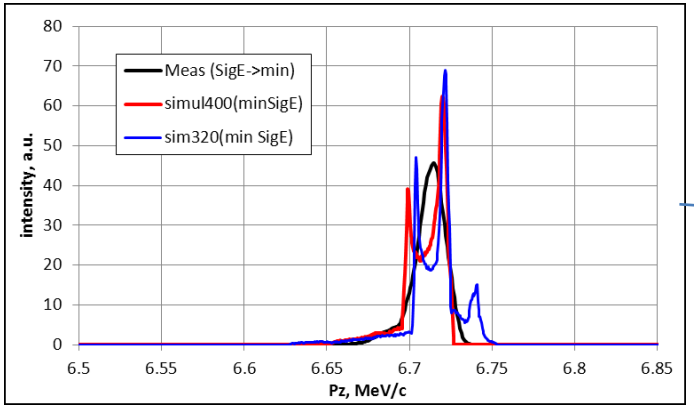
Momentum distributions at LEDA : M ← → S

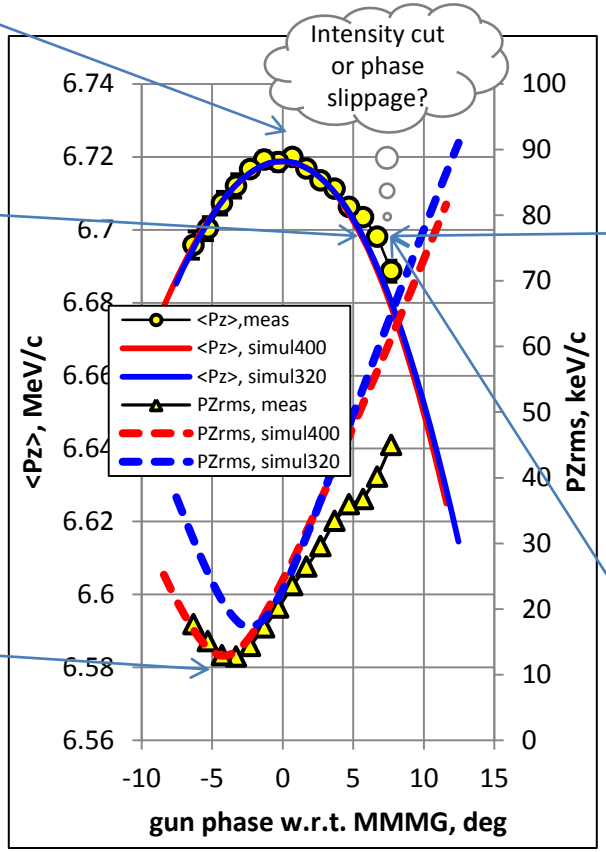


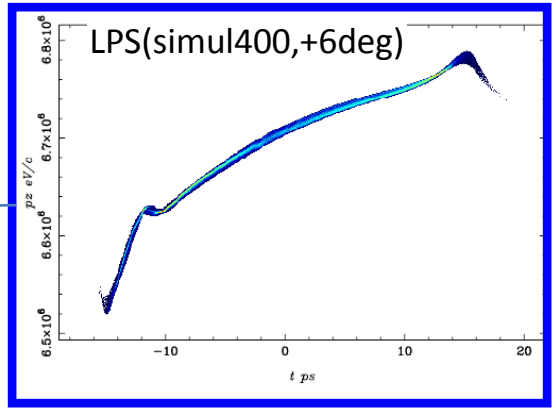


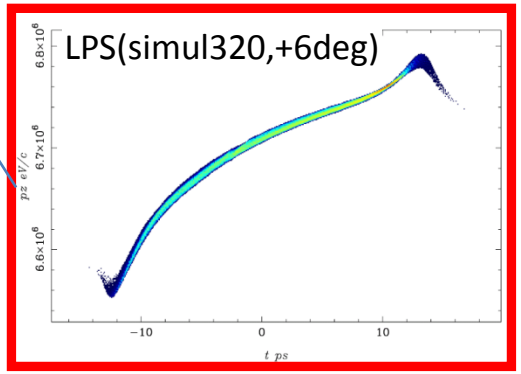






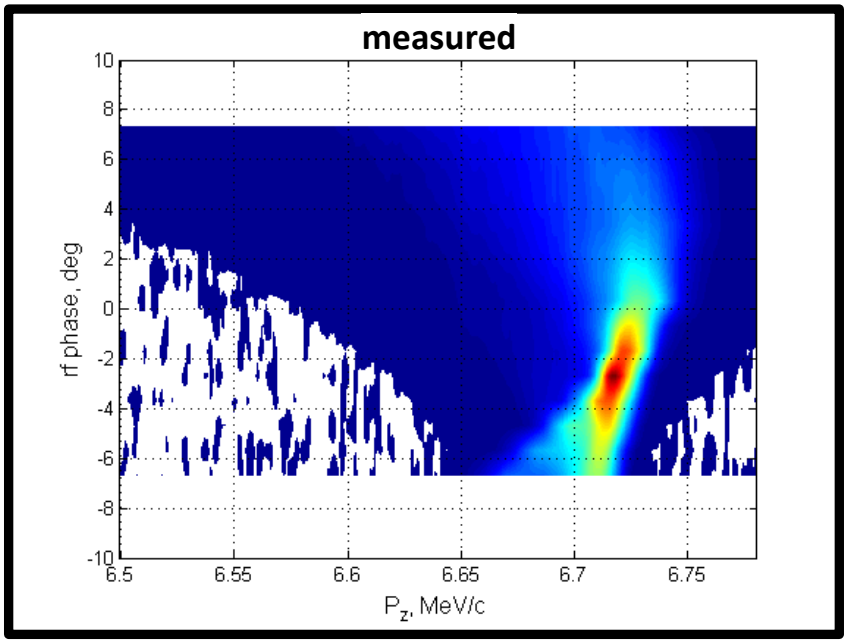


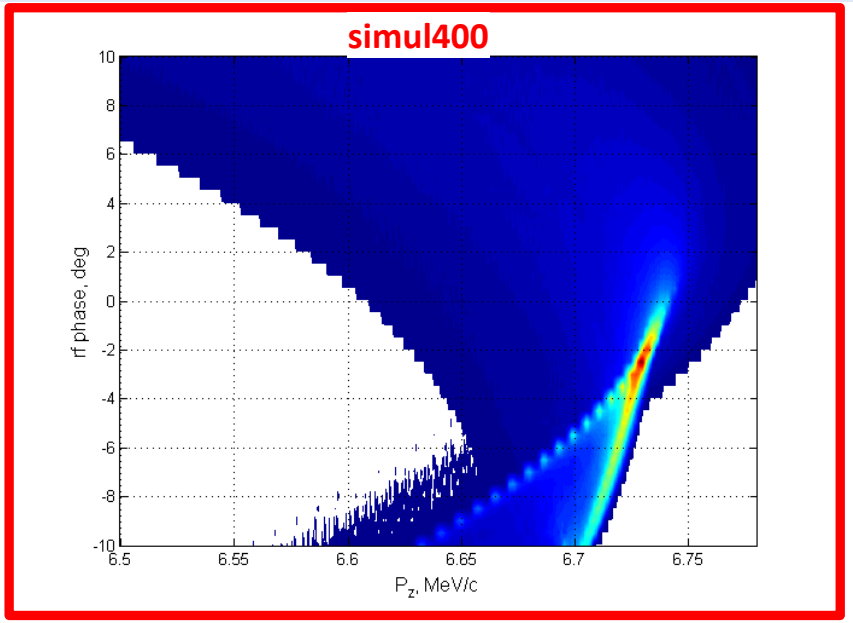


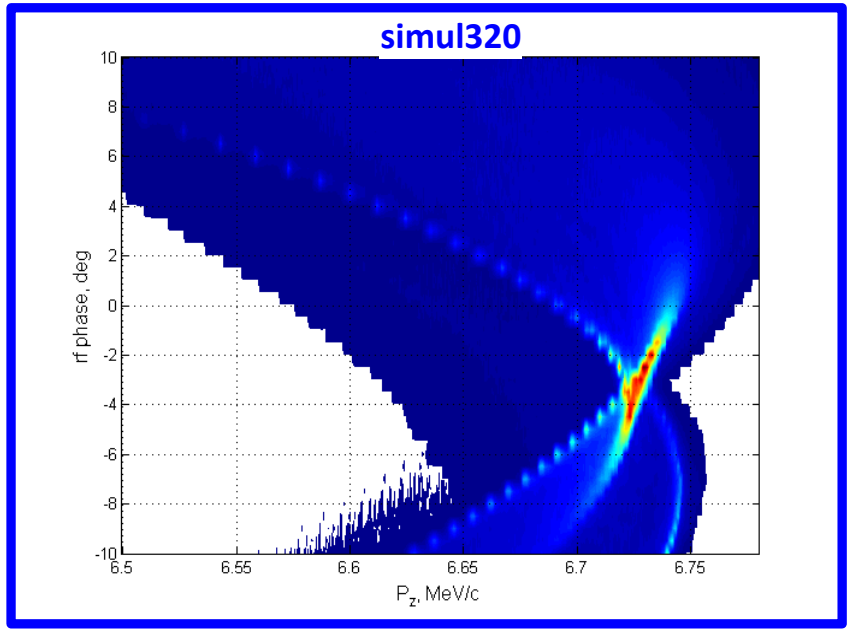


Momentum distributions at LEDA scan : M ← → S

Longitudinal momentum distribution
for various gun phases (w.r.t. MMMG)







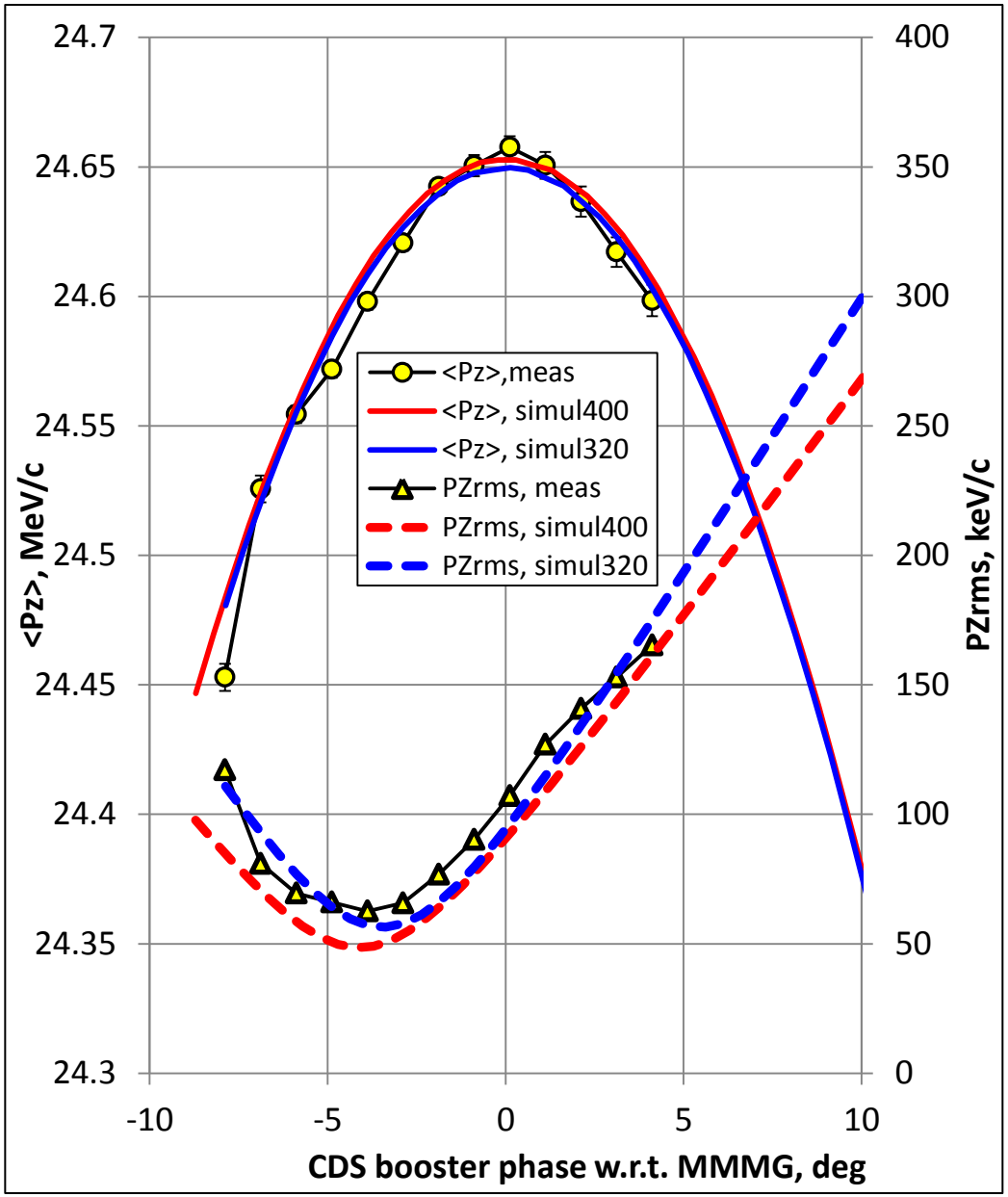
HEDA Scan: M ← → S

Measured data (phase20110506_030309)

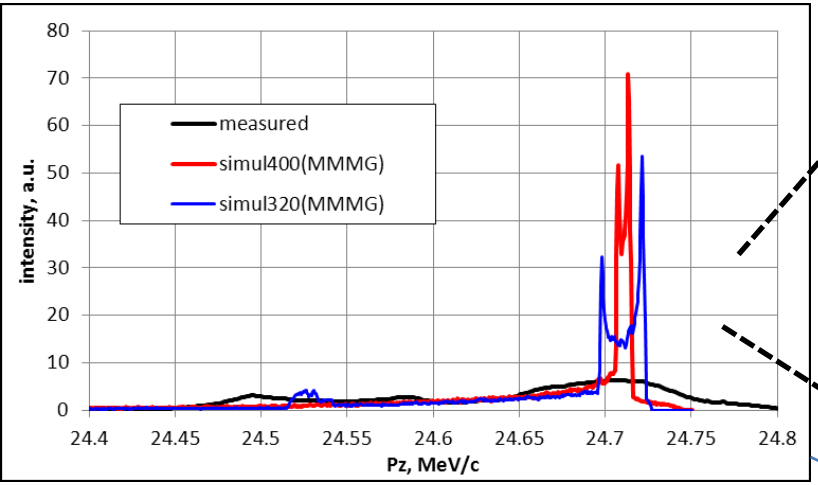
SPPhase	phase	<Pz>, MeV/c	error	PZrms, keV/c	error
148	4.12	24.598	0.0061	165.291	0.0023
149	3.12	24.617	0.0058	152.893	0.0018
150	2.12	24.637	0.0058	140.782	0.0016
151	1.12	24.651	0.0052	126.977	0.0023
152	0.12	24.658	0.0043	107.088	0.0027
153	-0.88	24.651	0.0041	90.285	0.0022
154	-1.88	24.642	0.0024	76.752	0.0017
155	-2.88	24.621	0.0029	65.737	0.0010
156	-3.88	24.598	0.0031	62.576	0.0006
157	-4.88	24.572	0.0033	66.037	0.0014
158	-5.88	24.554	0.0033	69.510	0.0016
159	-6.88	24.526	0.0052	80.974	0.0041
160	-7.88	24.453	0.0052	117.136	0.0020

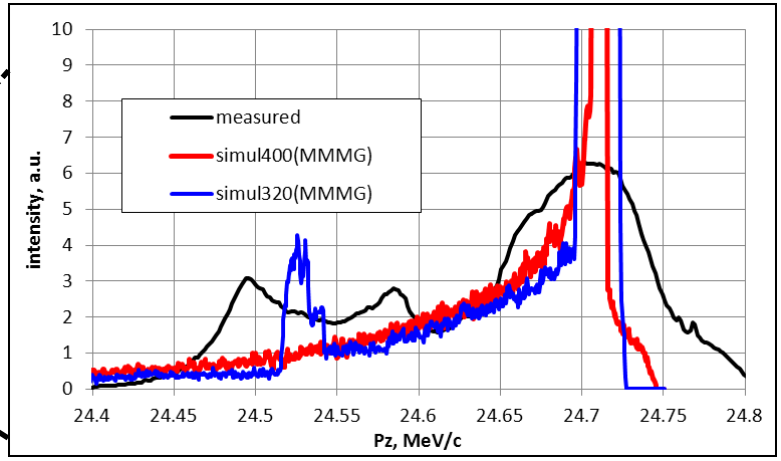
Simulation fit

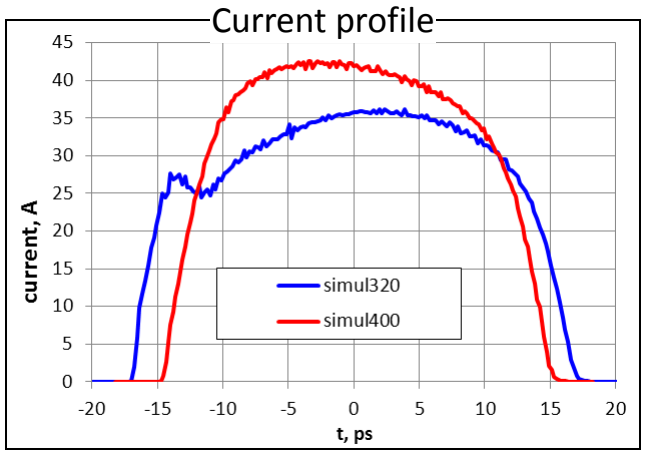
- **Simul400:**
  Ecath=60.889MV/m
  DeltaPhi1(AUTOPHASE)=-1.58deg
  Phi(1)=4.42deg → +6deg
  MaxE(2)=20.595MV/m
  DeltaPhi2(AUTOPHASE)=-1.29deg
- **Simul320:**
  Ecath=60.932MV/m
  DeltaPhi1(AUTOPHASE)=-2.46deg
  Phi(1)=3.54deg → +6deg
  MaxE(2)=20.604MV/m
  DeltaPhi2(AUTOPHASE)=-2.13deg

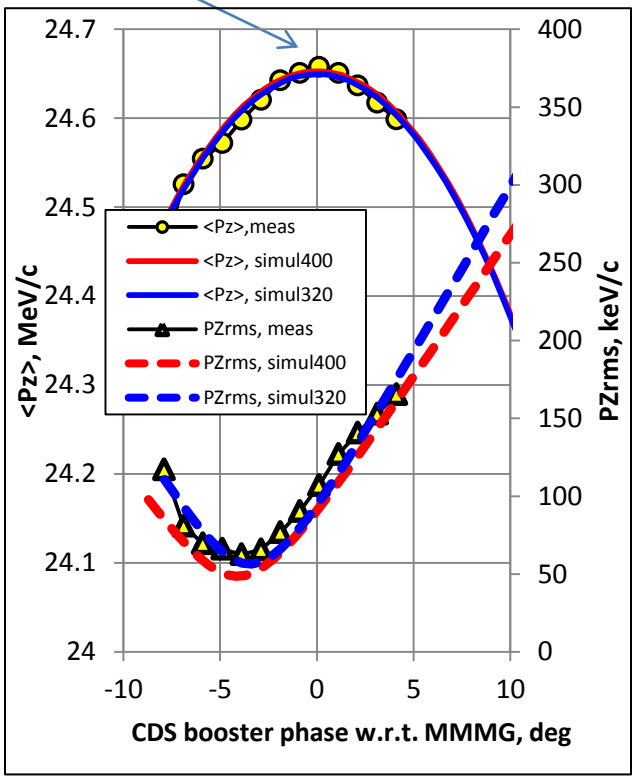


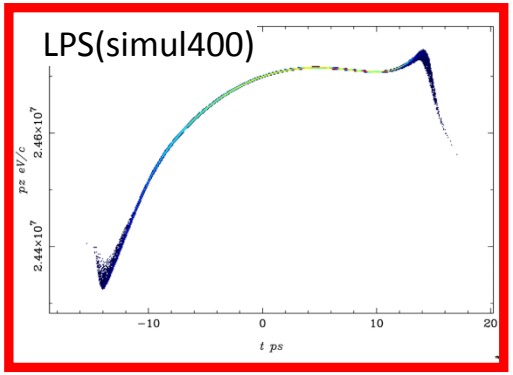
Momentum distributions at HEDA : M ← → S

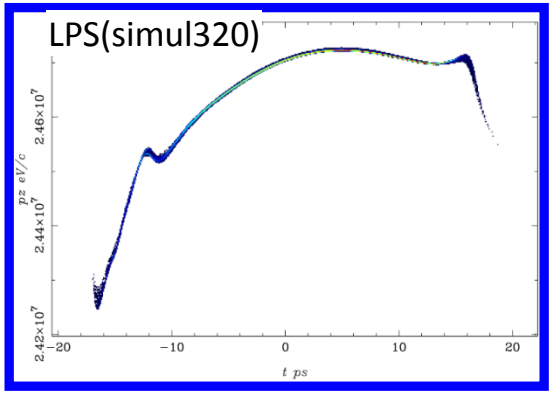






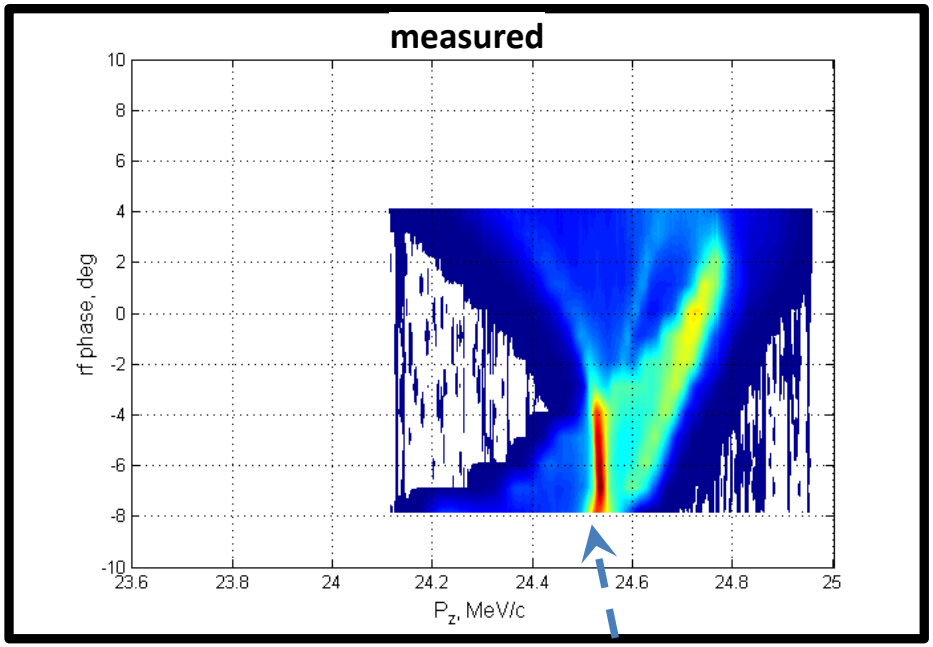


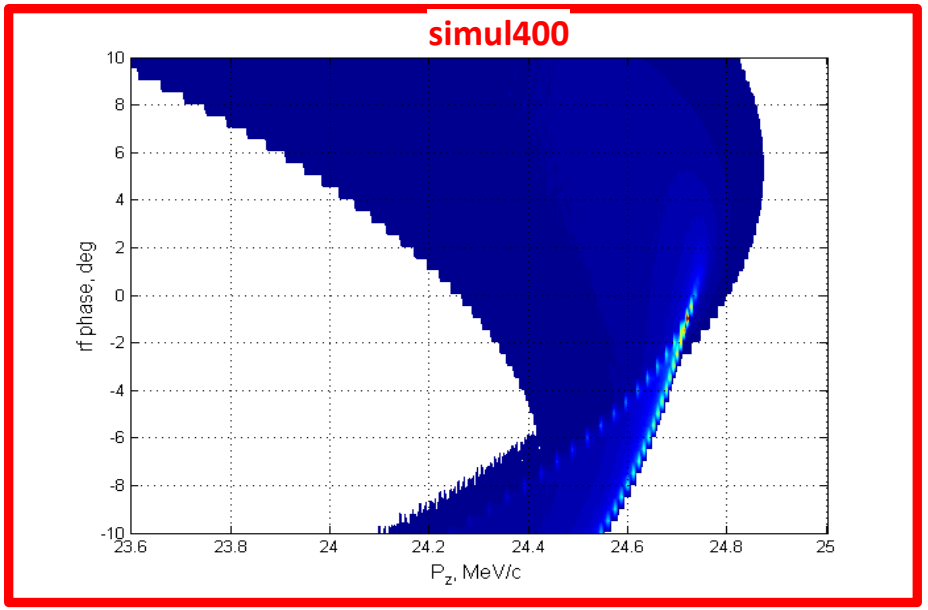


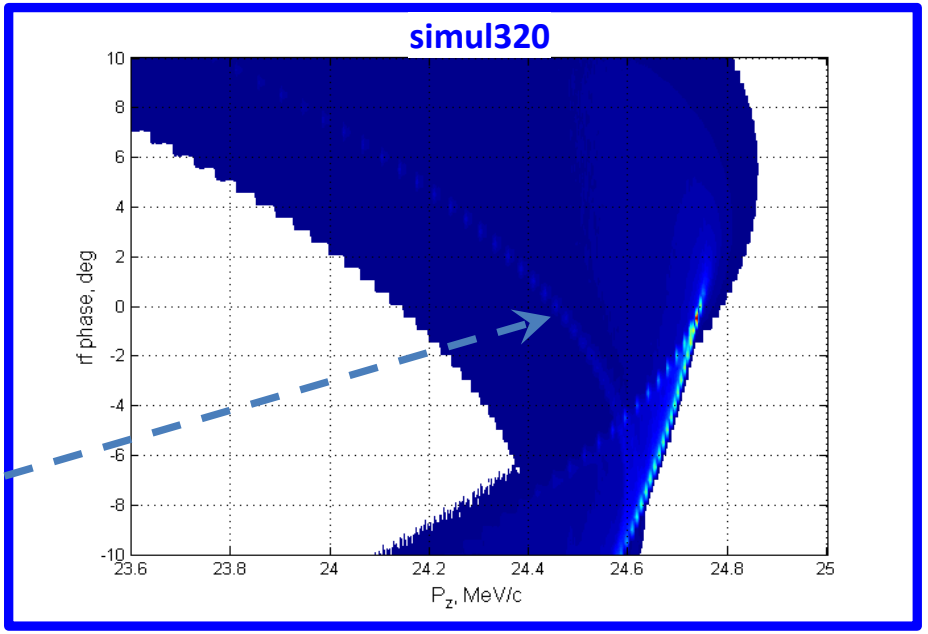


Momentum distributions at HEDA scan : M ← → S

Longitudinal momentum distribution
for various gun phases (w.r.t. MMMG)







SC limited emission?

Conclusions and Outlook

- Longitudinal momentum simulations using 2 laser spot sizes at the cathode (radial homogeneous distribution):
  - 0.4 mm rms (optimum from simulations)
  - 0.32 mm rms (closer to the experimental optimum of 0.3 mm)
- Gun phase scan for LEDA:
  - Both simulation setups → good agreement for <Pz> near the MMMG, but +6..+8deg simulations underestimate the measured values (?intesity losses, beam size impact?)
  - RMS momentum spread is better reproduced by simulations with 0.4mm laser spot size, smaller laser spot yields higher momentum spread
- Momentum distributions in LEDA:
  - Narrow spikes in simulations whereas more smooth in measurements (beam size impact + jitter?)
- Gun phase scan for HEDA – relatively good agreement for both setups, but 0.32mm laser spot size yields rms spread closer to the measured values
- Momentum distributions in HEDA:
  - Narrow spikes in simulations whereas more smooth in measurements (jitter?)
  - Simulation with 0.32mm shows spikes which could be correlated with the measured structure
  - Minimum rms spread in HEDA is by a factor 5 higher than in the LEDA (induced by CDS + space charge)
- Despite discrepancies – the bunch length estimation (not-direct, e.g. from the momentum spread for various rf phases) yields reasonable values

Setup	Trms, ps	Tfwhm, ps	Zrms, mm	Zfwhm, mm	Ipeak, A
Simul400	7.3 ps	25.2 ps	2.2 mm	7.6 mm	43 A
simul320	8.6 ps	30.1 ps	2.6 mm	9.0 mm	36 A

- ?To be done?
  - Tracking in dipoles (beam size and space charge impact?)
  - Beam jitter (rf phase and amplitude) influence?
- For the future measurement program:
  - LPS measurements in HEDA2 using TDS are of great importance!
  - But LEDA measurements are also of interest, especially z-Pz correlations
  - Together with emission studies (Schottky scans)!
  - 2D momentum scan representation could be useful

For the “PITZ-1.8 paper”

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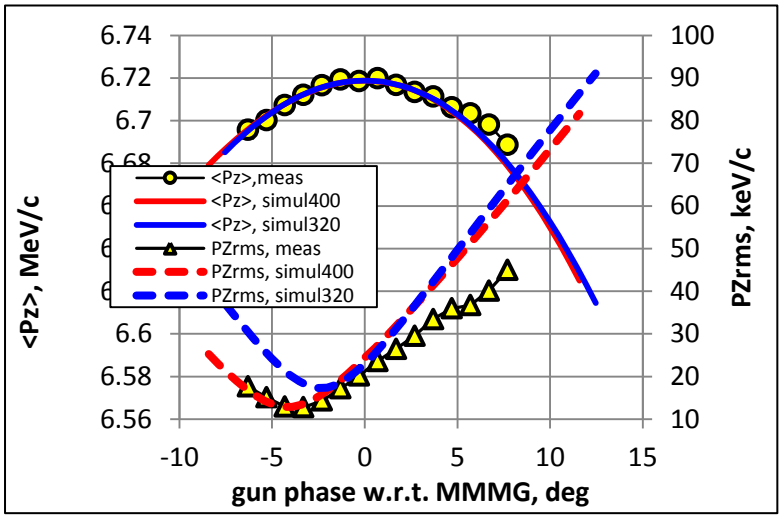

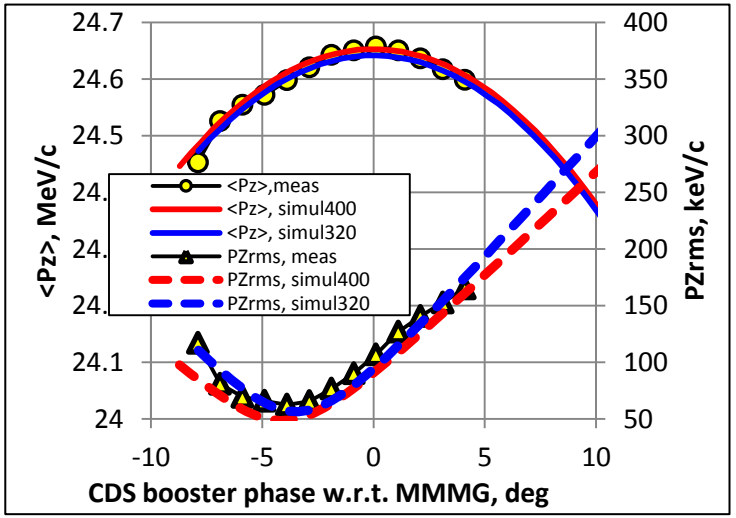

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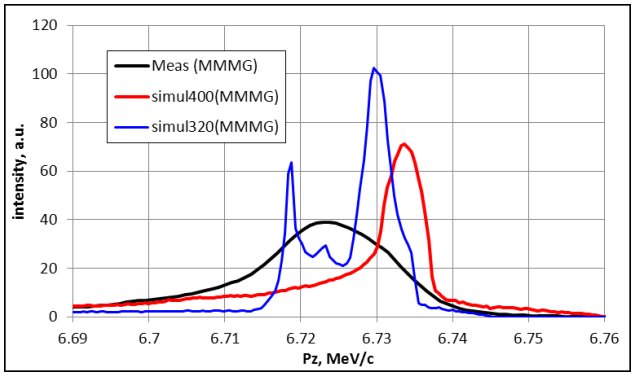

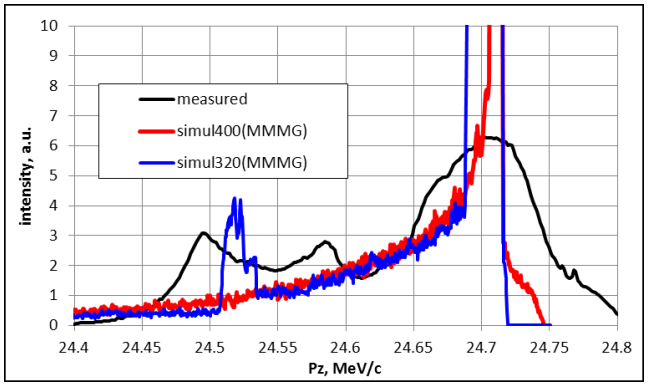

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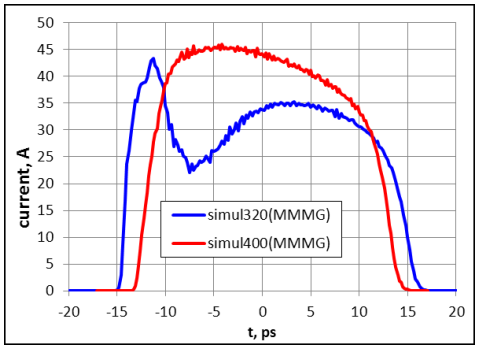
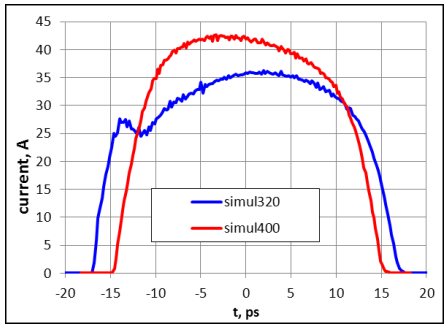




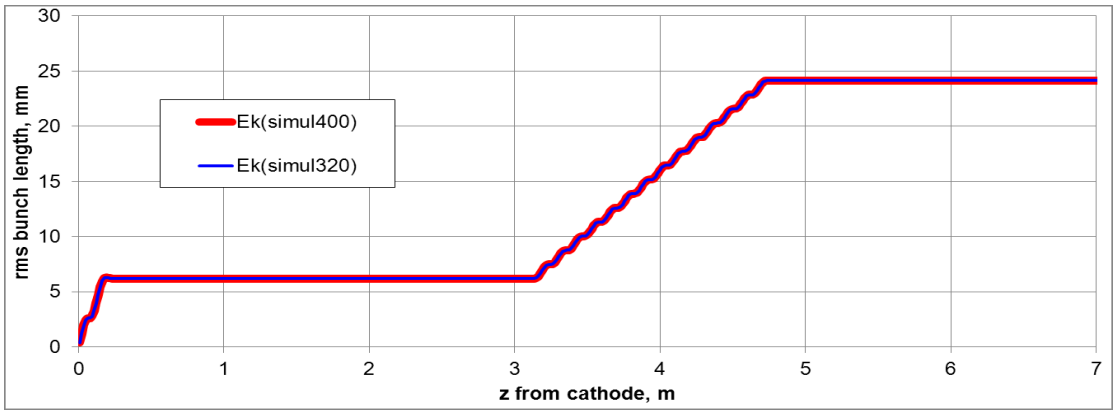
Thanks to Grigory and Yevgeniy for the script to extract Pz-profiles from mama-files

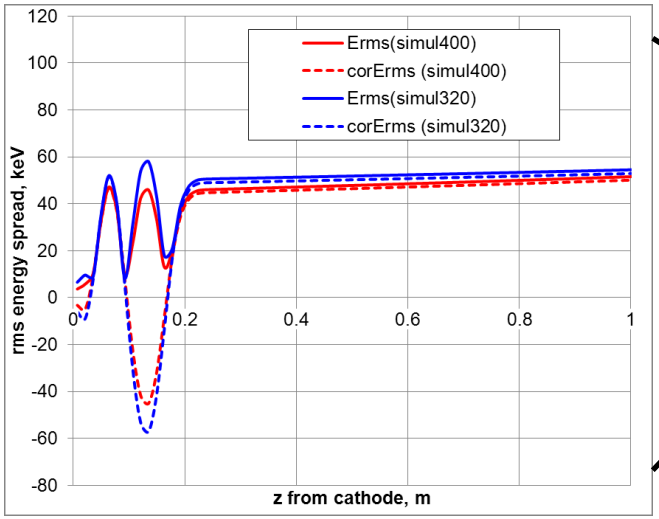
Appendix:

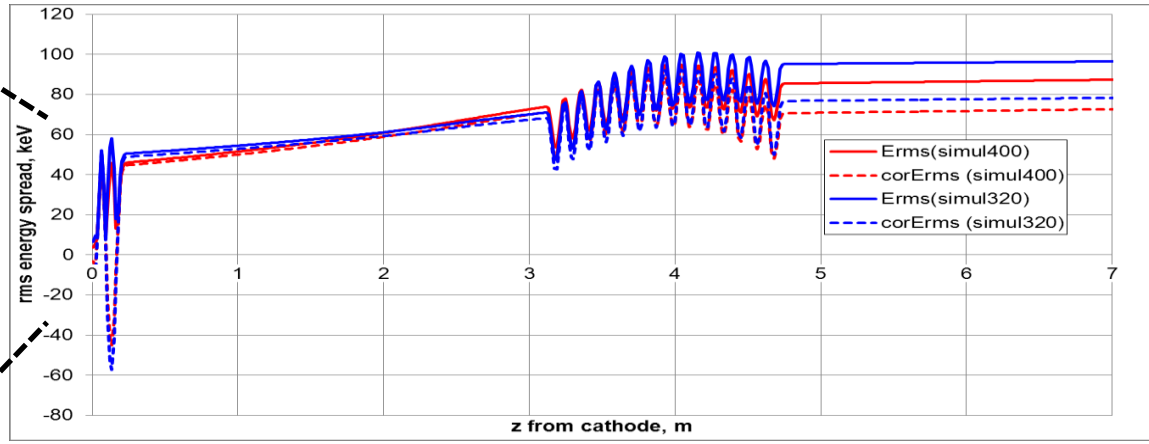
-Simulated LPS parameters along the beamline

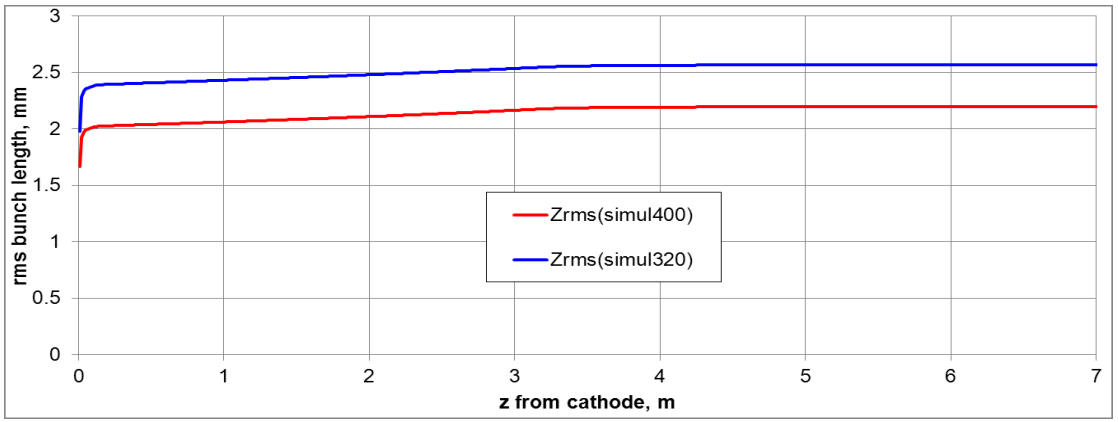
-Simulated beam phase space cuts before LEDA

Simulated LPS parameters along the beamline



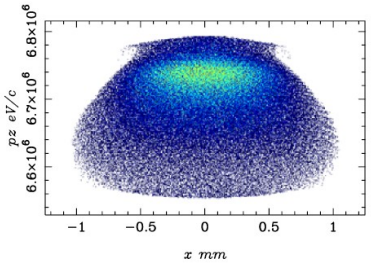


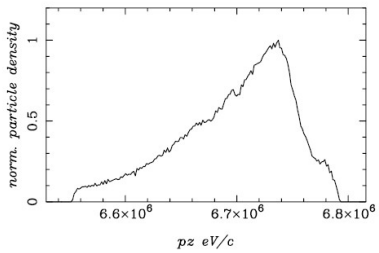


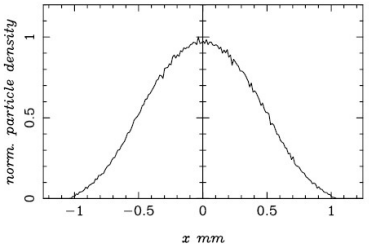


Simulated beam phase space cuts before LEDA

X(Y)-Pz(simul400)







X(Y)-Pz(simul320)