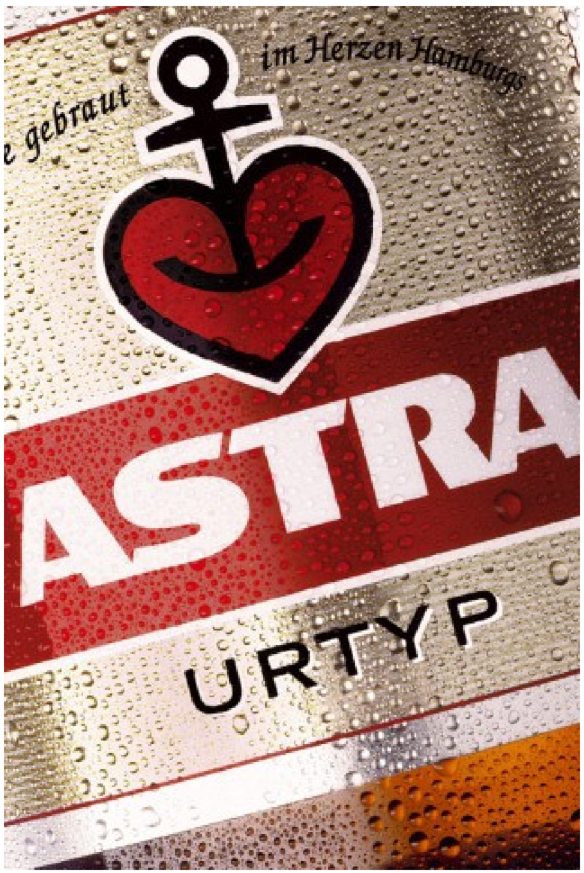
OBLA Simulations: OPAL vs ASTRA



Thomas Schietinger, PSI

FELSI Meeting, 5 May 2009

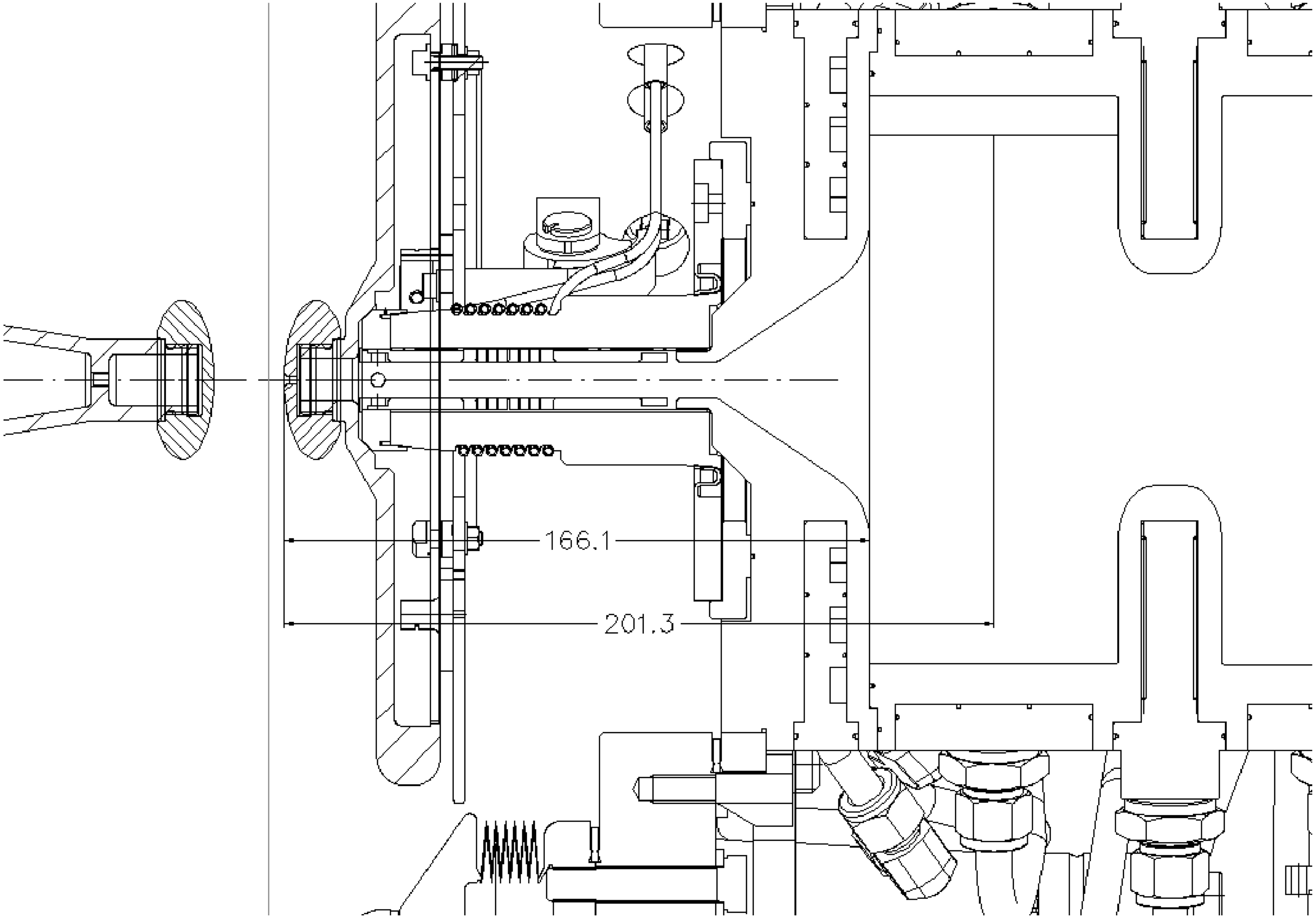
Content

- **Motivation / history**
- **LEG geometries**
- **Comparison OPAL/ASTRA**
  - For one working point, with current geometry/laser
- **OPAL optimizations for Ti:Sapph laser**
  - For all geometries
  - But only for elliptical electrodes (as currently installed)

Motivation / history

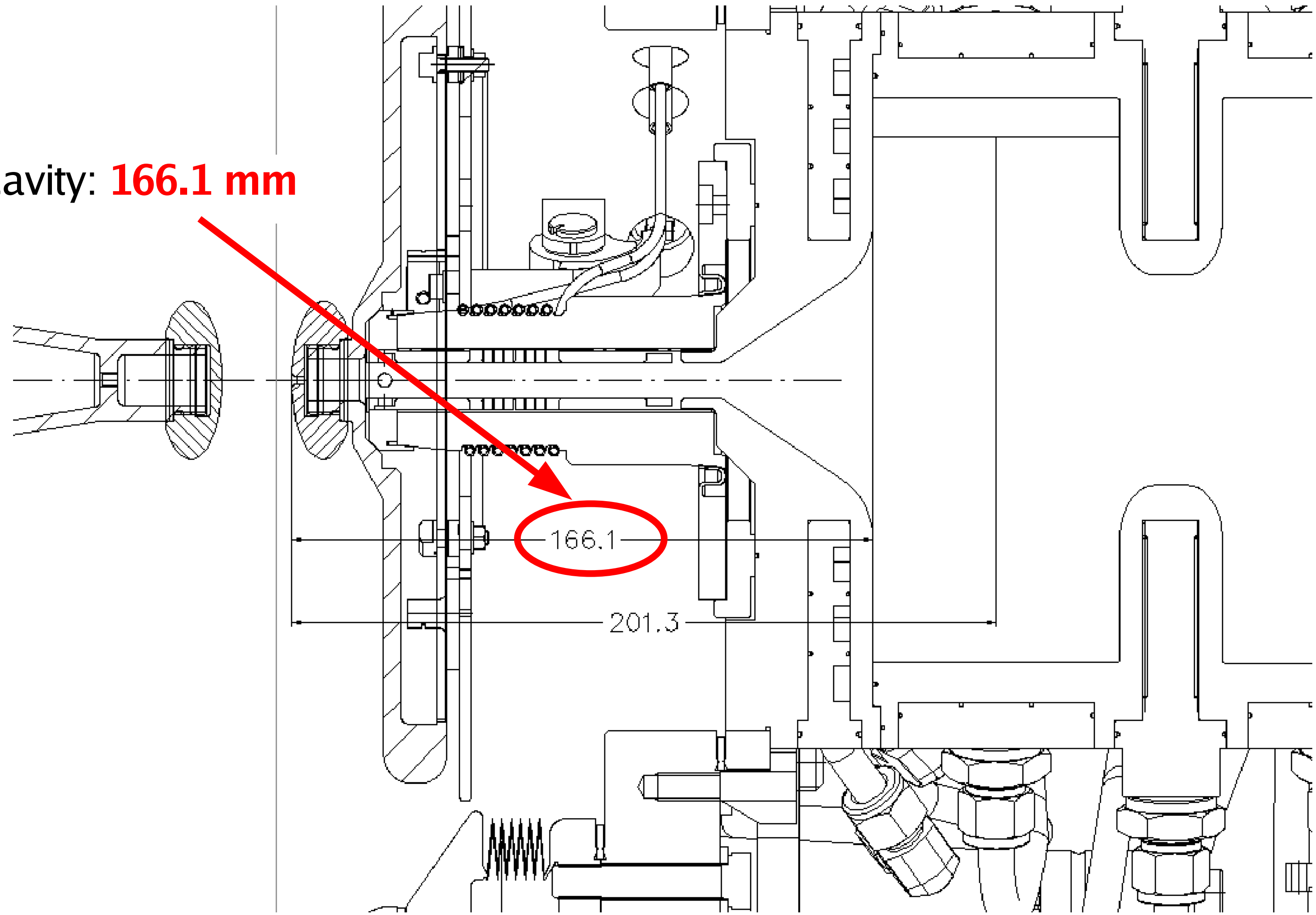
- OBLA retreat: both KL and TS who simualtions for Ti:Sapph laser (200 pC, flat-top with 9.9 ps FWHM) produced electron beam at OBLA
- KL (ASTRA): 0.8 mm mrad for currently standard elliptical electrodes, 0.4 mm mrad for specially designed “nose” electrodes
- TS (OPAL): ~4 mm mrad for elliptical electrodes
- Where does the difference come from?
  - different codes (OPAL vs ASTRA)
  - different geometries?
- Purpose of this meeting to sort out the difference!

LEG geometry as is now



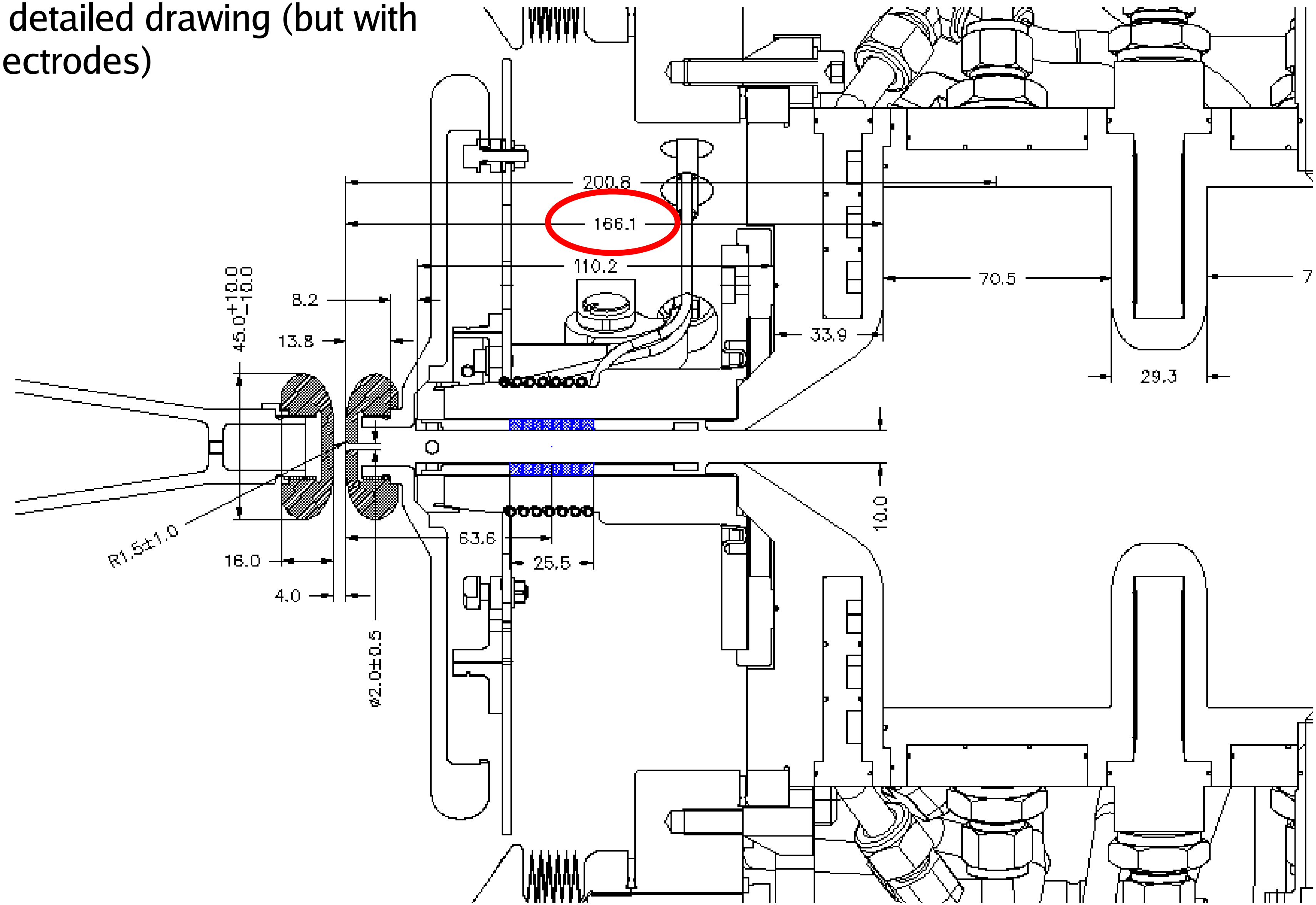
LEG geometry as is now

Distance anode-cavity: **166.1 mm**

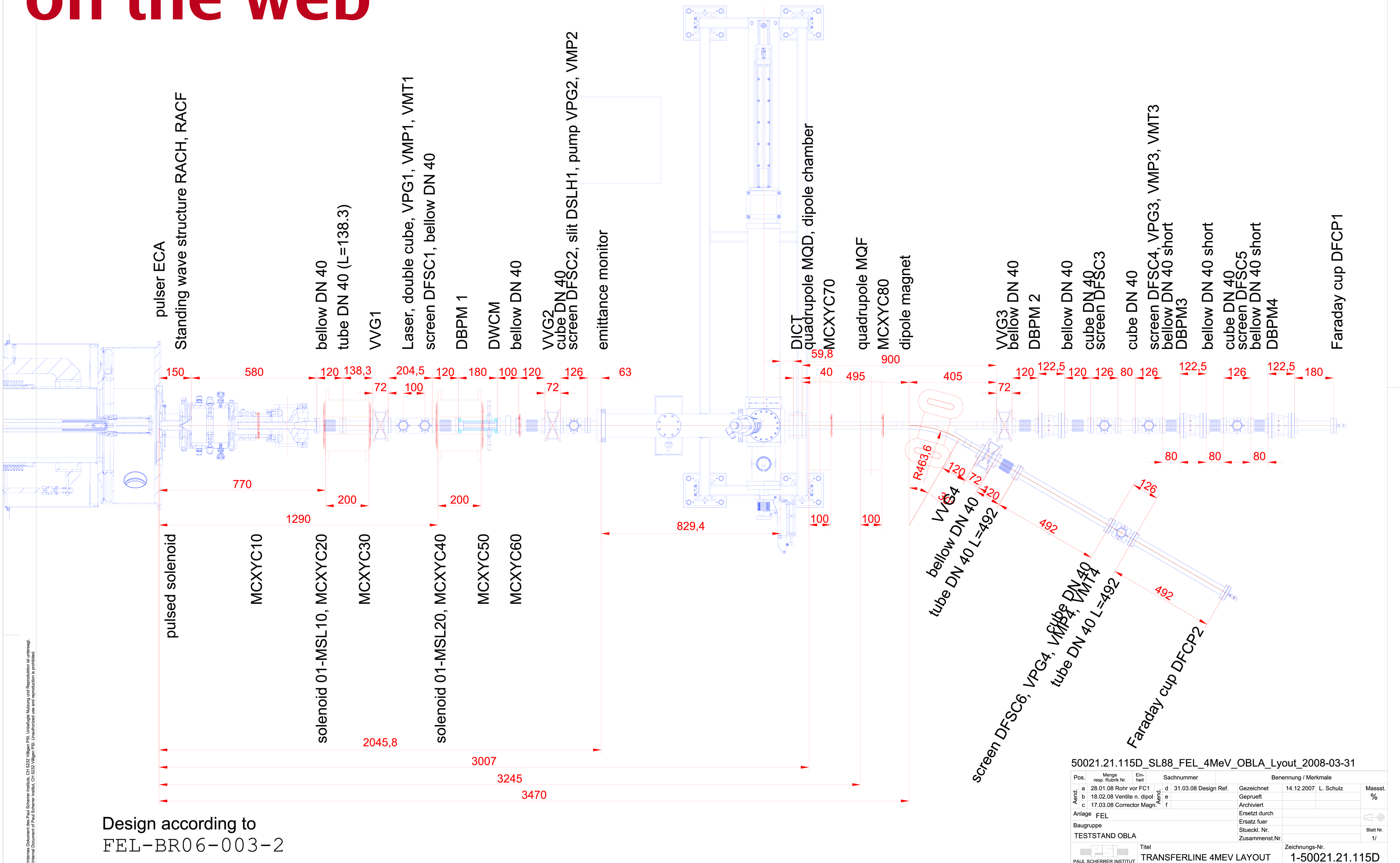


LEG geometry as is now

More detailed drawing (but with flat electrodes)

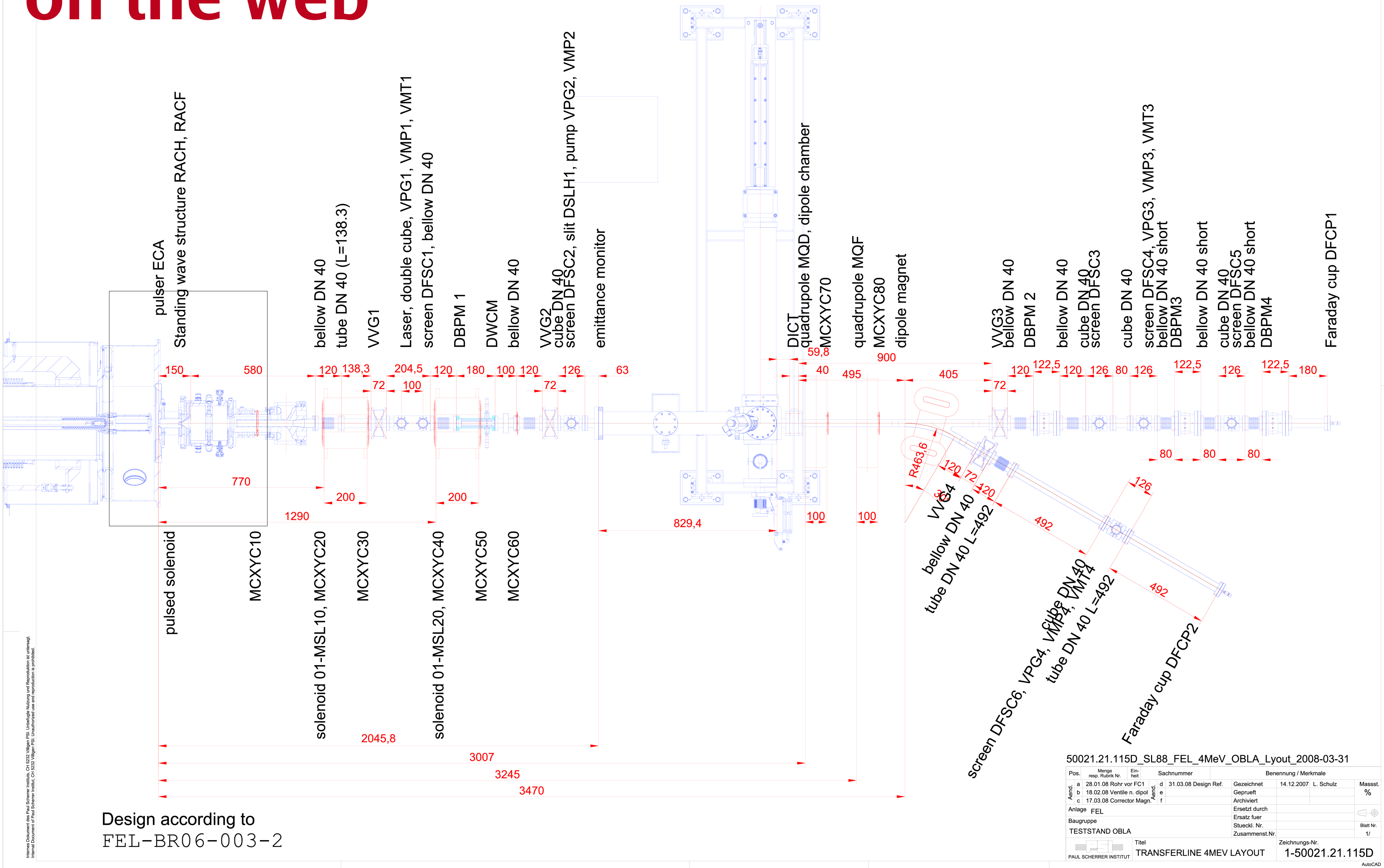


LEG geometry according to drawing on the web



Design according to
FEL-BR06-003-2

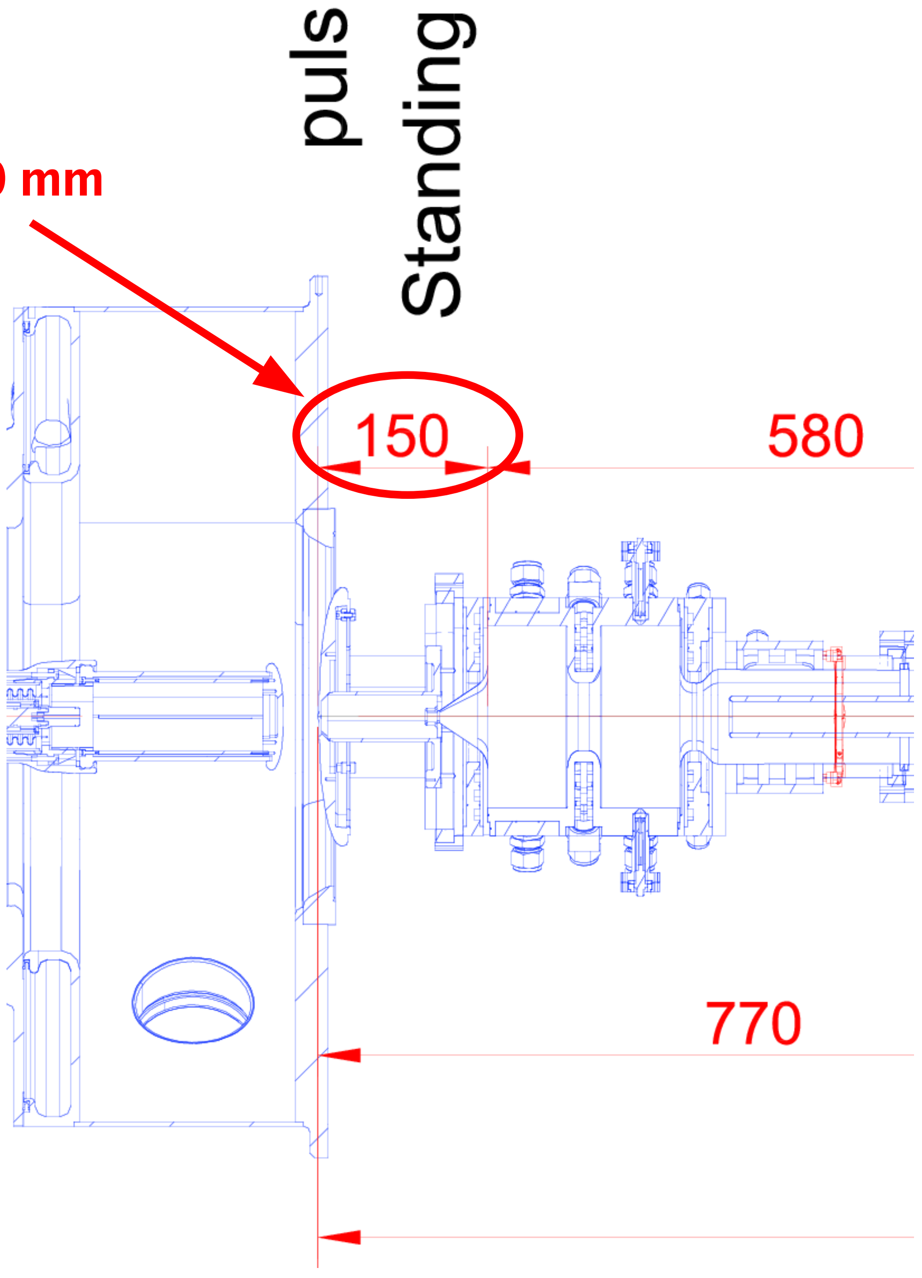
LEG geometry according to drawing on the web



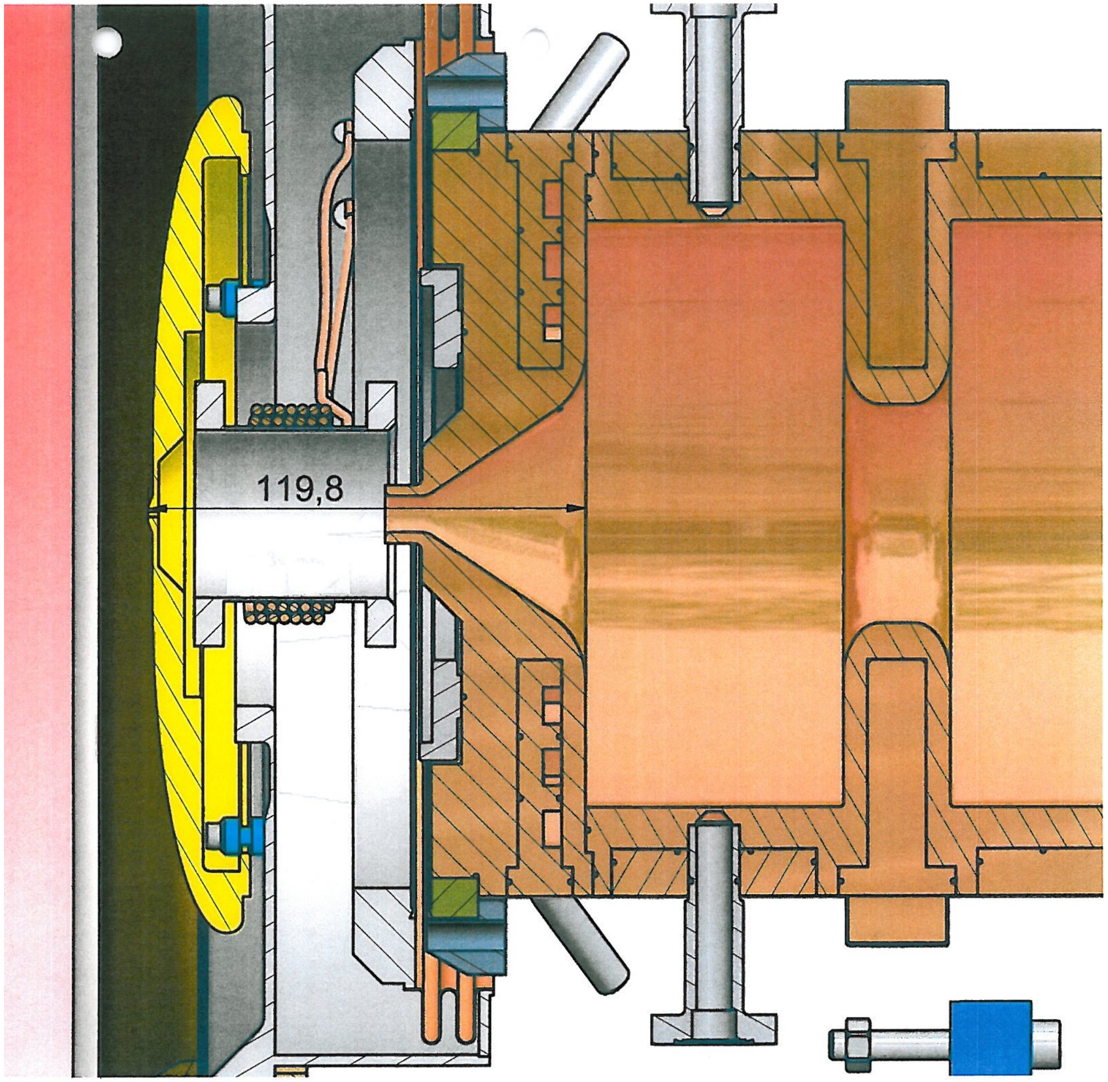
Design according to
FEL-BR06-003-2

LEG geometry according to drawing on the web

Distance anode-cavity: **150 mm**

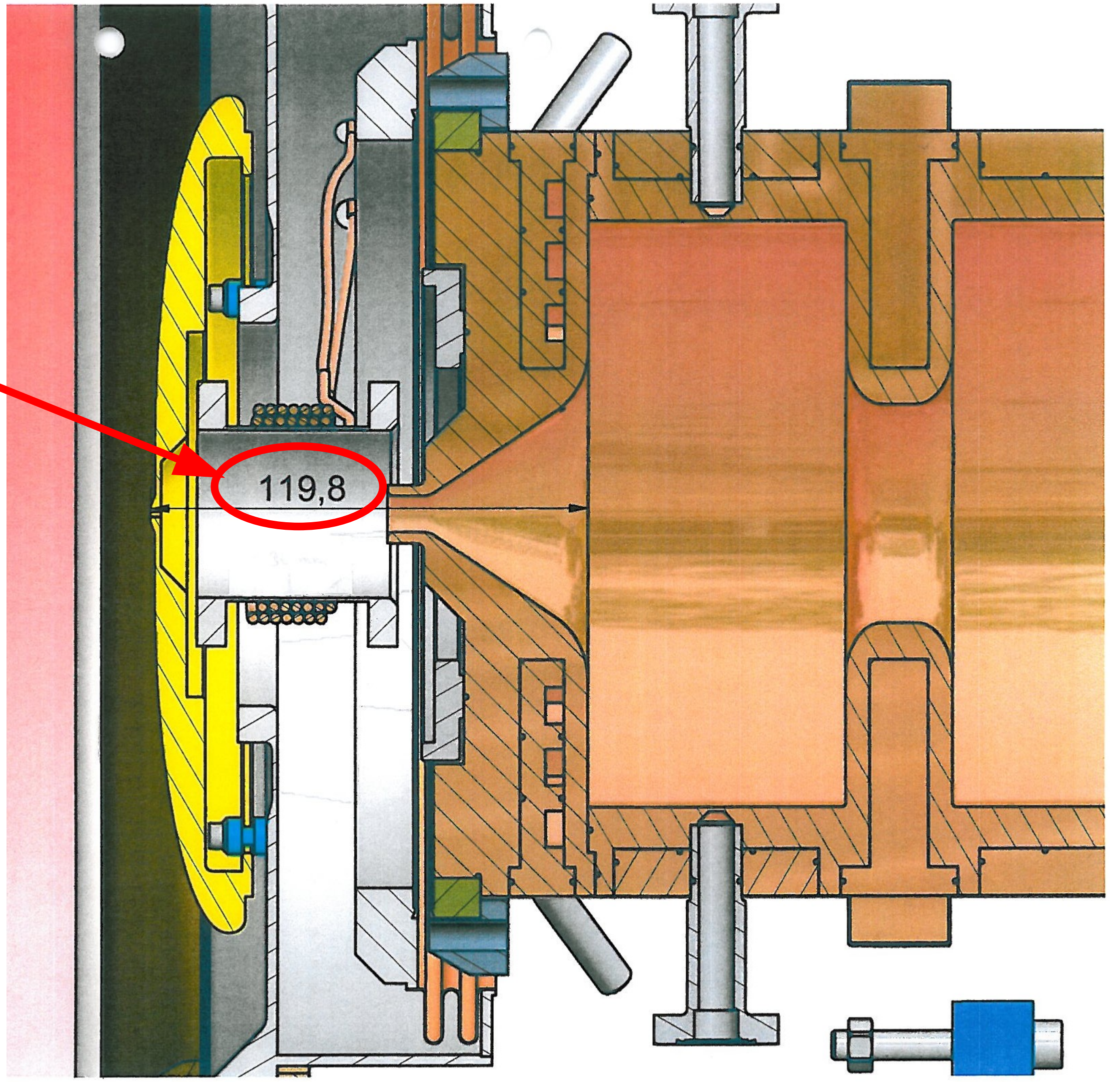


LEG geometry as designed once



LEG geometry as designed once

Distance anode-cavity: **119.8 mm**



LEG geometries: summary

Three geometries have been considered:

Distance to cavity:	120 mm	150 mm	166.1 mm
Distance to pulsed sol.:	40 mm	47.5 mm	63.6 mm
	used by Kevin for OBLA retreat simulations	used by Thomas for OBLA retreat simulations	Current reality

For the OBLA-ASTRA comparison, use the geometry corresponding to the current reality (166 mm drift), with the current laser (JAGUAR)

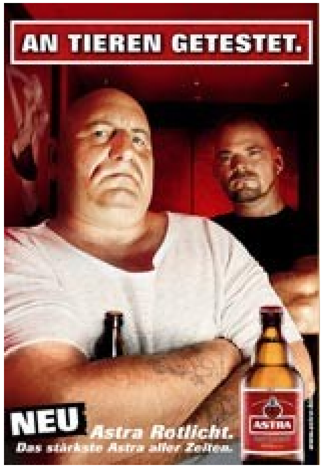
Working point 1 (166 mm drift geometry)

	low charge		high charge
Bunch charge:	10 pC		100 pC
Laser spot diameter:	0.6 mm		1.4 mm
Laser σ_t		14.8 ps	
Pulser voltage:		300 kV	
Pulser gap:		6 mm	
Pulsed solenoid:	145 mT		144 mT
RF phase:		~on-crest (adjustable)	
RF gradient:		42 MV/m	
Double sol. 10	120 mT		121 mT
Double sol. 20		90 mT	

Use these two points for OPAL/ASTRA comparison!

Known differences OPAL-ASTRA

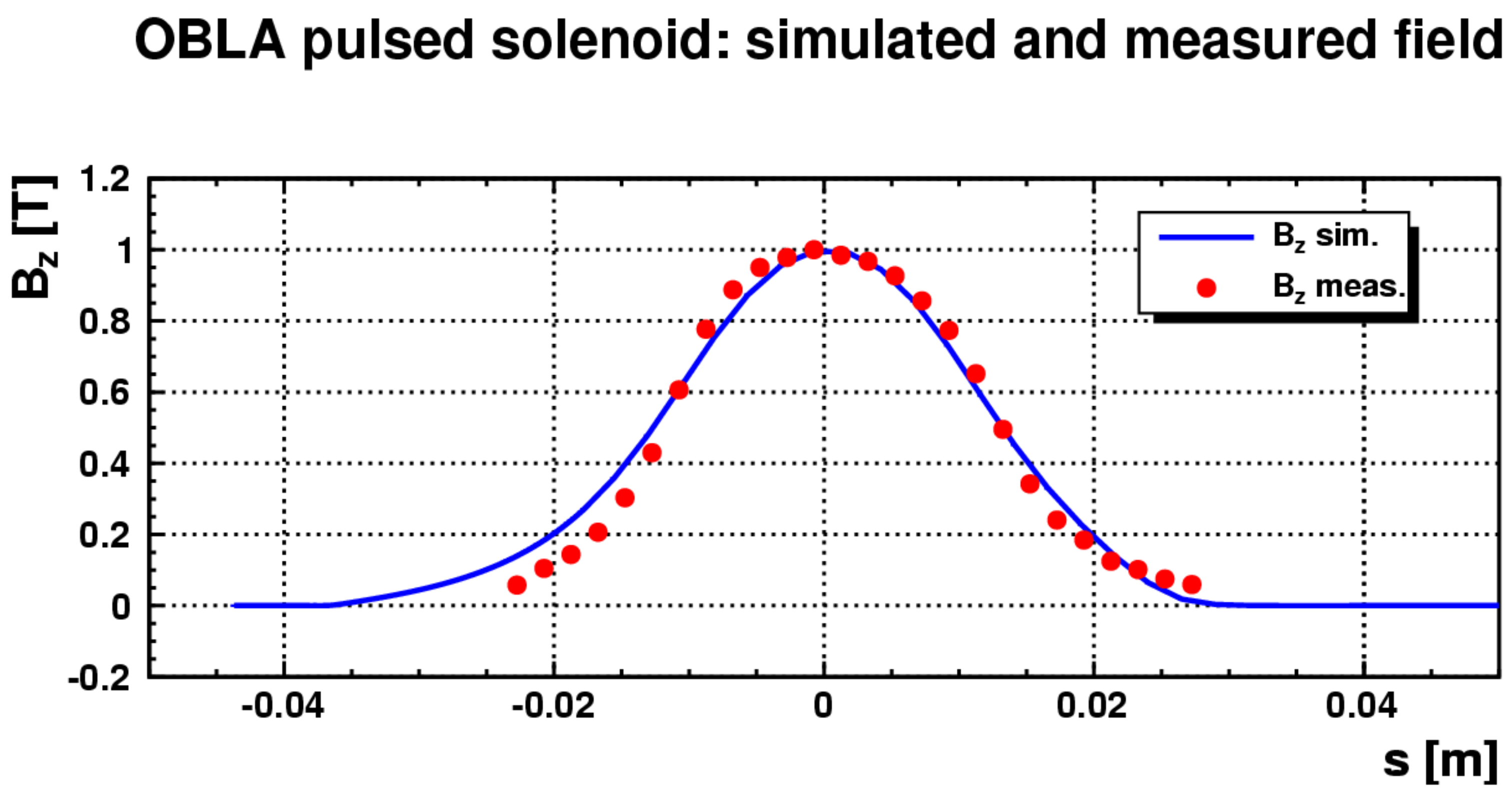
	OPAL	ASTRA
General:		
Tracking:	3D	2.5D
Mirror charges at emission:	yes	yes
Wakefields:	no	no
Specific (this simulation):		
Mesh	32x32x64	20x20x30
Number of particles:	100k	2k
Time step (diode):	0.1 ps	0.1–1 ps
Time step (beamline):	1 ps	0.1–1 ps
Energy bins at emission:	10	1
Longitudinal emission energy:	1 eV	1 eV
Transverse emission energy:	0 eV	0 eV



i.e. no thermal emittance!

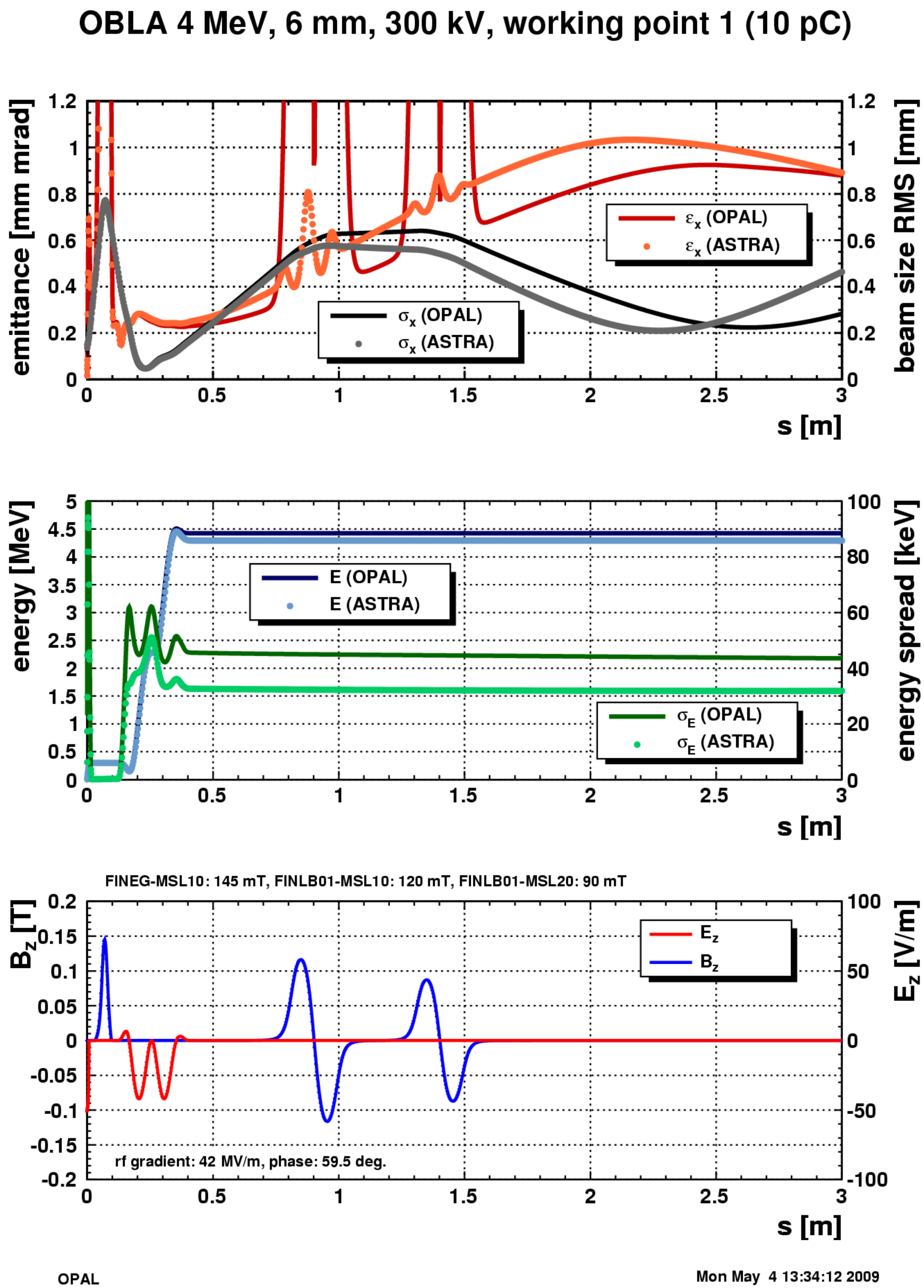
Fieldmaps are exactly the same!

Fieldmap for pulsed solenoid



Comparison OPAL-ASTRA

- For “working point 1” with 10 pC
- Elliptical electrodes
- Current lattice (166 mm drift between anode and RF cavity)
- Jaguar laser (Gaussian profile, σ_t = 14.8 ps)
- RF phase in OPAL adjusted to match ASTRA curves



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Comparison OPAL-ASTRA

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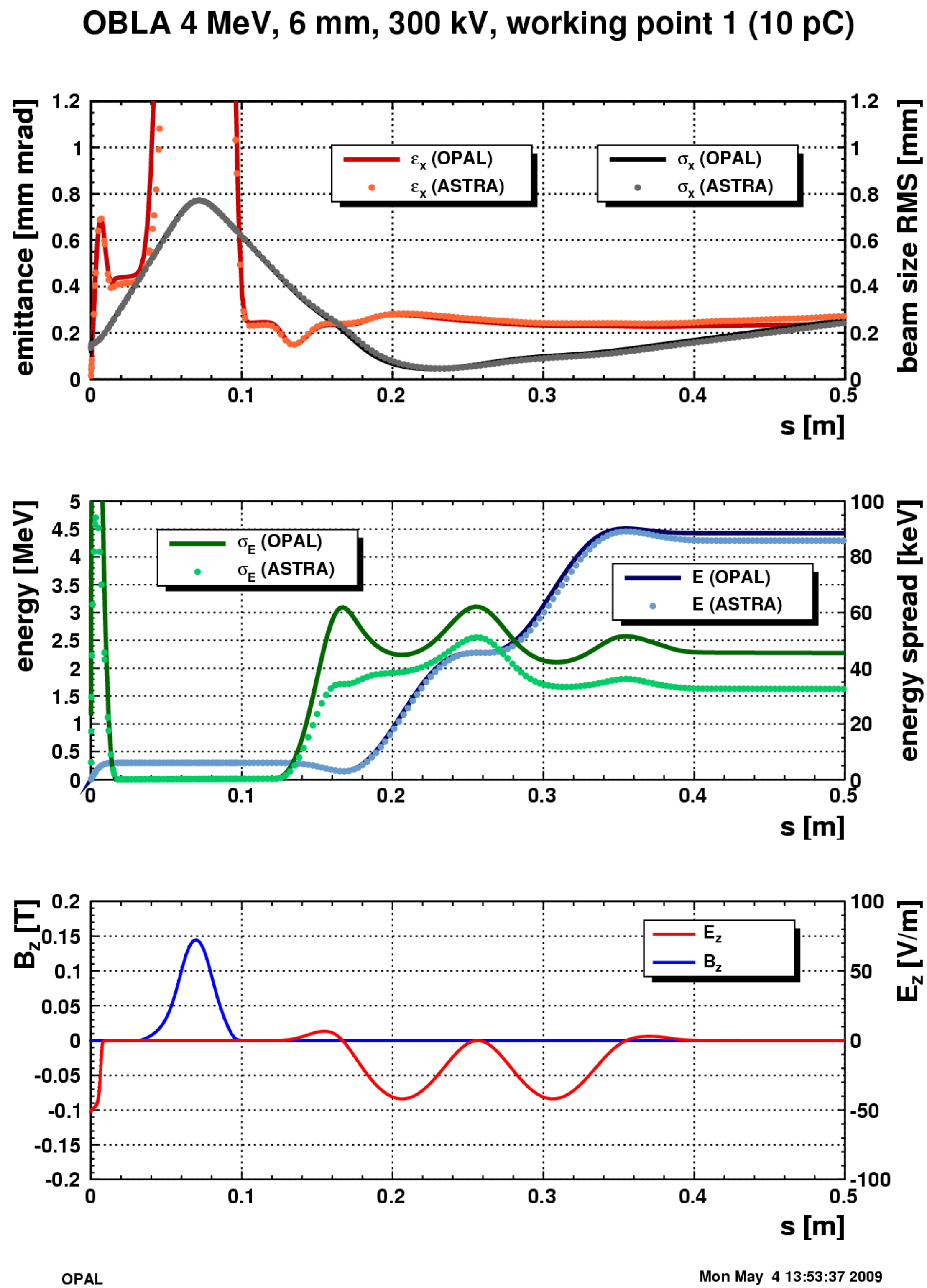

Comparison OPAL-ASTRA

- For “working point 1” with 100 pC
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- Current lattice (166 mm drift between anode and RF cavity)
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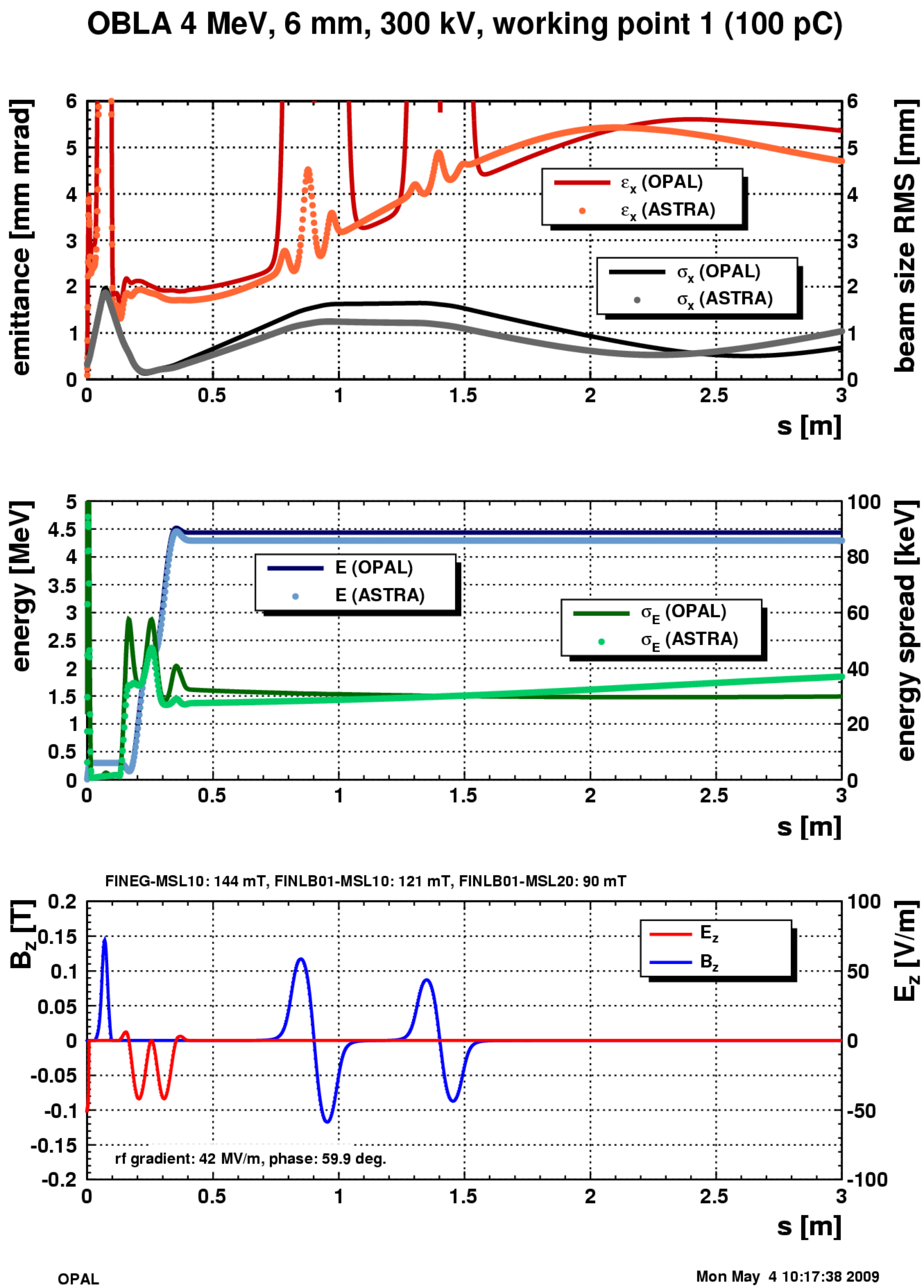

Comparison OPAL-ASTRA

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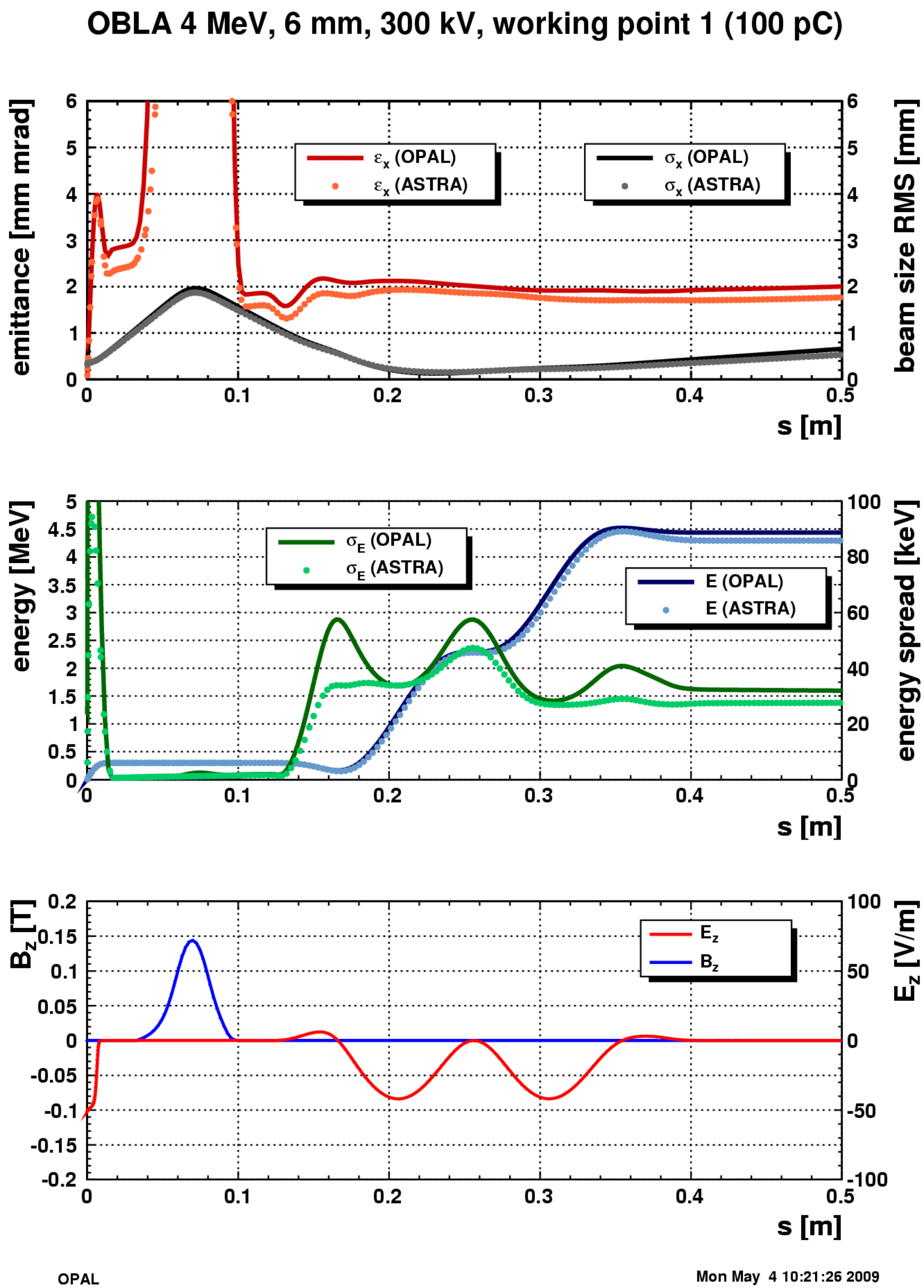
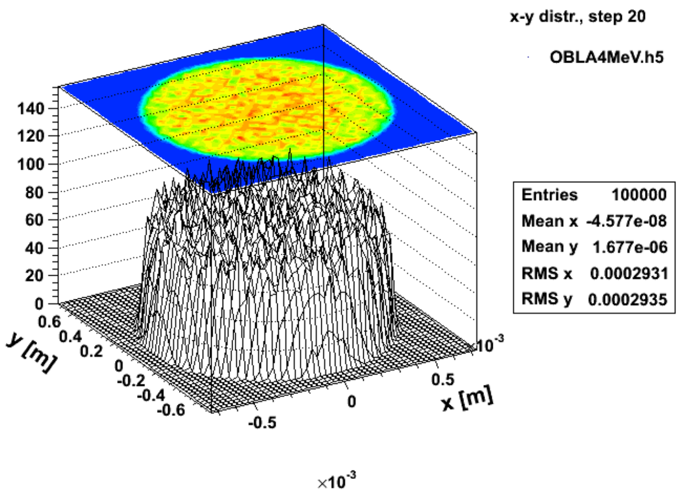


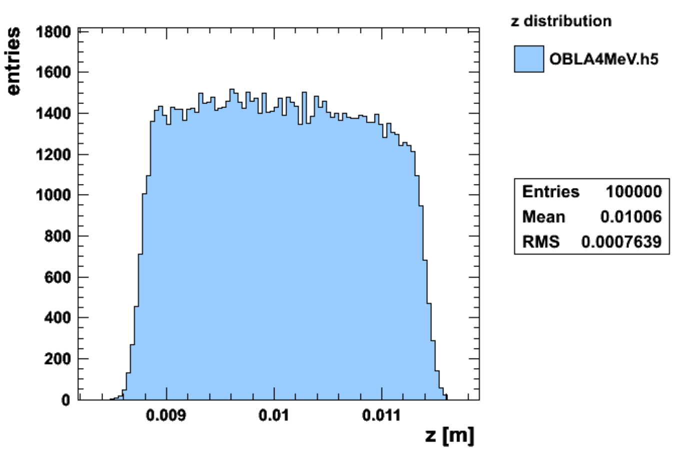
Conclusion: OPAL/ASTRA comparison

- For the OBLA setup, when using the same geometry, the two codes give very similar results
- The differences can probably be attributed to differences in the emission process.
  - Would take more effort to find out – is it worth it?
- In any case the differences seem irrelevant for OBLA
  - Agreement within a few percent
  - The problems are elsewhere!

Ti:Sapph optimizations

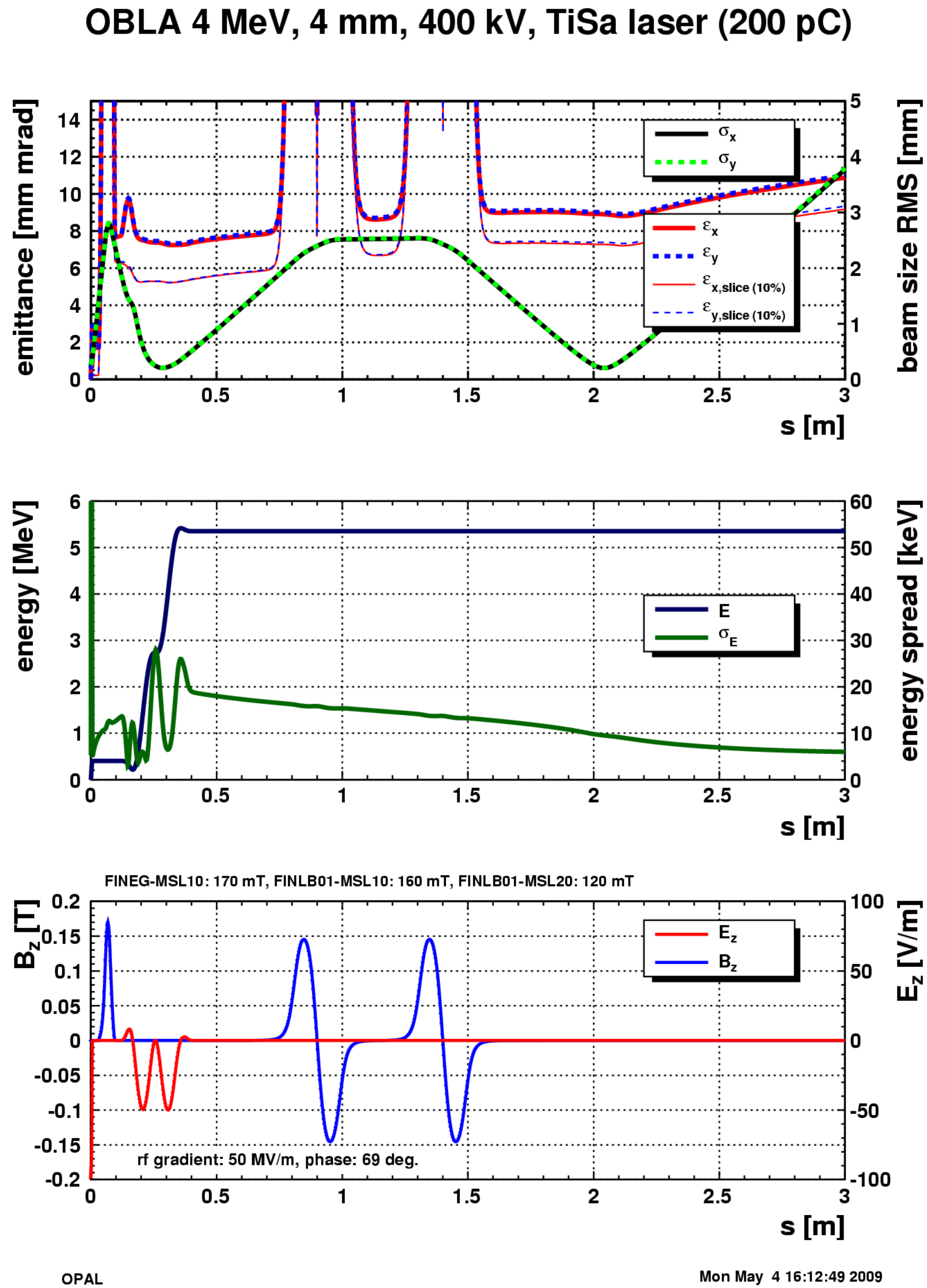
- Ti:Sapph laser: flat-top longitudinal profile with 9.9 ps FWHM and 0.7 ps rise and fall time
- 200 pC charge (~20 A), 1.08 mm laser spot diameter
- Optimization = adjustment of solenoid strengths and RF phase to get lowest emittance between 2 and 3 meters distance (range covered by the emittance monitor)
  - Pulser gradient constant at 400 kV / 4 mm = 100 MV/m
  - RF gradient constant at 50 MV/m
- Do this for the three geometries: 120, 150 and 166 mm drift between anode and RF cavity





Ti:Sapph laser 166 mm drift

- Elliptical electrodes
- Current lattice (166 mm drift between anode and RF cavity)
- Ti:Sapph laser (flat-top profile, FWHM = 9.9 ps, t_{rise} = 0.7 ps)
- Smallest projected emittance is about 9 mm mrad
- Pulsed solenoid: 170 mT



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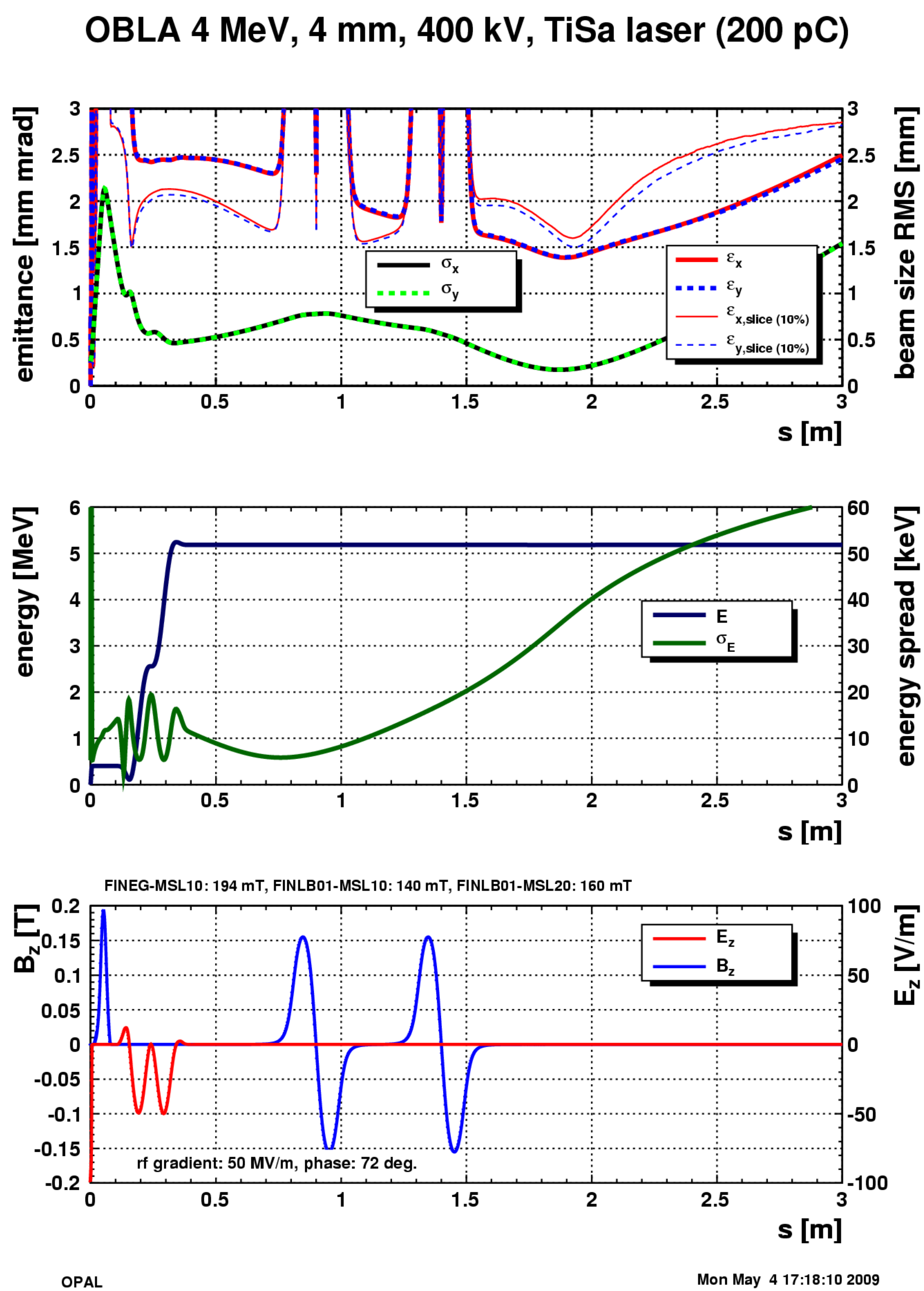
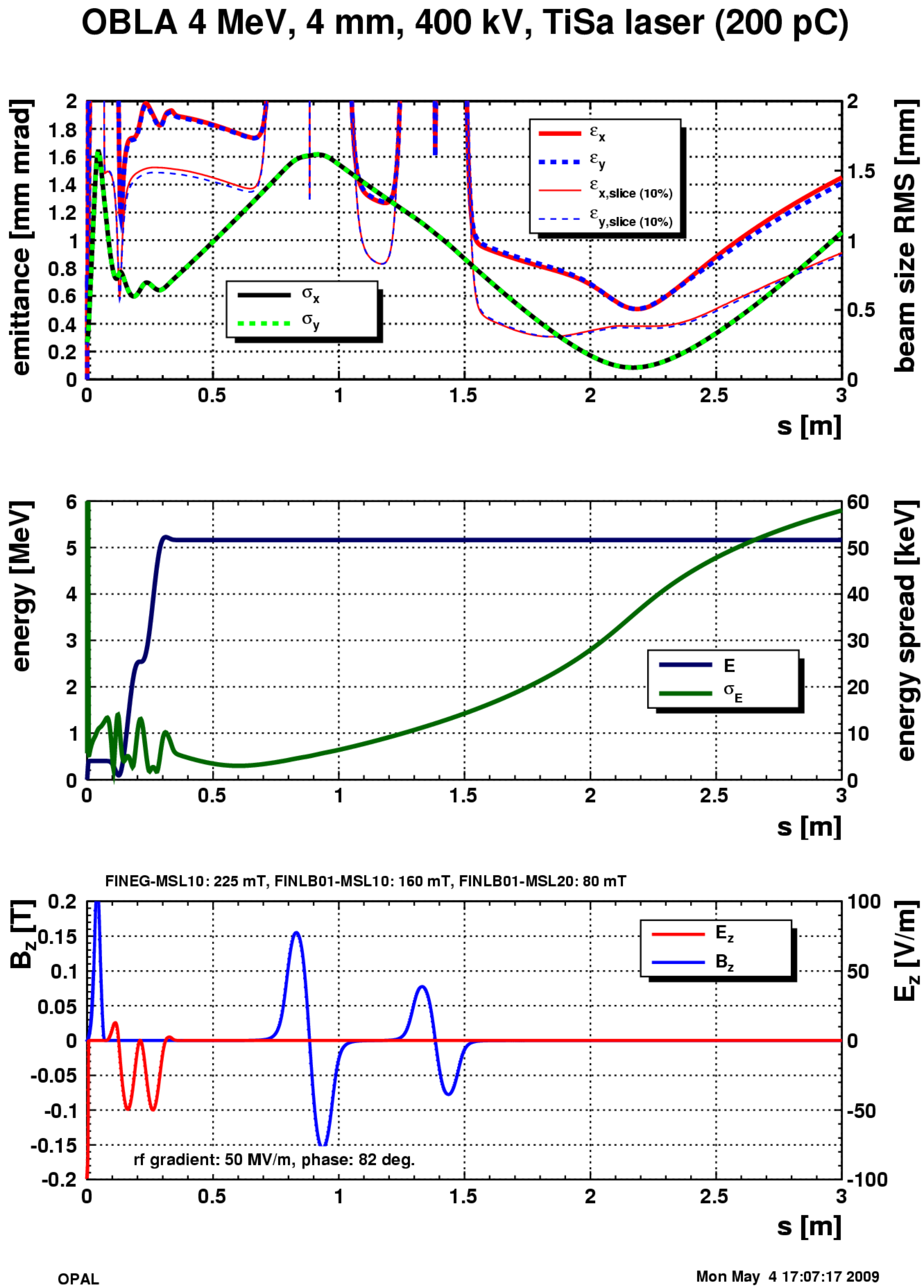
Ti:Sapph laser
150 mm drift

- Elliptical electrodes
- Current lattice (150 mm drift between anode and RF cavity)
- Ti:Sapph laser (flat-top profile, FWHM = 9.9 ps, t_{rise} = 0.7 ps)
- Smallest projected emittance is 1.4 mm mrad
- Pulsed solenoid: 194 mT



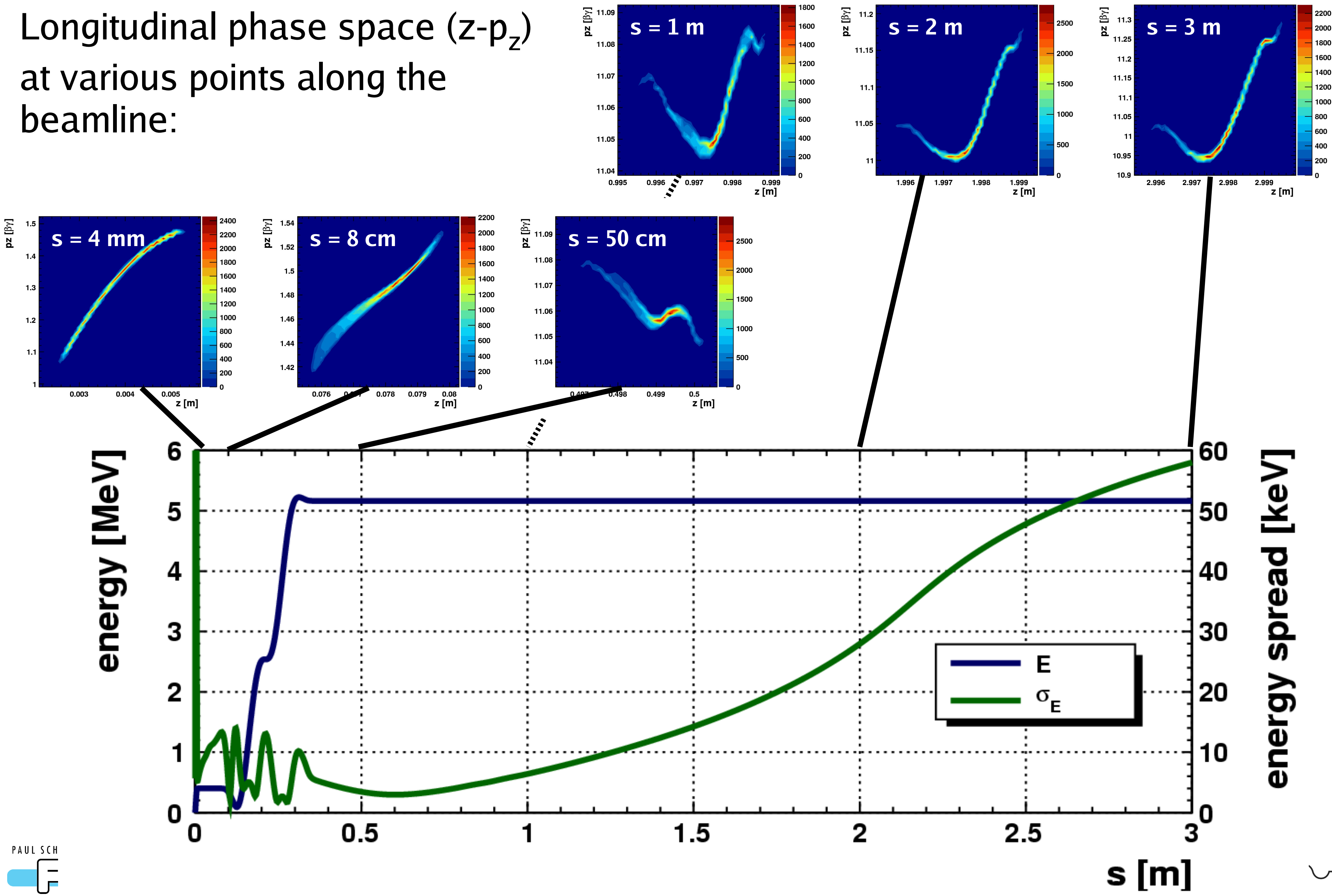
Ti:Sapph laser 120 mm drift

- Elliptical electrodes
- Current lattice (120 mm drift between anode and RF cavity)
- Ti:Sapph laser (flat-top profile, FWHM = 9.9 ps, t_{rise} = 0.7 ps)
- Smallest projected emittance is 0.55 mm mrad
- Pulsed solenoid: 225 mT



Growth in energy spread?

Longitudinal phase space (z-p_z) at various points along the beamline:



Conclusion: Ti:Sapph optimization

Minimum reachable emittance between 2 and 3 m, in mm mrad:

Cathode shape	Drift distance from anode to cavity: 120 mm	150 mm	166 mm
Elliptical cathode:	0.55	1.4	9.0
Nose cathode:	0.4?	?	?

Nose cathode simulations not yet done with OPAL (problem with fieldmap) – see Kevin's ASTRA simulations!

Conclusion: Ti:Sapph optimization

- Emittance extremely sensitive to drift distance in front of cavity
  - The longer the drift distance, the less focusing we can apply with the pulsed solenoid
- With standard elliptical cathodes ("doorknobs") cannot expect emittance below 1 mm mrad for drift distance around 150 mm (at 20 A current).
- Only shortened drift distance, or redesigned cathode (or, better, both) can give a substantial reduction in emittance.
  - Huge effort needed to get down to 0.4 mm mrad (where we start to *compete* with the RF photo-injector...)
- At lower current, the emittance becomes correspondingly smaller
  - $\varepsilon(\lambda)$ still makes sense to measure!