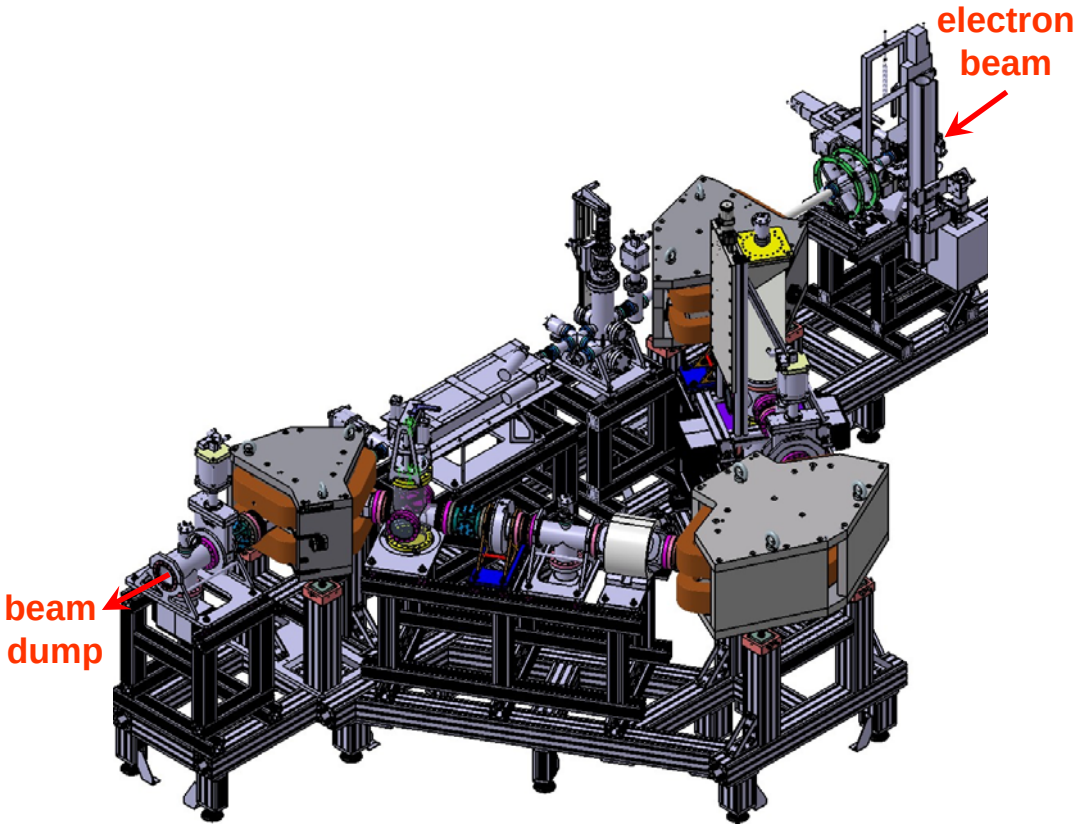
Summary of HEDA2 and Preparation for Commissioning

Second High Energy Dispersive Arm (HEDA2) or DISP3

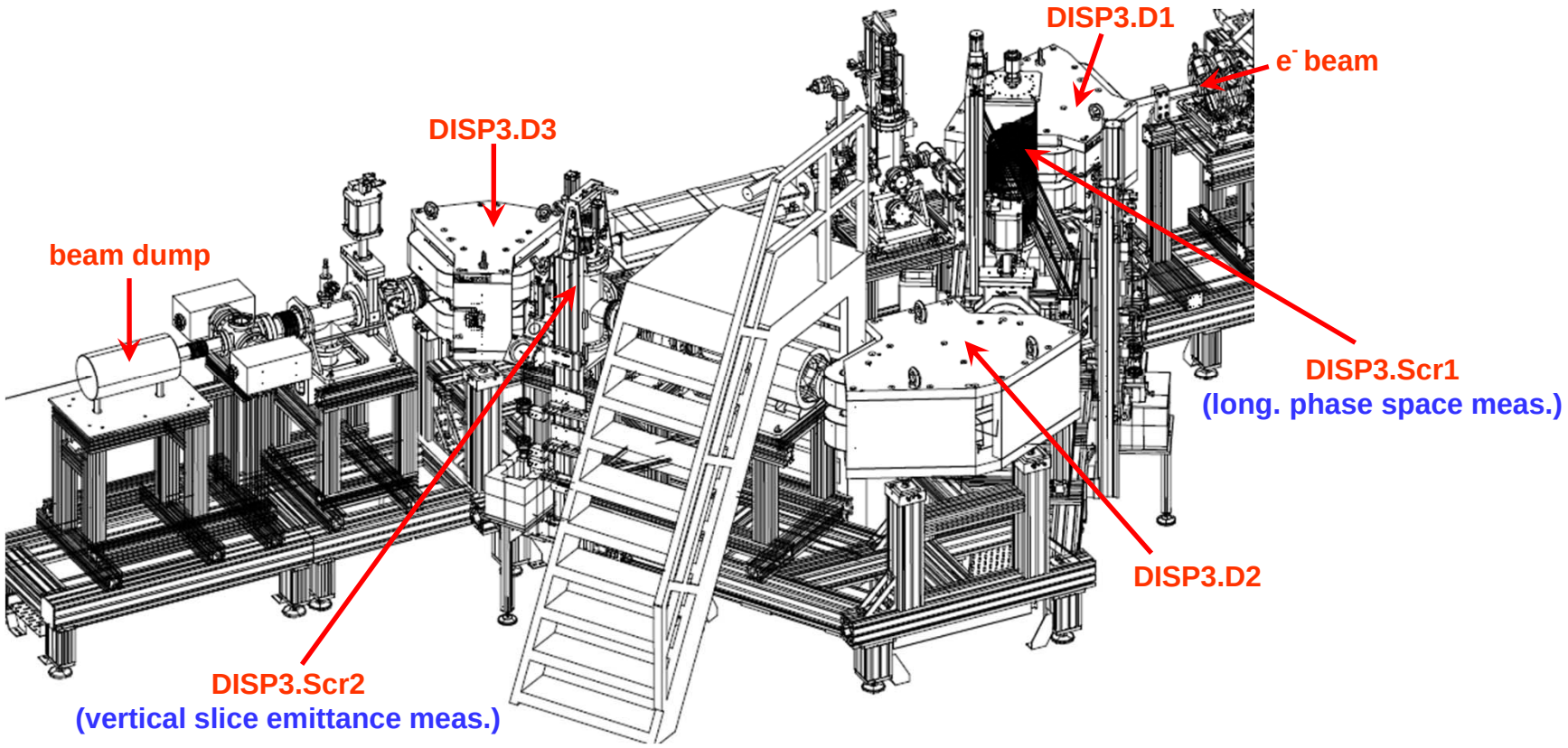
Measurements @ HEDA2

- Momentum and momentum distribution for maximum momentum of 40 MeV/c
- Longitudinal phase space for slice momentum spread down to 1 keV/c (gun and booster on-crest phases) by using combination of a dipole magnet and
  - an RF-deflecting cavity with a beam monitor screen
- Transverse slice emittance in vertical plane at off-crest booster phases (large momentum spread)
  - the horizontal slice emittance measurement at HEDA1



Main components in HEDA2	
3 Dipole magnets	3 Quadrupole magnets
2 Screen Stations	1 Kicker magnet
3 BPMs	2 ICTs

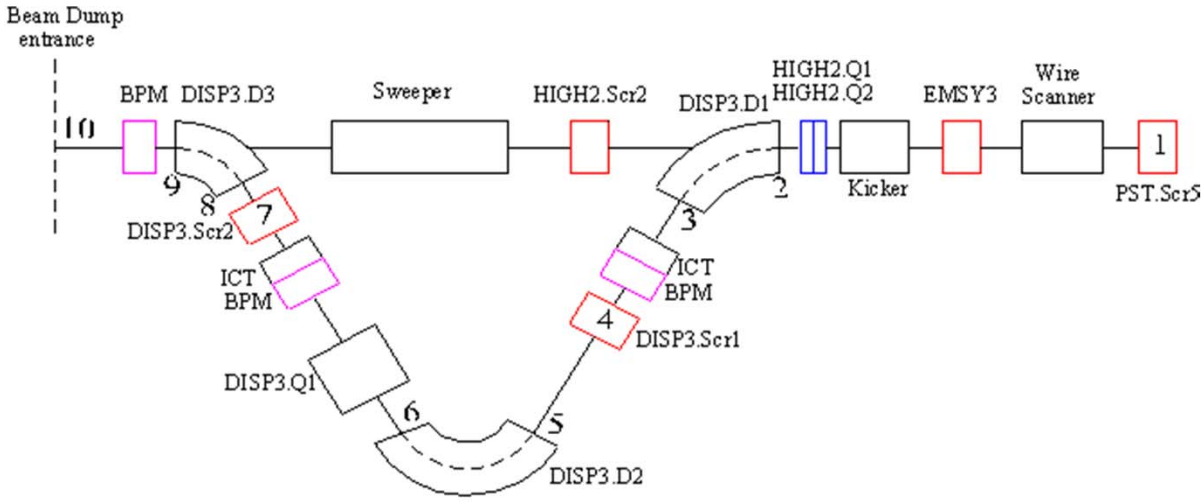
Installation of HEDA2

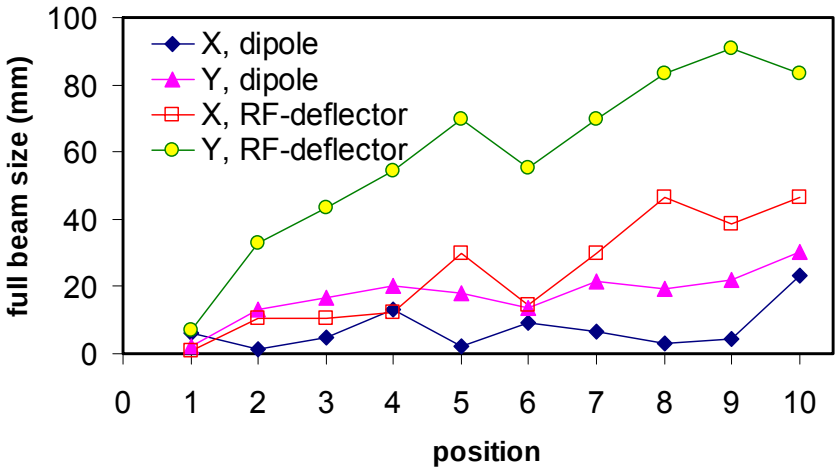


Installation of components almost finish except

- kicker magnet, TV & streak readouts
  - Design of TV readouts are available, ordering & construction are on-going
  - Design of kicker magnet is on-going
- Cabling and electronic works (on-going)

Beam Zize Calculations along HEDA2 Section





Simulated beam size at different locations along HEDA2 (on-crest condition)

Beam size study along the dispersive section to define:

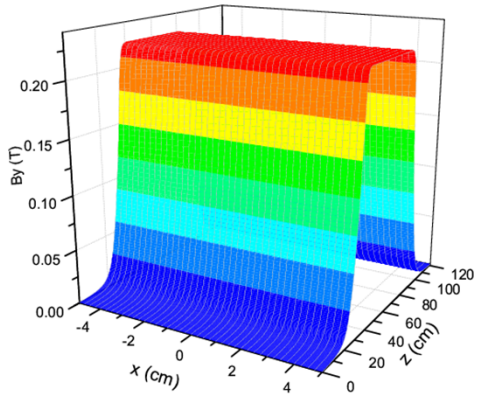
- dipoles' gap width: 60 mm
- sizes of screens
- sizes of vacuum tube: 100 mm diameter
- aperture size of other components

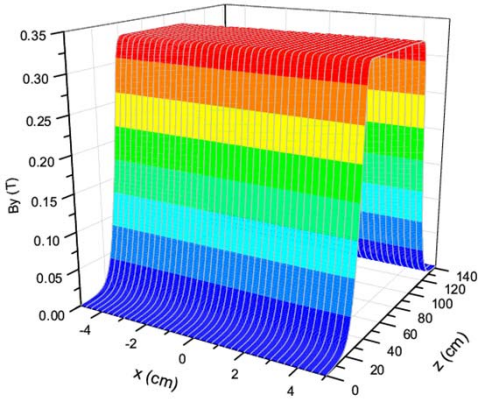
* Transverse beam size after the exit of DISP3.D2 dipole can be controlled by using DISP3.Q1

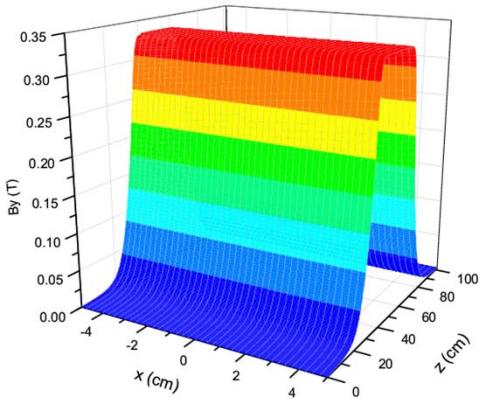
Dipole Magnets (DISP3.D1, DISP3.D2, DISP3.D3)

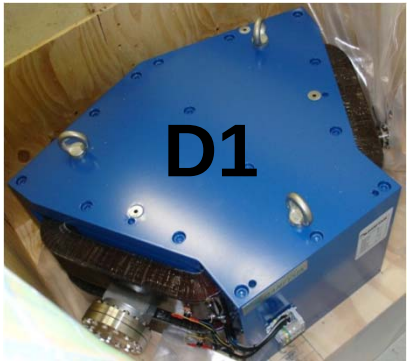
Construction of dipoles and vacuum chamber incl. magnetic field measurement @ Danfysik

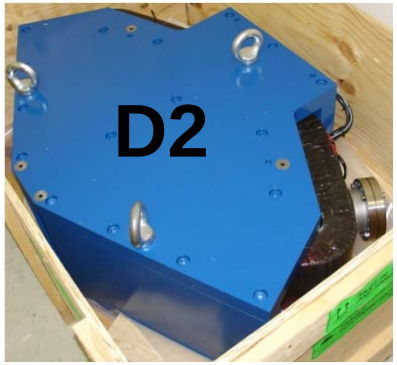
dipole	bending radius (mm)	bending angle (°)	Entrance wedge (°)	exit wedge (°)	Gap width (mm)	max. power supply current (A)	max. meas. field (T)	meas. effective length (mm)
D1	600	60	0	0	60	±20	0.256	0.626
D2	400	-120	0	+9	60	±20	0.368	0.832
D3	400	60	0	0	60	±20	0.374	0.416

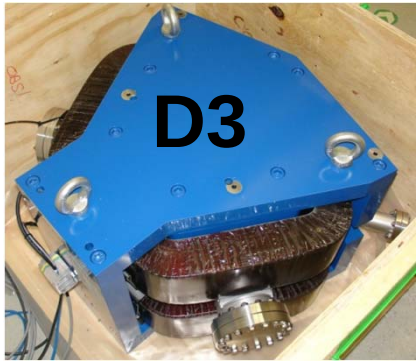




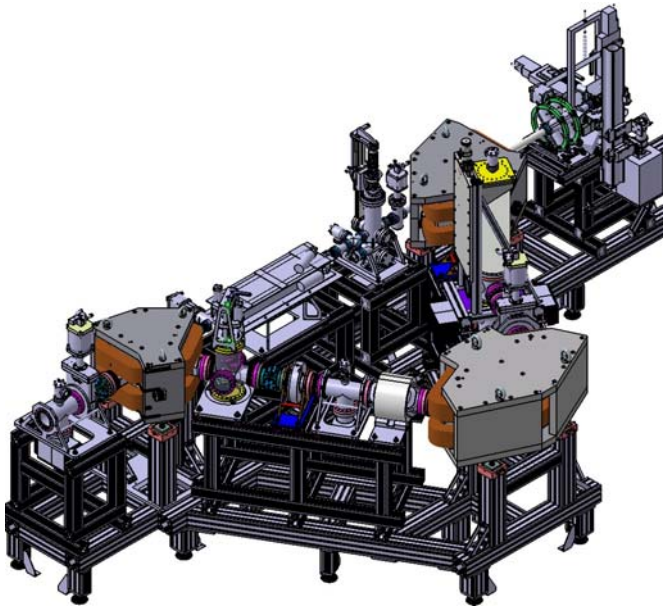


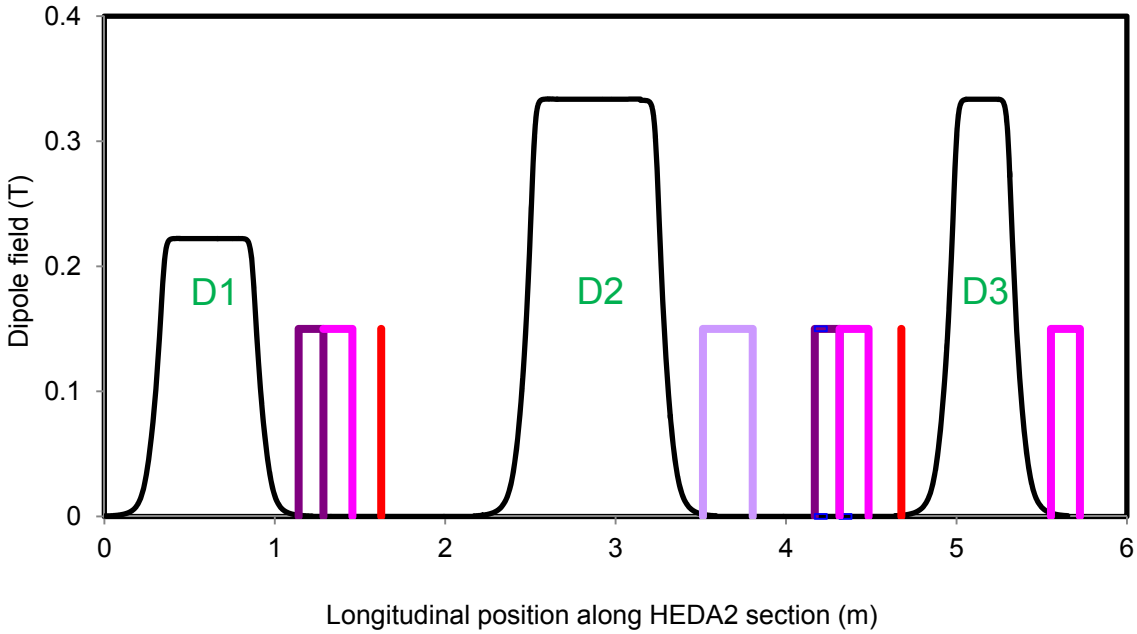






Dipoles' field along HEDA2





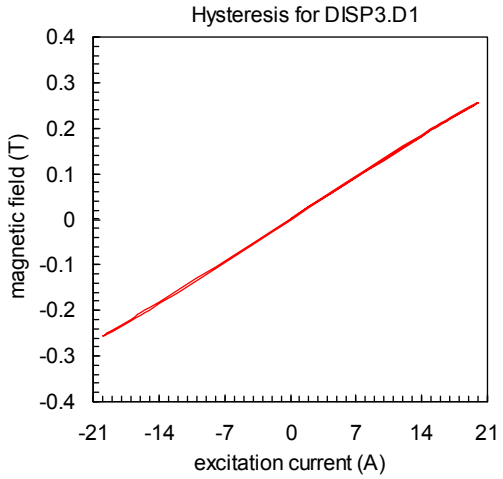
ICT BPM Quadrupole Screen station (center)

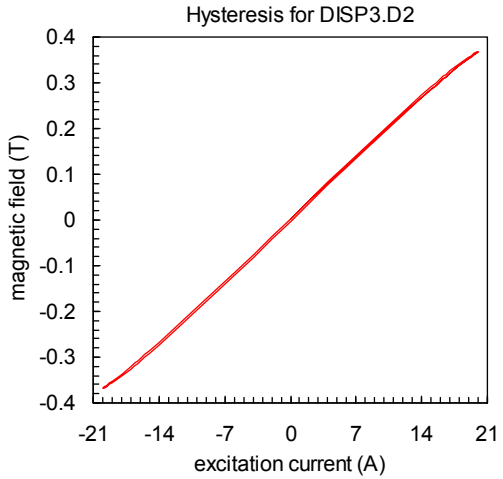
- Effect of dipole fields at DISP3.ICT1, DISP3.Scr2, and HIGH2.BPM1 is needed to be study.

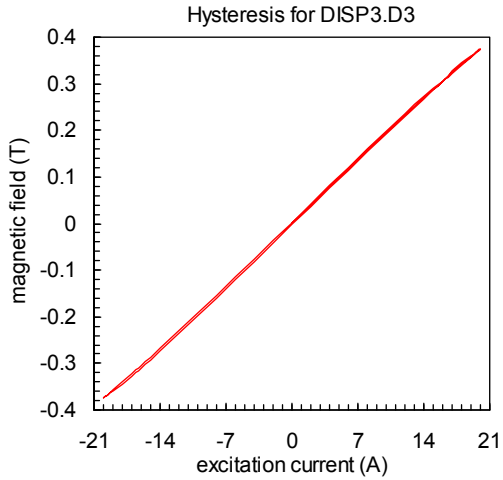
→ especially for vertical slice emittance measurement at DISP3.Scr2

Excitation Curves of Dipole Magnets

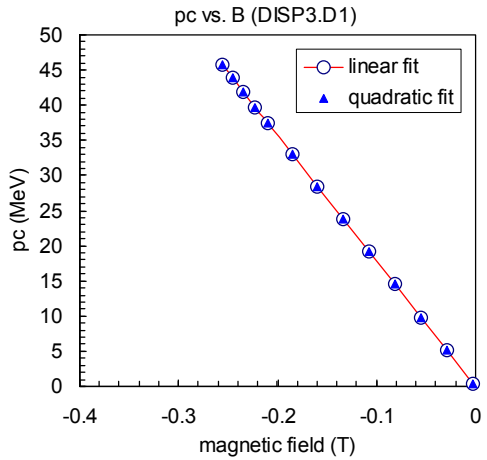
$I \rightarrow B = f(I) \rightarrow pc = f(B)$ ⇐ **How to calibrate B vs. I & pc vs. B**

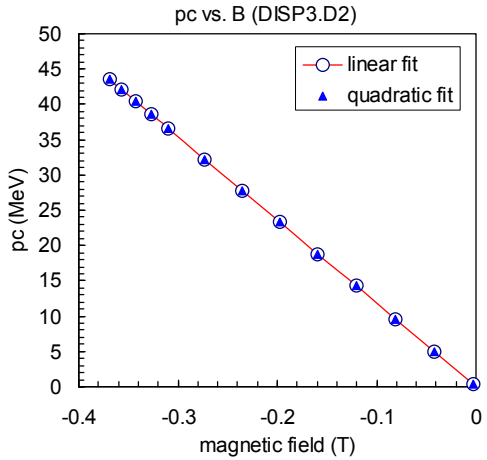


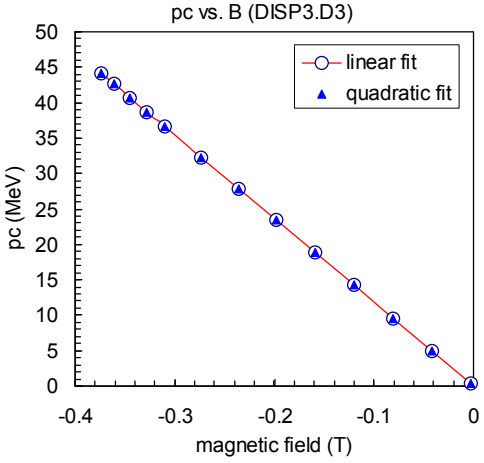




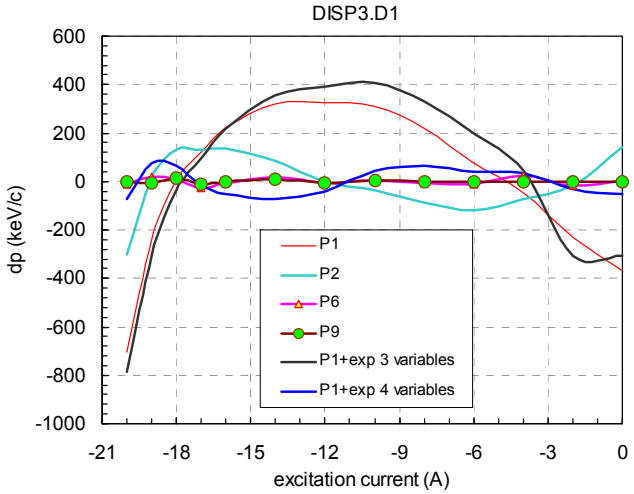
Momentum calculation from simulation of an electron through the re-sampling of measured magnetic field (K. Kusoljariyakul)

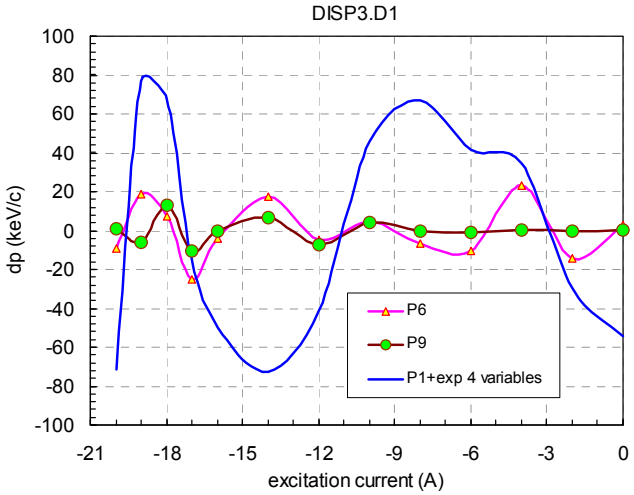






B vs. I Calibration: Example of Fittings



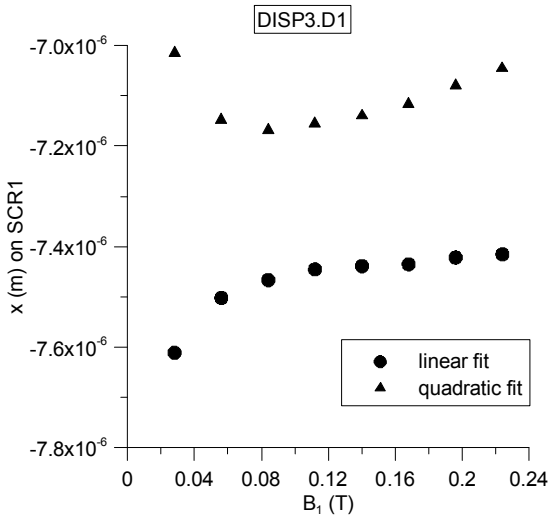


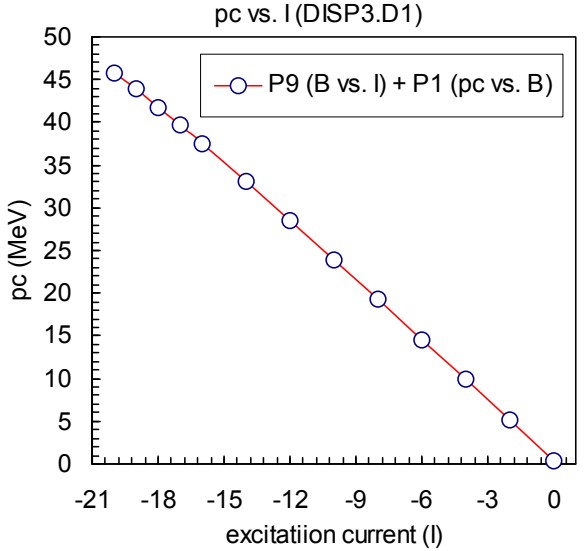
$$B(I) = a_0 + a_1 I + a_2 I^2 + a_3 I_3 + a_4 I^4 + a_5 I^5 + a_6 I^6 + a_7 I^7 + a_8 I^8 + a_9 I^9$$

$$B(I) = \frac{a(I-b)}{d + e^{-c/(I-b)^2}}$$

P1+exp 4 variables

P1+exp 3 variables $\rightarrow$ d =1





Momentum and momentum spread measurements using MAMA

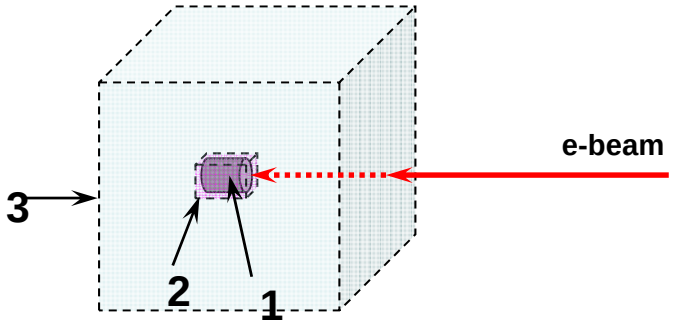
- B = f(I)
- Matrix transportation approximation

(Reference: K. Kusoljariyakul)

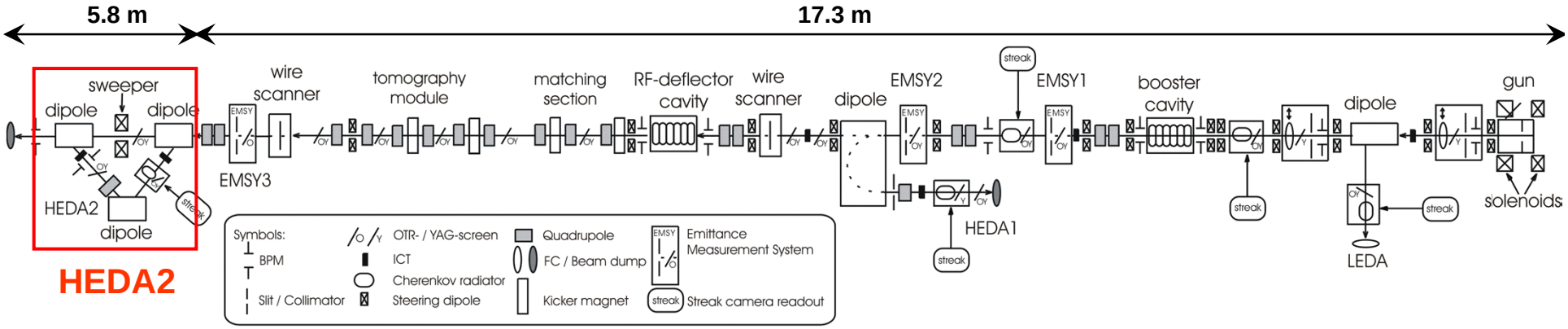
beam dump for 40 MeV/c beam with long pulse trains

for beam power ~3 kW (cooling is needed)

- pump and flanges should be outside concrete block
- rough configurations and dimensions are foreseen (e.g. beam dump for BC1 in FLASH beam line)

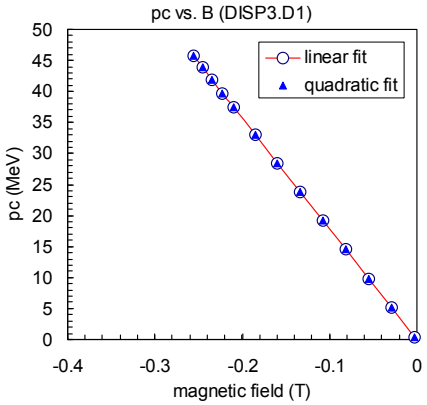


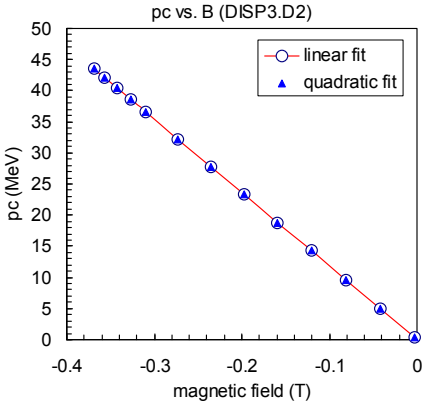
1. **Al-block beam dump (300 mm long)**
2. **Lead shielding (5 mm thick around Al-block)**
3. **Concrete block (69 mm thick from center)**

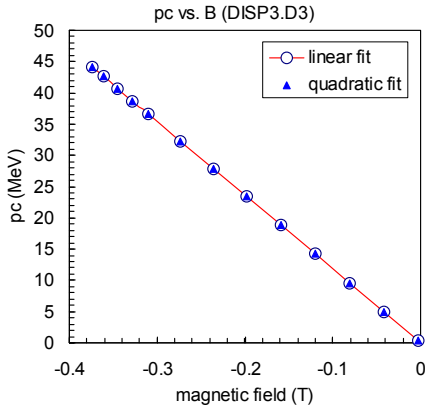


Dipole Magnets: Binding Current I_1, I_2, I_3

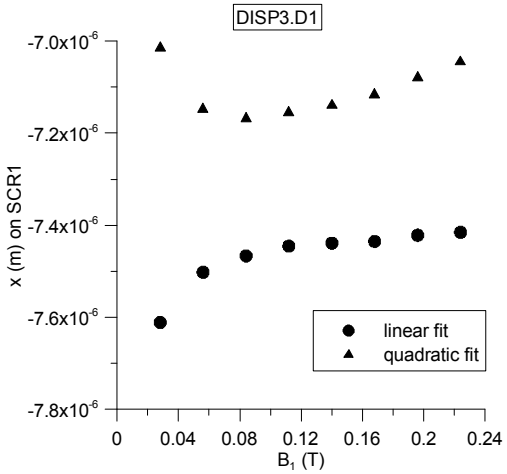
1. Simulate momentum as a function of measured magnetic field: pc = f(B_1), pc = f(B_2), cp = f(B_3)

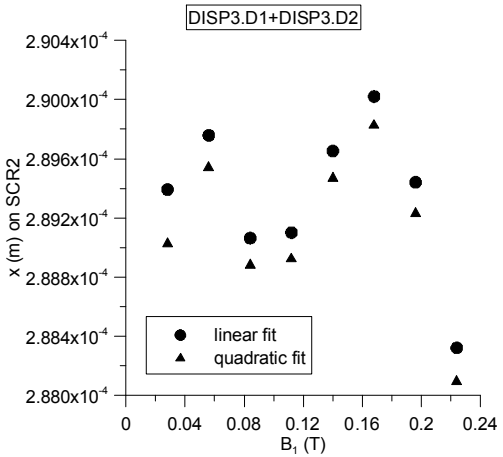


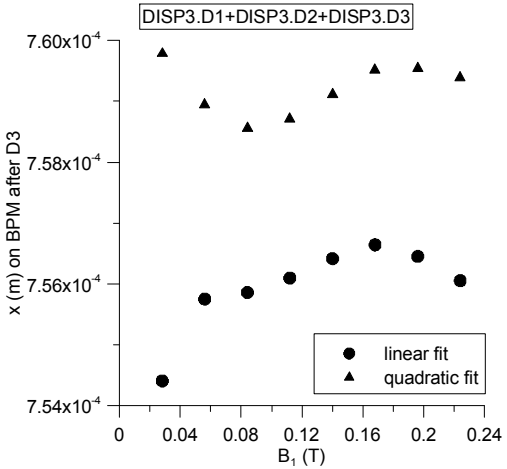




2. Calculate field of D2 and D3 as a function of field of D1: B_1, B_2 = f(B_1), B_3 = f(B_1)
   → check position of electron on screens or BPM

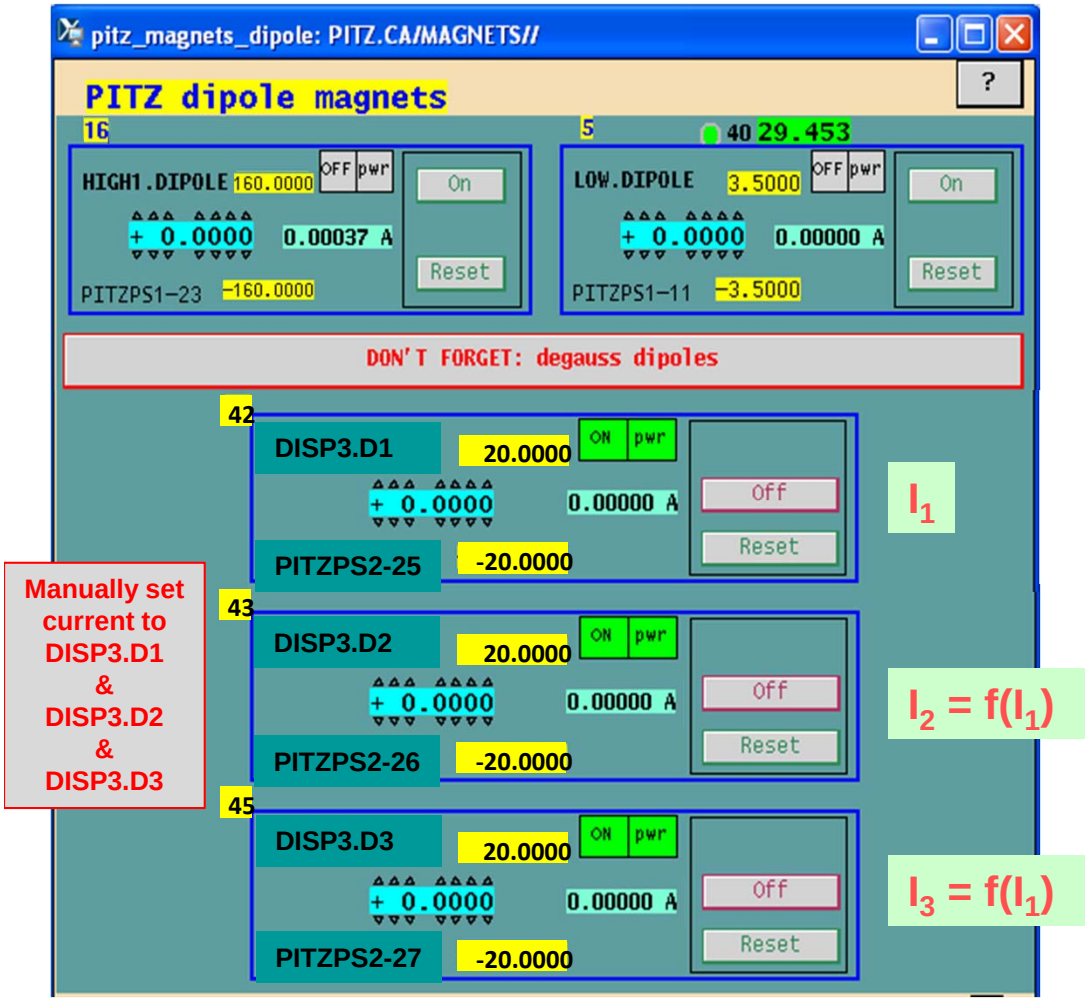






3. Calculate currents from excitation curves (B vs. I): **I_1, I_2 = f(I_1), I_3 = f(I_1)**

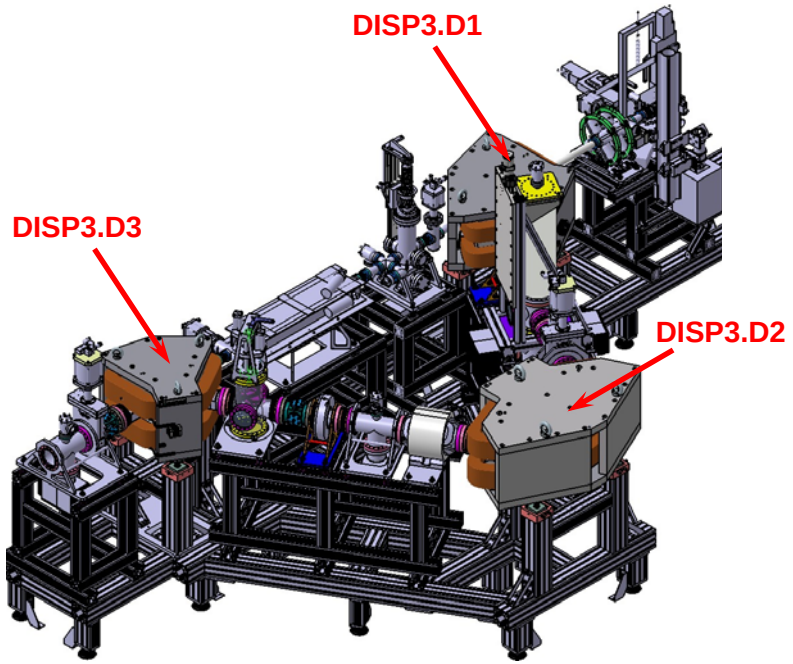
GUI & Control of Dipole Magnets



How to?

1. Set I_2 and I_3 automatically when given I_1 (work in magnet server)

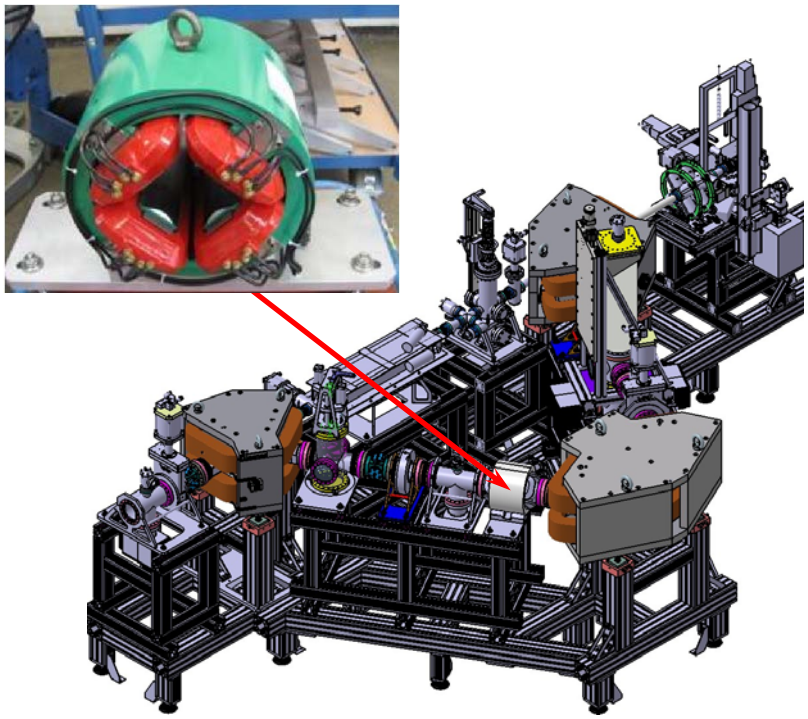
2. Push button to set I_2 and I_3 after given I_1 (can be set by Perl Script in GUI similar to "set bucking solenoid current")



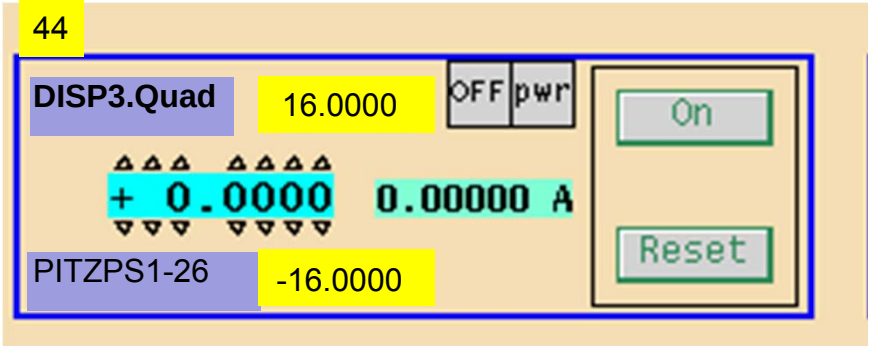
Quadrupole in Dispersive Section: DISP3.Q1

Magnetic field gradient → $g\,[T/m] = \dfrac{I\,[A]}{8.3}$

Parameter	Values
max. power supply current	±16 A
max. power supply voltage	±10 V
operating voltage	±7.2 V
gradient at max. current	1.93 T/m
temperature rising at max. gradient	21°C
effective length at max. current	224.93 mm
yoke length	200 mm
magnet length (yoke + coils)	280 mm
aperture (bore) radius	40 mm
homogenous region $\Delta g/g \leq 5\%$	X = ±25 mm
outer diameter	278 mm
number of turn	80 turn
max. ampere-turns (NI)	1328 A-turns
total weight	80 kg



DISP3.Q1 GUI and Control

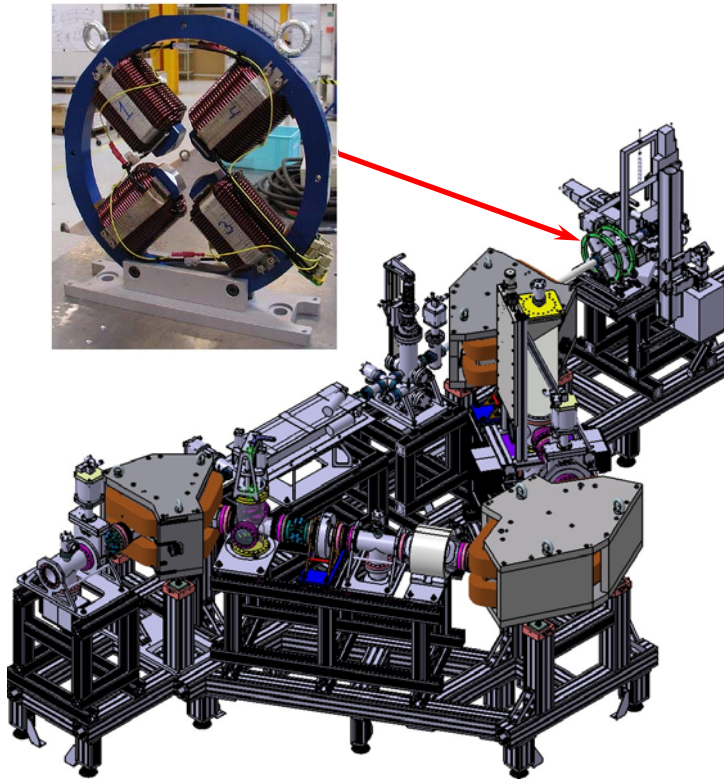


Quadrupole in Straight Section: HIGH2.Q1, HIGH2.Q2

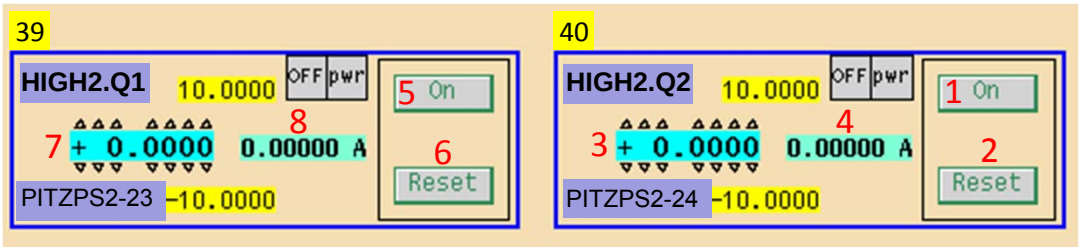
Magnetic field gradient:

$$HIGH\,2.Q1: g[T/m] = 0.6465 * \mathrm{I} + 0.9576$$
$$HIGH\,2.Q1: g[T/m] = 0.6249 * \mathrm{I} + 0.9132$$

Parameter	Values
max. power supply current	±10 A
max. power supply voltage	±12 V
gradient at max. current (I = 10 A)	Q1: 7.48 T/m Q2: 7.41 T/m
temperature rising at max. gradient (I = 10.2 A)	Q1: 12.9 °C Q2: 15.1 °C
effective length at max. current	Q1: 43.07 mm Q2: 43.07 mm
magnet length (yoke + coils)	63 mm
aperture (bore) radius	20 mm
homogenous region Δg/g ≤ …%	X = ±…. mm
outer diameter	278.3 mm



HIGH2.Q1, HIGH2.Q2 GUI and Control



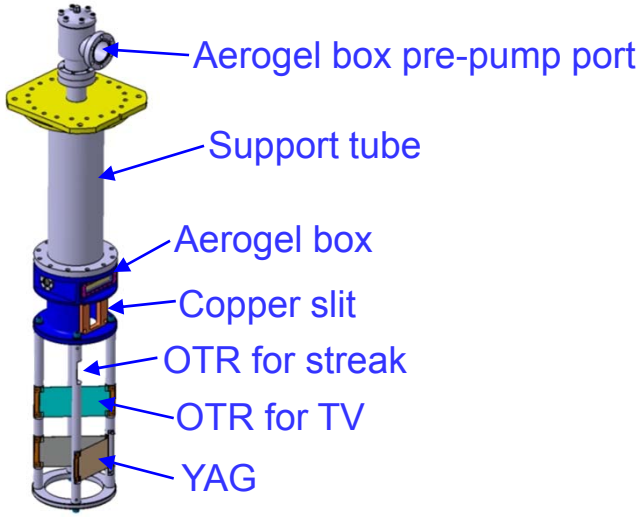
First Screen Stations: DISP3.Scr1

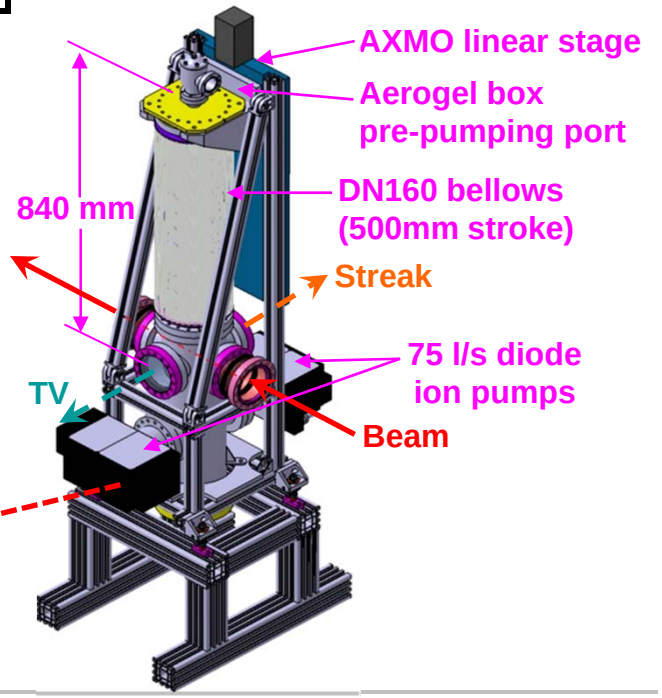
Screen arrangements and specifications

component	distance after D1 exit (mm)	actual area (mm × mm)	active area (mm × mm)	thickness (mm)	orientation to beam axis (°)
Aerogel screen Si-mirror	649 699	80 × 18 90 × 22	78 × 16	5 0.1	+90 +35.7
Slit opening	649	30 × 60	30 × 60	10	+90
OTR for streak	699	120 × 50	115 × 50	0.1	-45
OTR for TV	699	120 × 60	115 × 60	0.1	+45
YAG screen Si-mirror	649 699	95 × 60 120 × 60	76 × 60 115 × 60	0.1 0.1	+90 +45

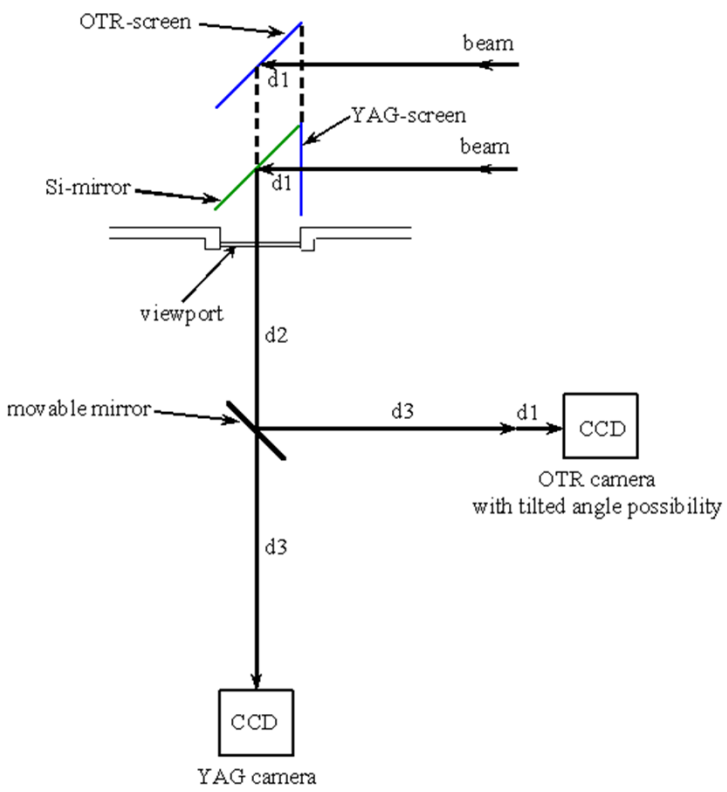
Status:

- TV system design finished
- Installation of TV system components finished except optical mirrors, lens and cameras (mirrors will be installed after the exchange of Si-mirror of YAG screen)





DISP3.Scr1 TV System



Requirement for measurement of momentum spread down to 1 keV/c :
→ need to be able to measure the slice beam size of ~80-100 μm (full) or ~20-25 μm (rms)

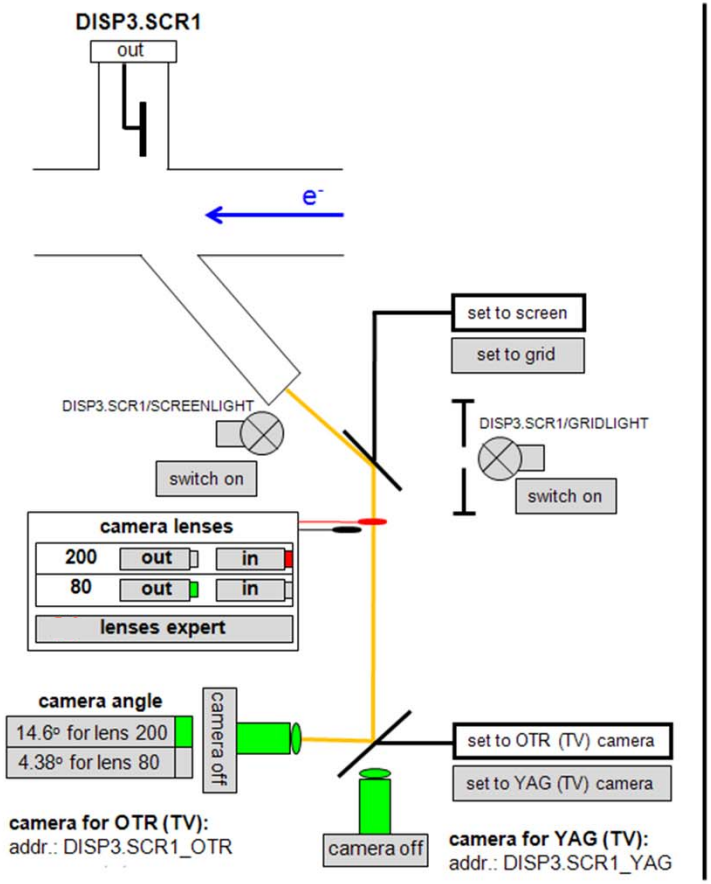
TV System components:

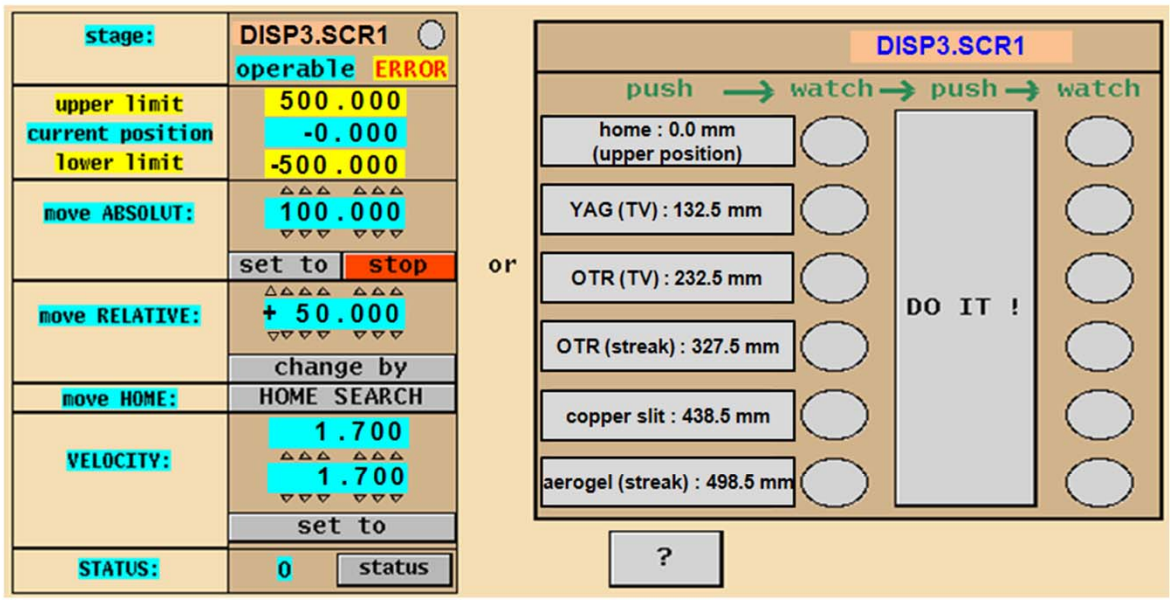
- 2 Prosilica GC-1350 cameras
  - YAG: fixed angle camera
  - OTR: movable angle camera
- 2 lenses:
  - f80: whole screen
    - full resolution: 60.8 μm
    - 2x2 binning: 121.6 μm
  - f200: part of the beam
    - full resolution: 17.6 μm
    - 2x2 binning: 35.3 μm
- 2 resolution grids
- 1 movable mirror
- 1 ring lamp

Scheinflug arrangements: CCD camera are tilted w.r.t. the light of sight, which partly removes the compression of the final image, while keeping it in focus.

DISP3.Scr1 GUI & Control

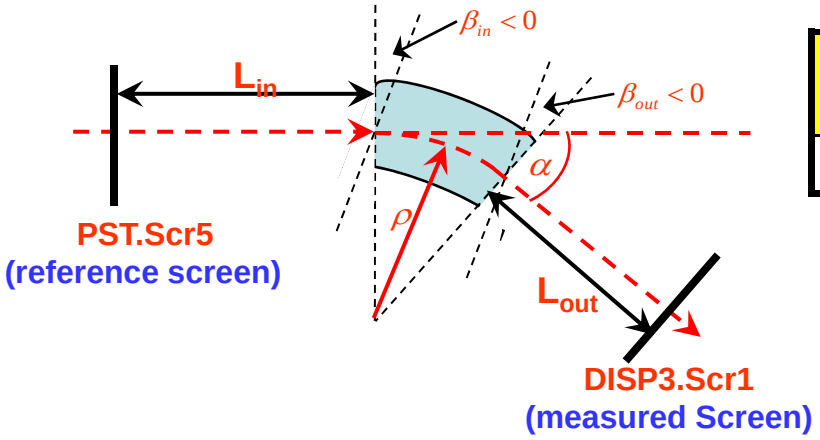
PITZ DISP3.SCR1





Simulated Measurements @ DISP3.Scr1: Astra + Linear Matrix Transformation

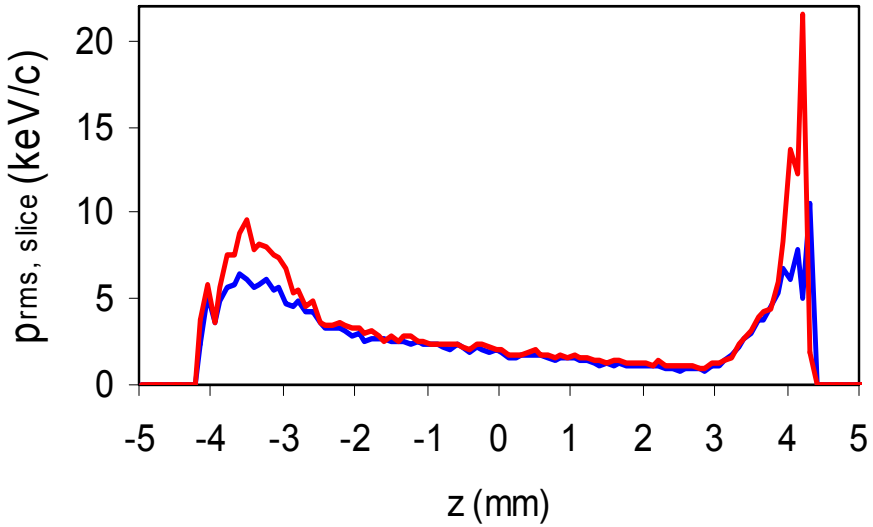
- Measurements @ DISP3.Scr1 using DISP3.D1 dipole magnet
  - Momentum and momentum distribution for nominal momentum of ~30 MeV/c
  - Longitudinal phase space for slice momentum spread down to 1 keV/c (gun and booster on-crest phases)



α (°)	ρ (mm)	β_{in} (°)	β_{out} (°)	L_{in} (mm)	L_{out} (mm)	R_{16} (mm)	$D(L_{DA})$ (mm)
60	600	0	0	1950	650	862.9	1079.4

Simulated momentum and momentum spread measurement for the case of minimum horizontal beam focusing at the reference screen

Parameter	distribution @ reference screen	relative deviation @ DISP3.Scr1
p_{mean} (MeV/c)	32.073	6.1×10^{-8}
p_{rms} (keV/c)	106.151	-1.90×10^{-5}
min. $P_{rms, slce}$	0.774	0.024
mean $P_{rms, slce}$	2.881	0.284

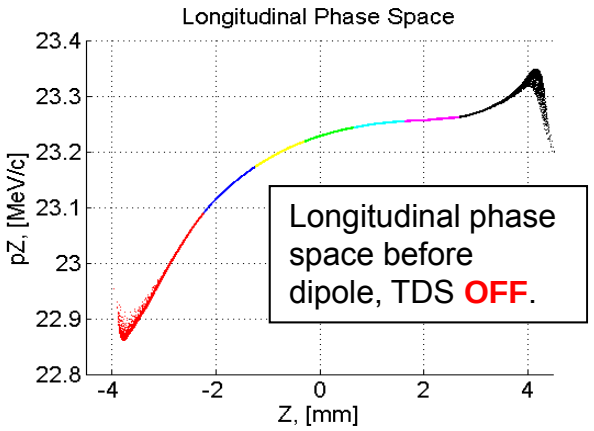


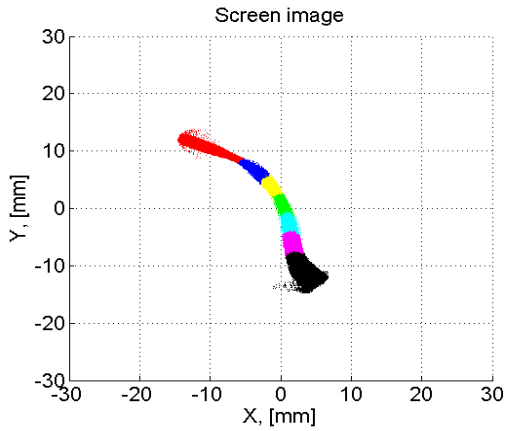
Slice momentum spread: blue → initial beam at the reference screen
red → beam at dispersive screen

Simulated Measurements @ DISP3.Scr1: Astra + TDS 3D-fields

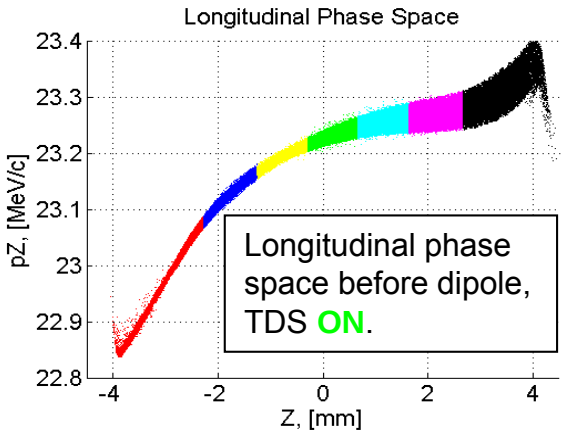
- Step 2: Including TDS 3D-fields (D. Malyutin, PITZ collaboration October 2011)

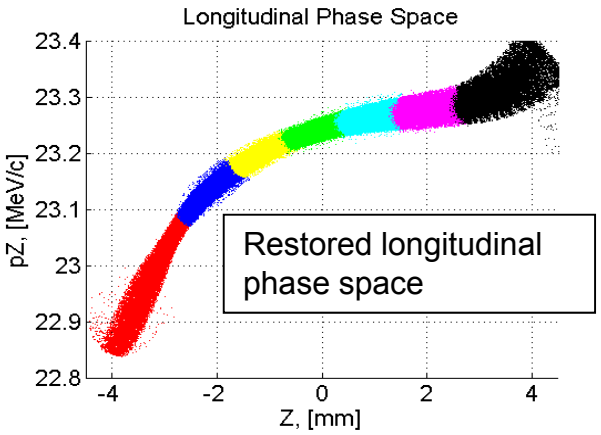
Longitudinal phase space & slice momentum spread @ DISP3.Scr1





Beam image on screen after dipole, for TDS field about 0.6MV (0.2 MW).





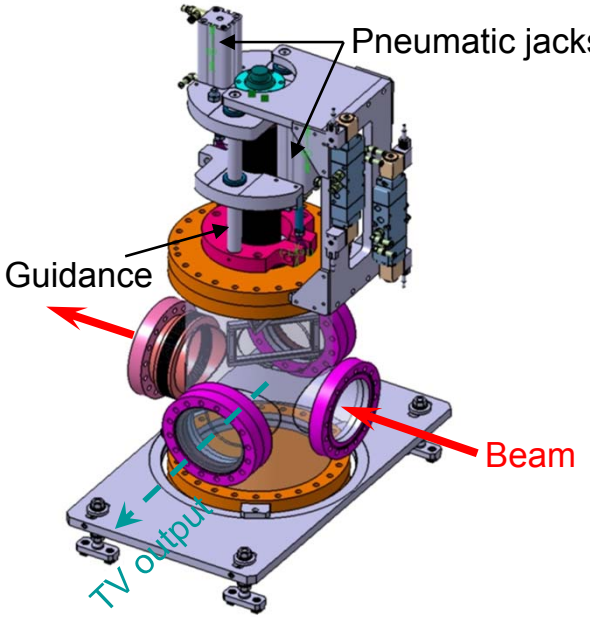
TDS induced slice energy spread is about 15 keV

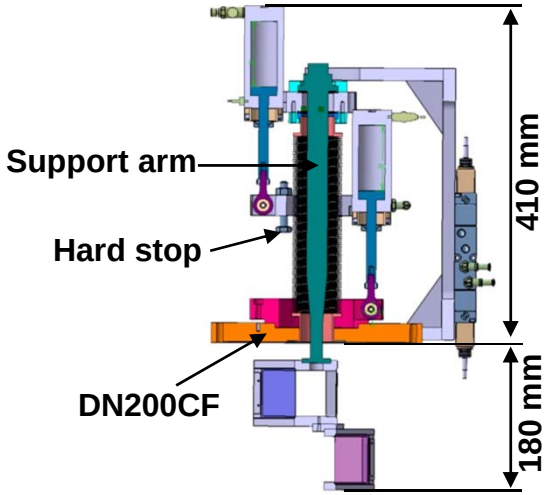
- Step 3: Including TDS 3D-fields & measured magnetic field of dipole magnets

Second Screen Stations: DISP3.Scr2

Screen arrangements and specifications

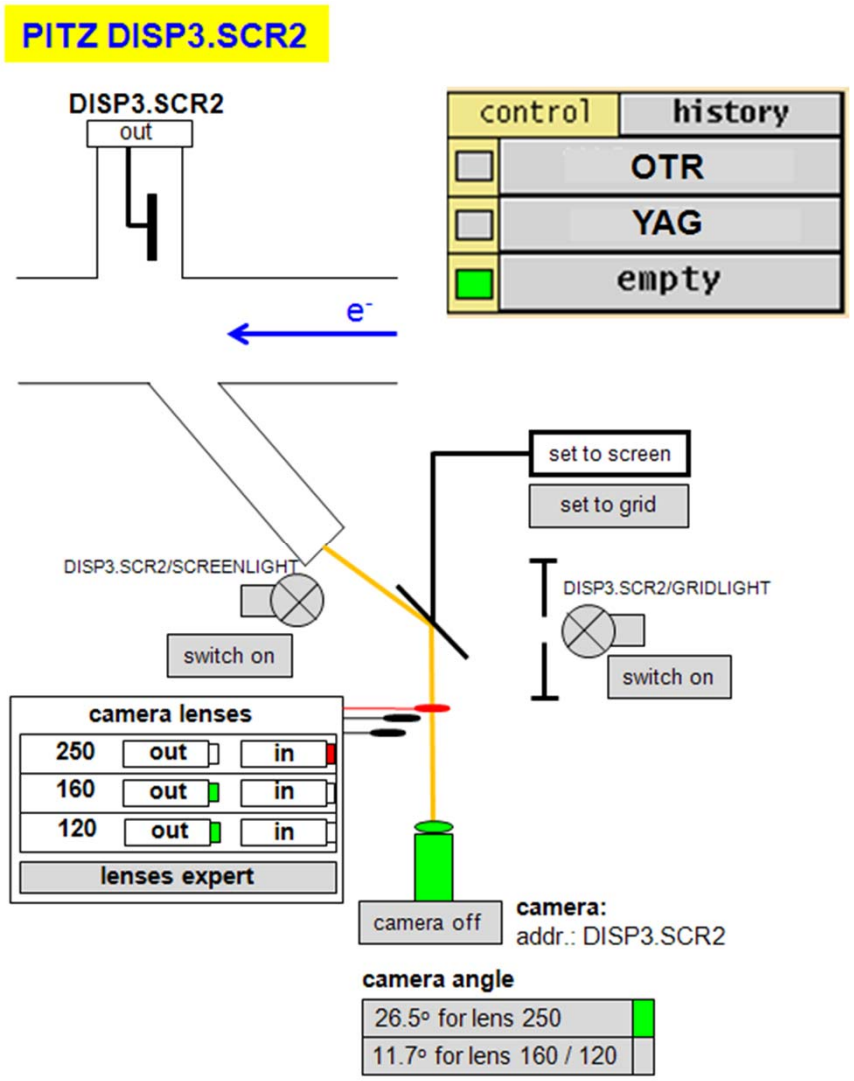
component	distance after D2 exit (mm)	actual area (mm × mm)	active area (mm × mm)	thickness (mm)	orientation to beam axis (°)
OTR for TV	1382	120 × 60	115 × 60	0.1	-45
YAG screen	1382	120 × 60	115 × 60	0.1	-45





- 2 pneumatic actuators on the same support arm
- OTR / YAG screen with common TV readout
  - Technical design is finished (J. Meissner)
  - Production of the mechanic parts is on-going

DISP3.Scr2 GUI & Control

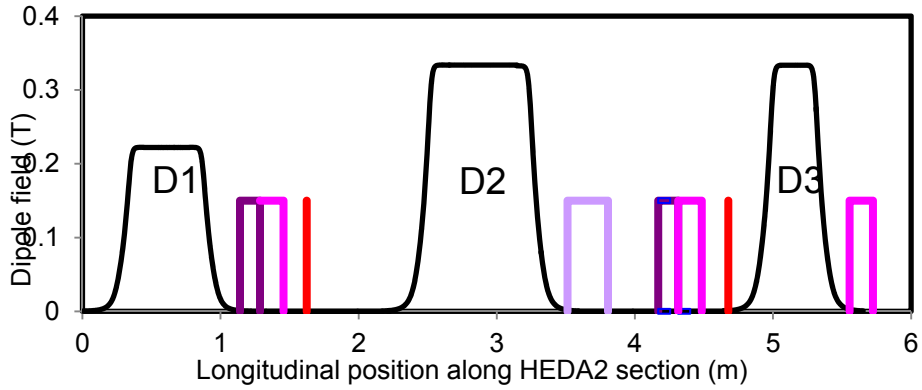


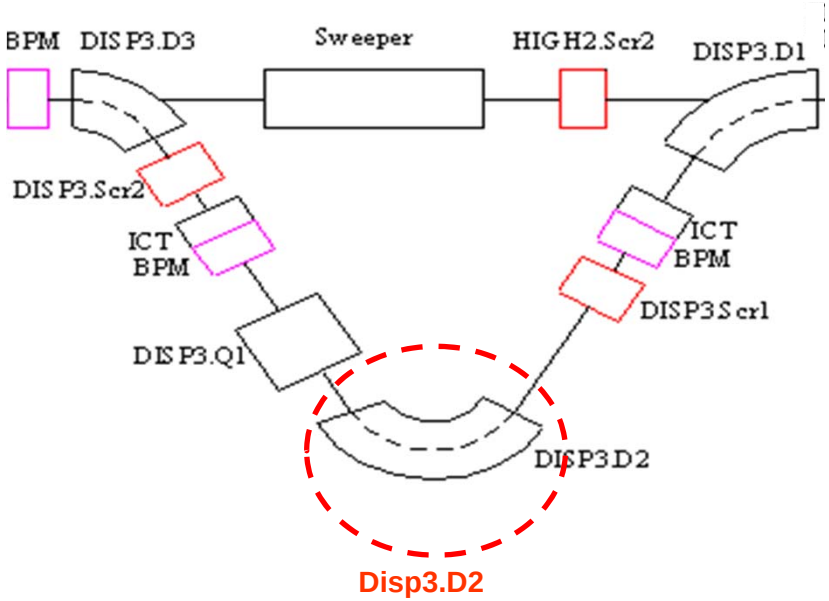
TV System components:

- JAI RM-2030GE camera
- 3 lenses:
  - f250
  - f160
  - f120
- 3 resolution grids
- 1 movable mirror
- 1 ring lamp

Measurements @ DISP3.Scr2

- Transverse slice emittance measurements at DISP3.Scr2 using DISP3.D2 dipole and DISP3.Q1 quadrupole magnet
  → based on required specifications from
  Y. Ivanisenko and system at HEDA1
- Dispersion of ~300 mm on the observation screen (DISP3.Scr2)
- For operation of off-crest phases
  → booster phase range limitation
- Large momentum spread of about 10%
  → based on conditions @ HEDA1 $\frac{dp_{\max}}{p} = \frac{1.1\,MeV}{12\,MeV} = 0.09 \approx 0.1$
- Drift length between DISP3.Q1 and DISP3.Scr2 should be the same as in HEDA1 (1.273 m) or at least longer than 1 m.
  → drift length = 1.092 m
- Include influence of dipole D2 and D3 in the measurement analysis



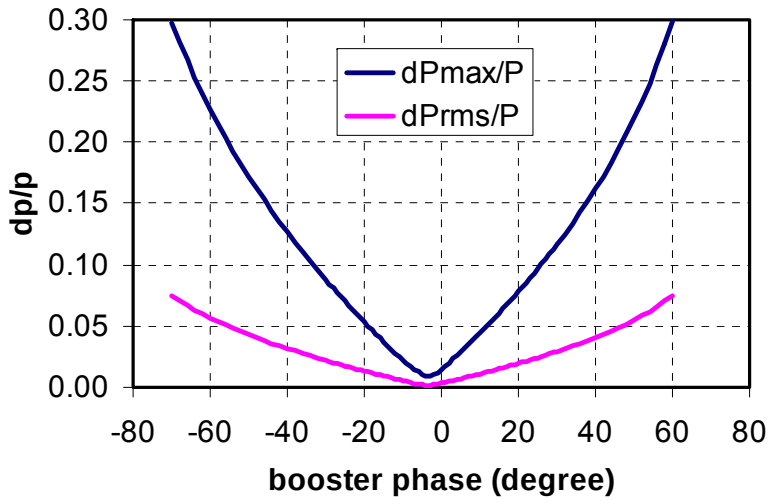


α (°)	ρ (mm)	β_{in} (°)	β_{out} (°)	L_{in} (mm)	L_{out} (mm)
120	400	0	9	892	1406

ICT BPM Quadrupole Screen station (center)

Limitation of Booster Phases

Simulated rms (**magenta**) and maximum (**dark blue**) relative momentum spread as a function of the booster phase for the gun phase of maximum momentum gain.

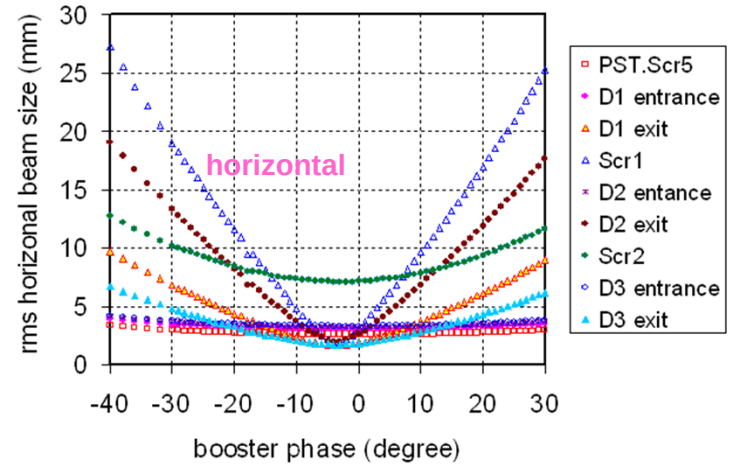


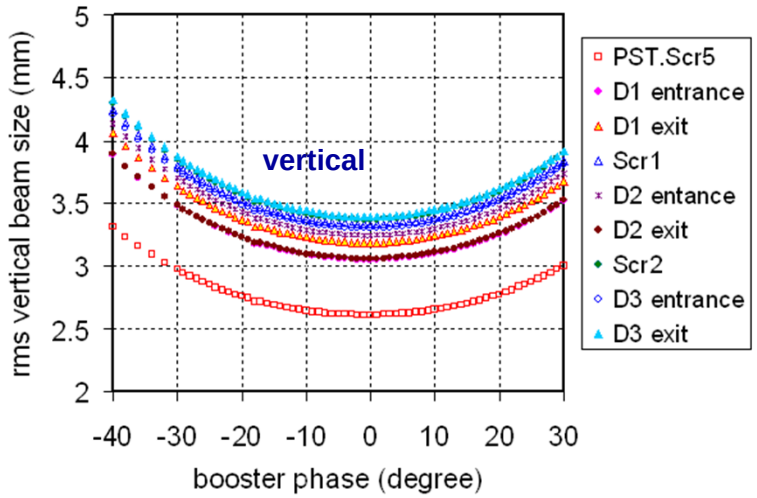
Booster phase range for $dp_{max}/p \leq 10\%$

↓

-36° → + 26°

Simulated rms horizontal (**top**) and vertical (**bottom**) beam size as a function of the booster phase for the gun phase of maximum momentum gain.





Integrated Current Transformer: DISP3.ICT1, DISP3.ICT2

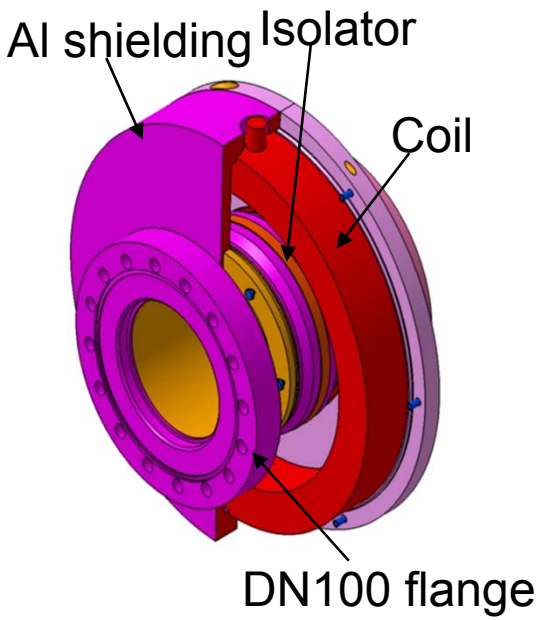
- ICTs are used to measure a bunch charge without destructing the beam.
  - ICT functions as an inductive core of a transformer while the beam acting as the primary coil
- Specifications
  - mounted over a ceramic insulator inserted in stainless steel vacuum tube to avoid the image current.
  - can operation with bunch charge of 0.1 – 1 nC
  - the same design as the one in HEDA1
  - 78 mm aperture & 145 mm long (including CF flanges)
  - Coil:Bergoz-ICT-178-070-20:1 (1.25 Vs/C sensitivity)
  - mechanical parts:

    ⇒ vacuum chamber

    ⇒ ceramic isolator (Friatec-559-3848-1)

    ⇒ covering shell, flanges

    ⇒ support



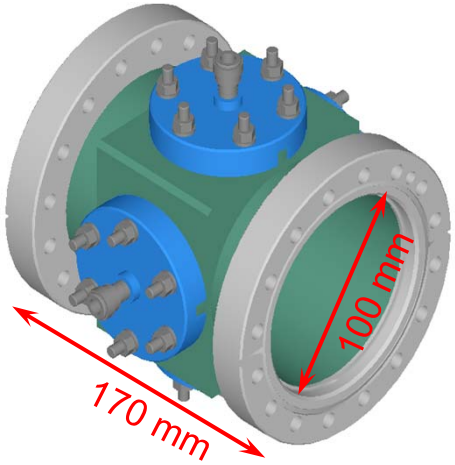
Beam Position Monitors: DISP3.BPM1, DISP3.BPM2, HIGH2.BPM1

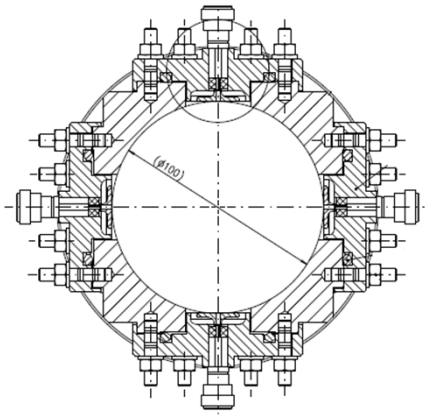
Specifications:

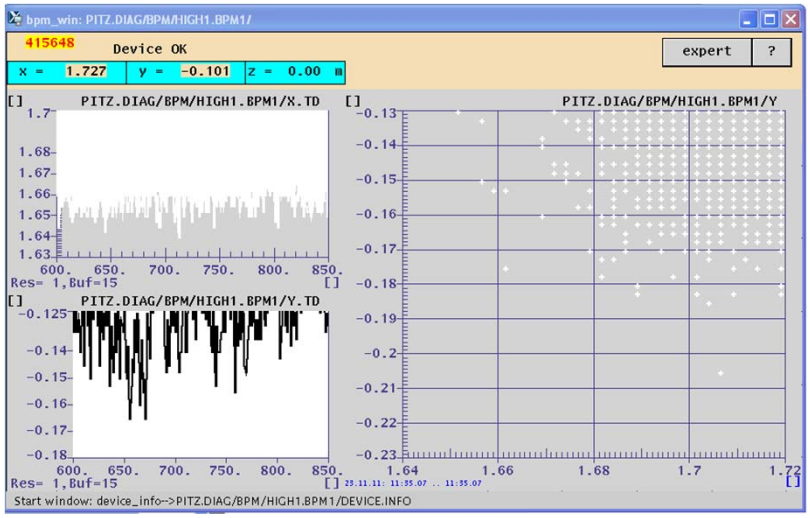
- operation with bunch charge of 0.1 – 1 nC
- resolution in the range of millimeter due to large beam size
- design was done by DESY MDI group based on the cold button BPMs for the European XFEL
- a stainless steel chamber with 100 mm aperture and 170 mm long including CF flanges
- feedthroughs of 20 mm with N-type connectors

Status:

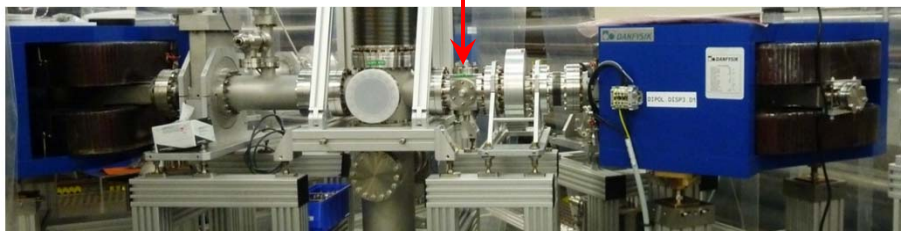
- F. Tonisch finished the timing adjusting and the electronic parts for BPMs will be ordered
- GUI → similar to other BPMs @ PITZ



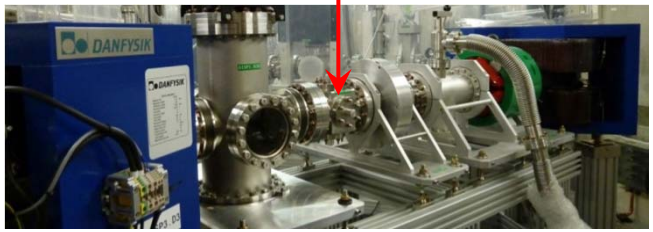




DISP3.BPM1



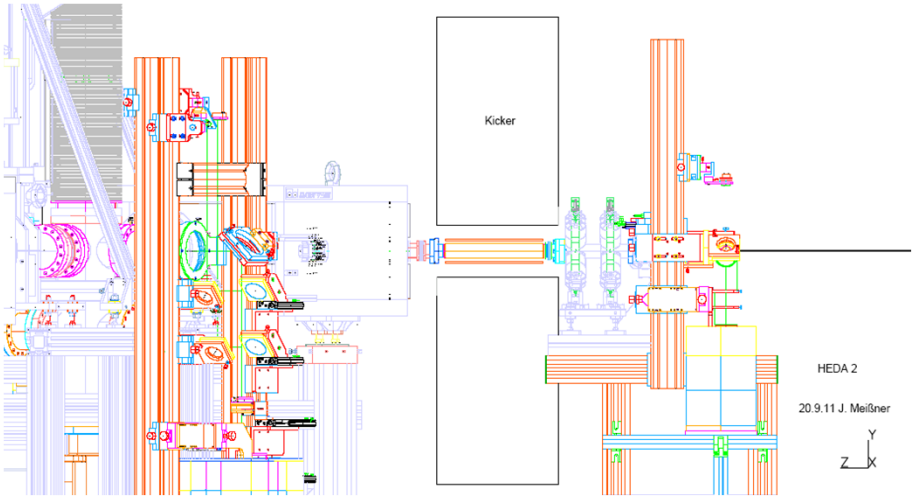
DISP3.BPM2



Pulse Kicker Magnet: HIGH2.Kick

Pulse kicker magnet: for characterizing electron bunches along the pulse train

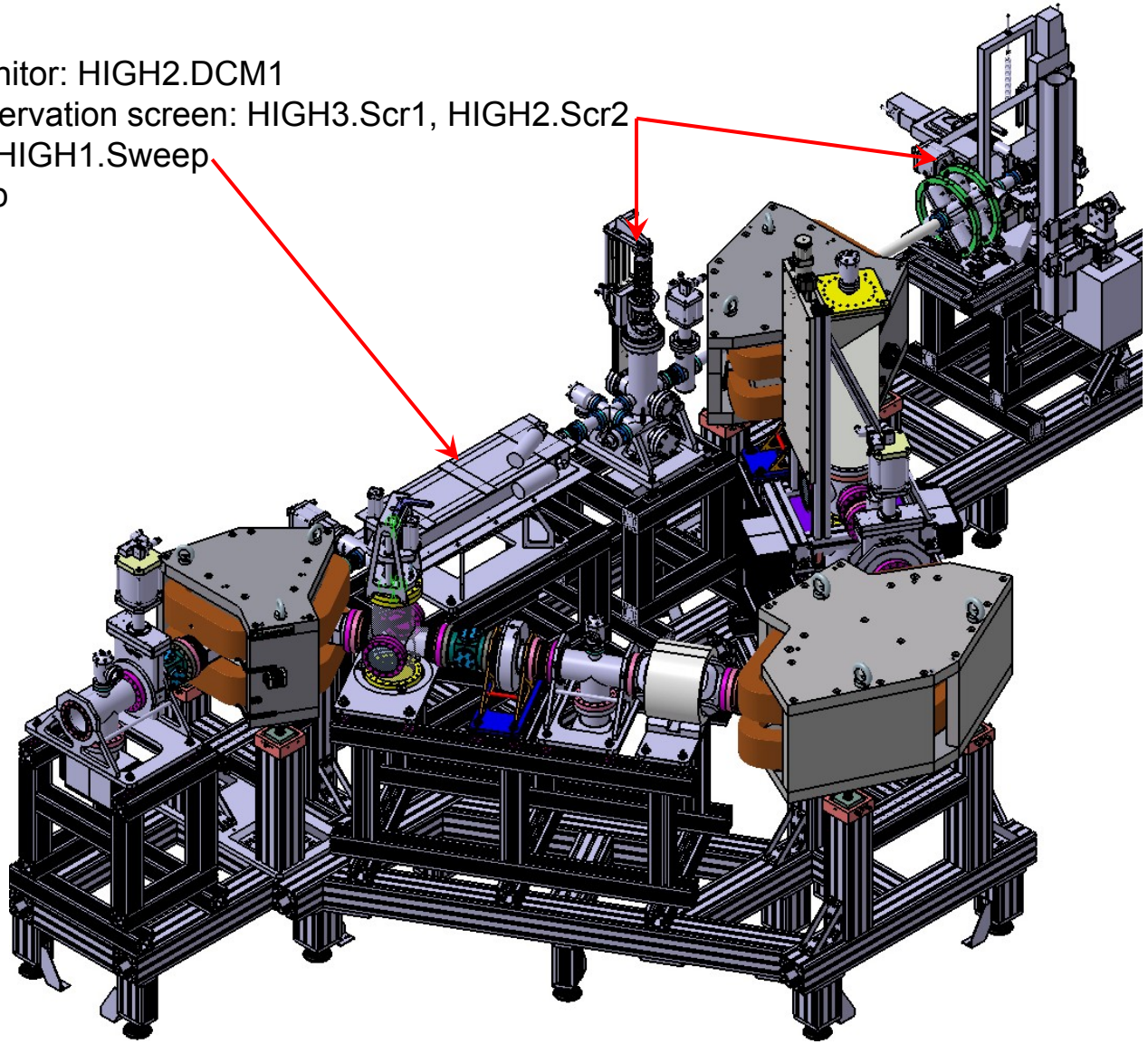
Status:
- Pulse kicker for HEDA2 will be design and built @ HH
- Foreseen delivery date: end of 2011
- Design and drawing of ceramic tube and flanges are done (J. Meissner)
  → Ordering process is on-going



Parameter	Description
Type of magnet	U-shape coil which is placed on the ceramic tube
Functionality	for kicking a few bunches out of the long pulse train for investigation of the momentum spread within the pulse
Kick plane	Vertical plane
Observed screen	DISP3.Scr1 + off-axis movement
Position	Upstream DISP3.D1
Deflection for 30 MeV	15 mrad for norminal 32 MeV
Total length	360 mm
Ceramic inner/outer diameter	34 / 46 mm
Comments	The same design as the ones in tomography module but opposite deflection

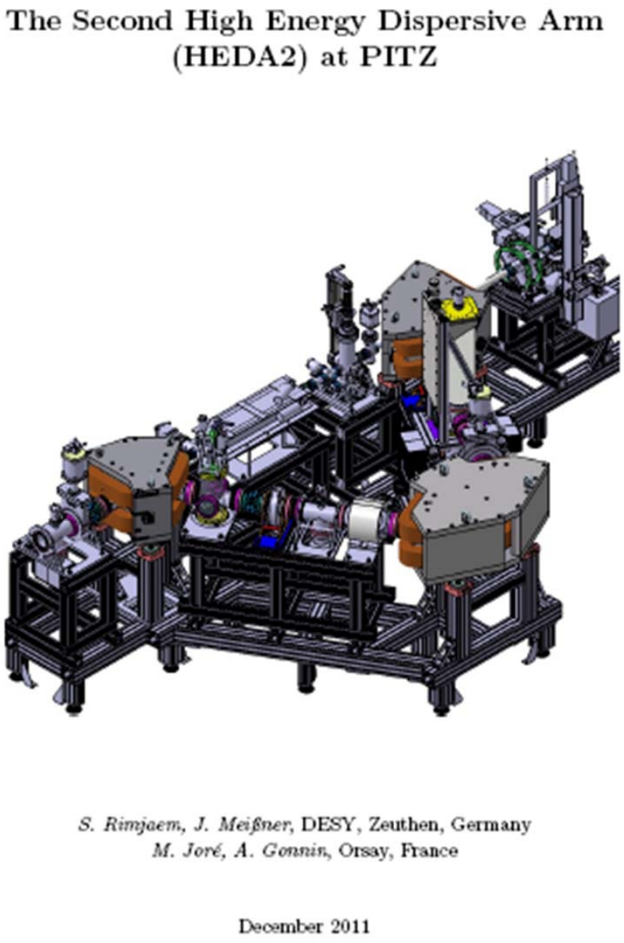
Other Components in HEDA2 Beyond my Responsibility

- Dark Current Monitor: HIGH2.DCM1
- EMSY3 & its observation screen: HIGH3.Scr1, HIGH2.Scr2
- Beam Sweeper: HIGH1.Sweep
- New Beam Dump



Summary

- Technical design and construction have been performed under collaboration of DESY (PITZ, MDI) and LAL with total budget ~ 942 k€
  - DESY ~896 k€, LAL ~46 k€
- Installation in the PITZ tunnel is finish except TV systems
- Commissioning & operation with beam are foreseen at beginning of 2012
- Next steps:
  - Methodical study of the measurements including TDS 3D-fields and measured magnetic field of dipole magnets is on-going
    → momentum, momentum spread, longitudinal phase space @ DISP3.Scr1
    → vertical slice emittance @ DISP3.Scr2
  - Design, construction and installation of kicker magnet
  - Design, construction and installation of beam dump for operation with electron beams of high charge and long pulse train
- Detailed internal reports will be available soon!



Acknowledgements

- Technical design:
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- Physics design suggestion & discussion:
  - J. Roensch-Schulenburg, PITZ group esp. F. Stephan, M. Krasilnikov, Y. Ivanisenko
- Screen stations and screen material:
  - M. Jore, A. Gonnin, A. Oppelt
- BPM design and construction:
  - S. Vilcins-Czvitkovits, N. Baboi
- TV-system:
  - J. Meisser, M. Mahgoub, Y. Ivanisenko, A. Oppelt, G. Vaschenko
- Construction & installation:
  - J. Meisser, A. Donat, J. Bienge, S. Philipp, DESY workshop
- Dipole magnetic field analysis
  - K. Kusoljaroyakul