4th International Workshop on Plasma Material Interaction Facilities for Fusion Research (PMIF 2013)

joint with

Fusion & Materials for Nuclear Systems Division

Plasma Facing Components 2013 Meeting (PFC 2013)

Sept. 9th-13th, 2013, Oak Ridge, TN, USA

iea Energy Technology Network

JÜLICH FORSCHUNGSZENTRUM

OAK RIDGE NATIONAL LABORATORY

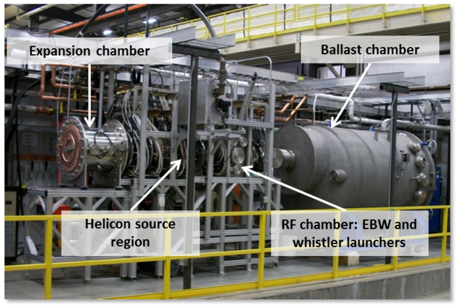
Managed by UT-Battelle for the Department of Energy

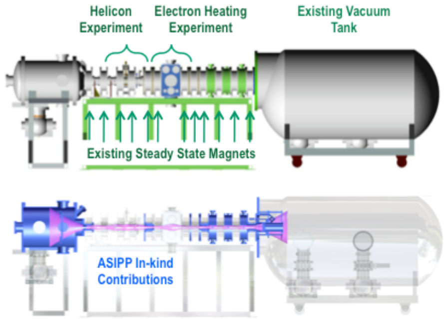
87 participants for PMIF/PFC meeting, including participants from:
Germany, Netherlands, France, Russia, Japan, South Korea, Australia

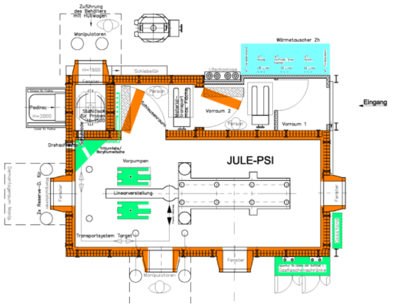
Monday		Tuesday		Wednesday	
8:30 AM	**Welcome Remarks**	8:30 AM	**Session II continued**	8:30 AM	**Session V: PFC-PMIF Joint Session**
	J. Rapp		R. Doerner		J. Brooks
	P. Pappano		F. Meyer		P. Pappano
	S. Zinkle		T. Abrams		S. Milora
9:00 AM	**Session I: Status of existing and planned PMI facilities**		J. Roth, R. Doerner		B. Unterberg
	J. Rapp		R. Goulding		N. Ohno / Y.Nakashima
	A. Kreter	10:50 AM	Discussion		R. Doerner
	N. Ohno	11:35 AM	Lunch		M. Ulrickson
	K. Ichimura	12:35 PM	**Session III: Diagnostics for PMI facilities**		B. Wirth
	J. Linke		H.J. van der Meiden		J. Brooks
	K.-S. Chang		E.E. Scime		E. Tsitrone
11:40 AM	Discussion		T. Thomas	11:50 AM	Lunch
12:15 PM	Lunch		T. Biewer		
1:15 PM	**Session II: Recent research highlights from PMI facilities**	2:15 PM	Discussion		
	Y. Nakashima	3:00 PM	**Session IV: Theory & Modeling for PMI facilities**		
	J. Yu		D. Reiser		
	Th. Loewenhoff, J. Linke		L . Owen		
	A. Huber, B. Unterberg		D. Borodin, D. Reiser		
	H. Greuner		A. Arakcheev		
	C. Corr	4:40 PM	Discussion		
	B. Unterberg				
4:25 PM	Discussion				
5:30 PM	IEA Executive Committee Meeting	5:15 PM	Leave for Tour of Fusion Facilities	5:30 PM	Bus departure for Banquet

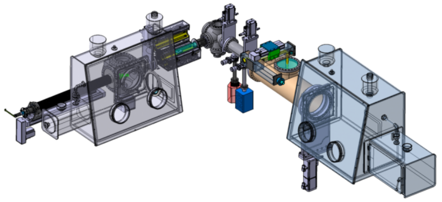
Session I: Status of existing and planned PMI facilities

- MPEX (Rapp, ORNL):
  - Density production of 4 x 10^{19}m^{-3} in helicon source has been achieved
  - Combined EBW coupling to overdense helicon plasmas was demonstrated
  - Upgrade from phase I to II of MPEX will increase RF power to 330kW (2014)
  - Installation of key diagnostics: Thomson Scattering, LIBS, IR camera, spectroscopy (2014)
  - Design of MPEX including target station able to handle neutron irradiated samples started (2014, 2015)
  - Modeling tools for linear systems are developed: SOLPS, EMC3-Eirene
- Jule-PSI (Kreter, FZJ)
  - Refurbishment of Hot Material Lab is completed, hot cells are being installed
  - Conceptual design of Jule-PSI completed
  - Design of versatile Be analysis facility completed, main parts purchased, assembly 2014
  - Pilot device of Jule-PSI, PSI-2 with new target station is operational

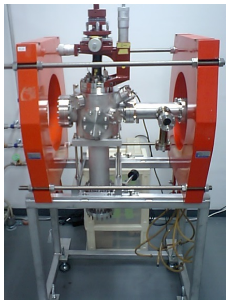


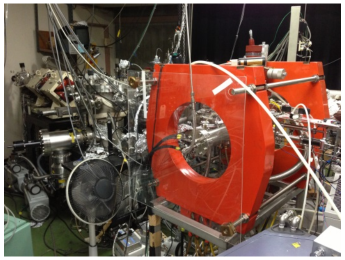


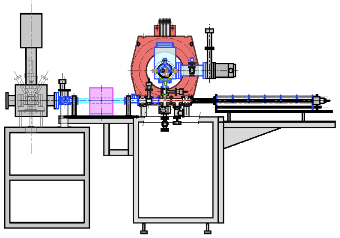




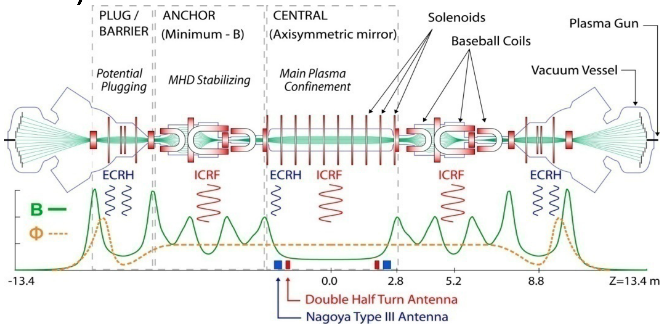
Session I: Status of existing and planned PMI facilities

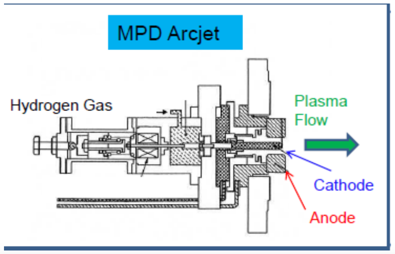






- Advanced divertor simulator (Ohno, Nagoya University):
  - New DC plasma source with zig-zag LaB_6 cathode and hollow Cu anode
  - Connected to Van de Graaf accelerator at Nagoya university
  - Plan to install the divertor simulator in radiation controlled area of Tohoku University to expose neutron irradiated samples (connected to TDS)
  - Main research thrust: hydrogen retention in irradiated materials
- Gamma-10/PDX tandem mirror (Nakashima, IchimuraTsukuba)
  - Additional ICRF heating increased ion flux to 10^{23} $m^{-2}s^{-1}$, $1MW/m^2$
  - Combined ICRF and ECH yielded $10MW/m^2$ (5ms pulsed)
  - New divertor simulation experimental module was installed
  - Increase of plasma density in front of target by combined H_2 and Ar seeding to 4 x $10^{17}m^{-3}$
  - Development of 1 MW gyrotrons for ECH to increase power on target to $20MW/m^2$
  - MPD Arcjet plasma source is added to Gamma 10 to study transient heat and particle loads (preliminary results: 4 eV, $10^{20}m^{-3}$)





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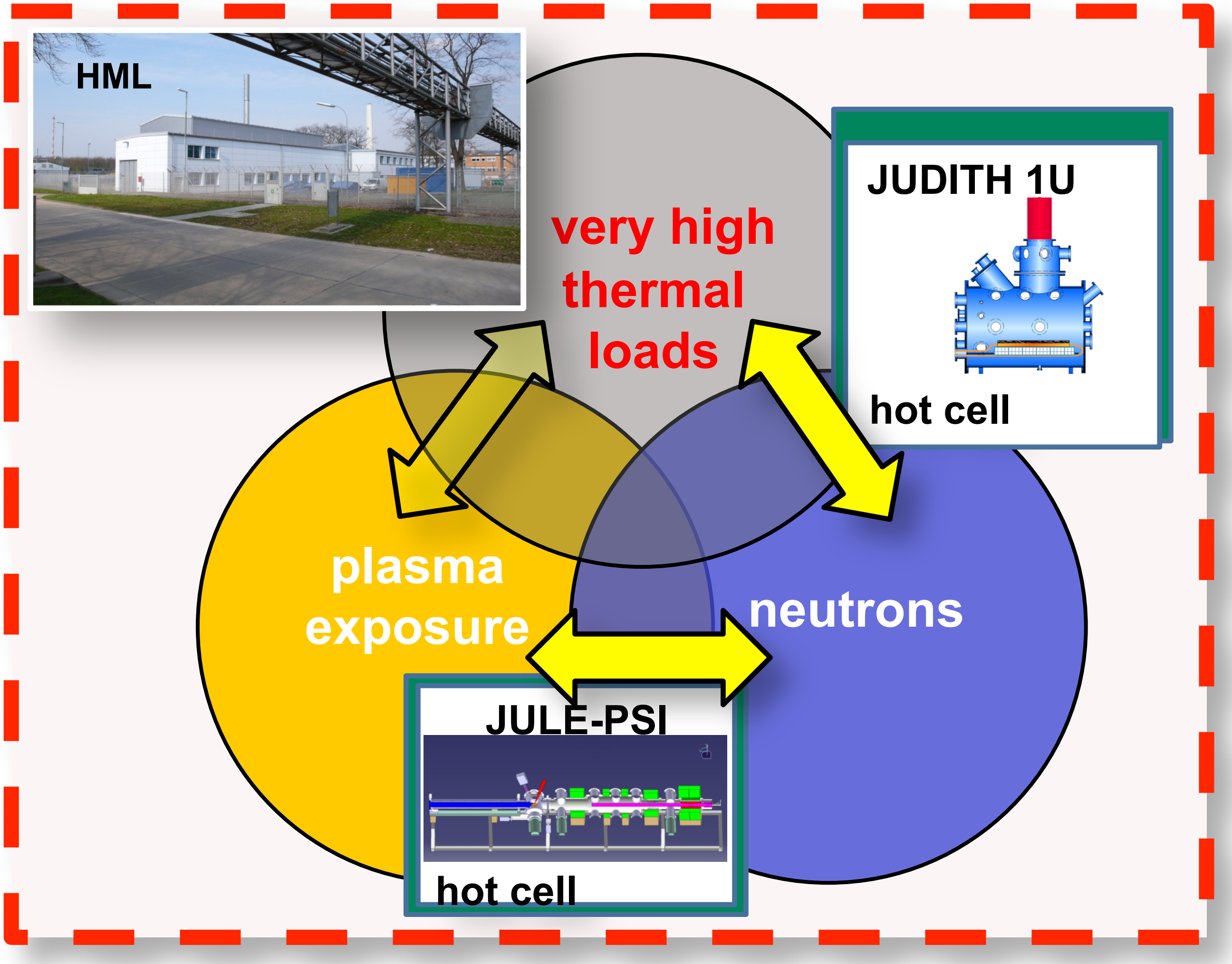
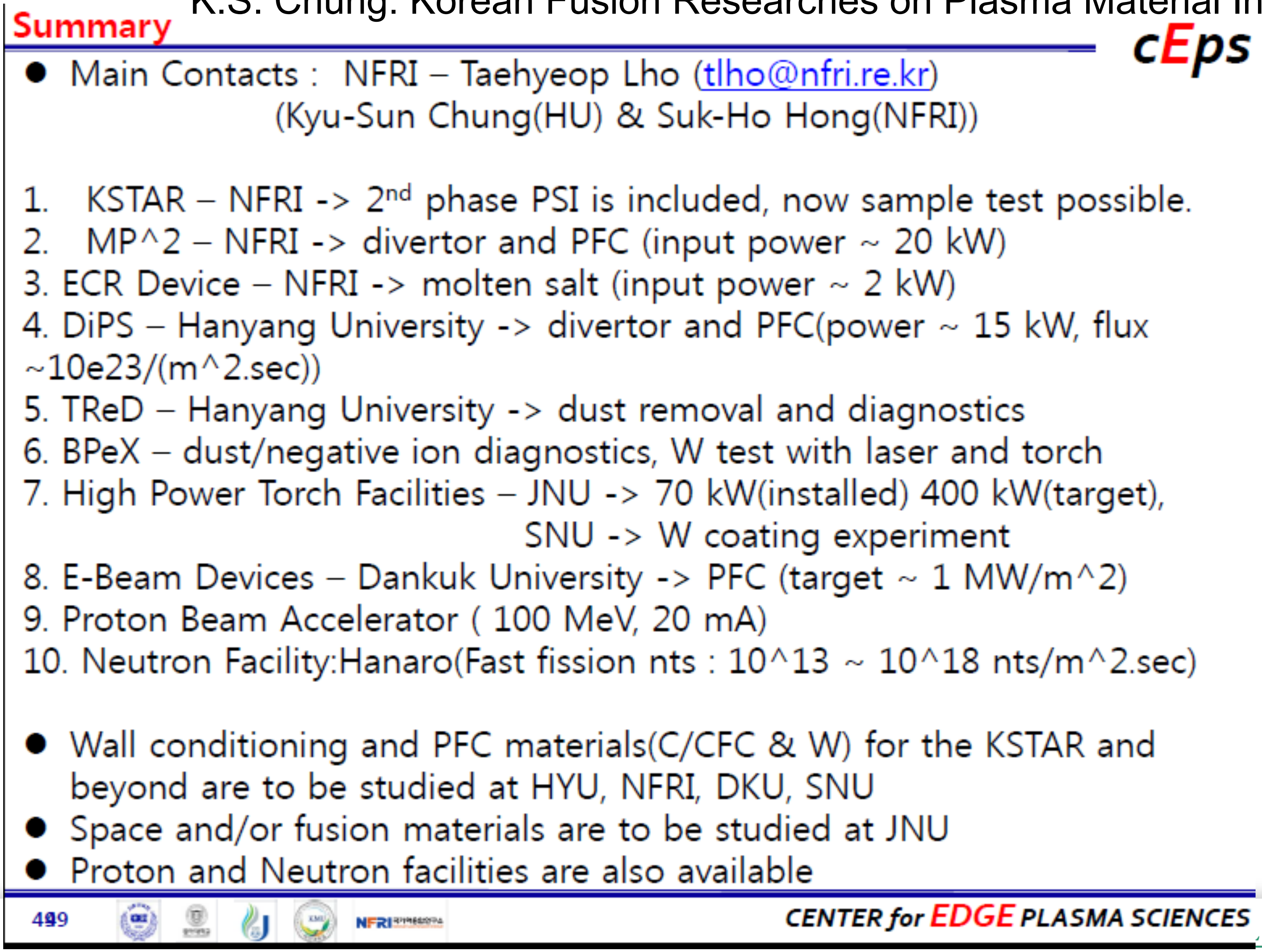


High heat flux facilities (Linke, FZJ):

- Comparison of e-beam (Judith), laser (FZJ) and plasma gun (QSPA)
- Neutron irradiation has effect on thermal conductivity and dust production (Judith)

Session I: Status of existing and planned PMI facilities

K.S. Chung: Korean Fusion Researches on Plasma Material Interactions



Summary

cEps

- Main Contacts : NFRI – Taehyeop Lho (tlho@nfri.re.kr)
  (Kyu-Sun Chung(HU) & Suk-Ho Hong(NFRI))

1. KSTAR – NFRI -> 2nd phase PSI is included, now sample test possible.
2. MP^2 – NFRI -> divertor and PFC (input power ~ 20 kW)
3. ECR Device – NFRI -> molten salt (input power ~ 2 kW)
4. DiPS – Hanyang University -> divertor and PFC(power ~ 15 kW, flux ~10e23/(m^2.sec))
5. TReD – Hanyang University -> dust removal and diagnostics
6. BPeX – dust/negative ion diagnostics, W test with laser and torch
7. High Power Torch Facilities – JNU -> 70 kW(installed) 400 kW(target),
   SNU -> W coating experiment
8. E-Beam Devices – Dankuk University -> PFC (target ~ 1 MW/m^2)
9. Proton Beam Accelerator (100 MeV, 20 mA)
10. Neutron Facility:Hanaro(Fast fission nts : 10^13 ~ 10^18 nts/m^2.sec)

- Wall conditioning and PFC materials(C/CFC & W) for the KSTAR and beyond are to be studied at HYU, NFRI, DKU, SNU
- Space and/or fusion materials are to be studied at JNU
- Proton and Neutron facilities are also available

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Main conclusions from discussion in session I

- PMI studies on n-irradiated materials essential: e.g. fuel retention, erosion due to synergistic effects of heat and particle load onto PFM with degraded properties
- PMI facilities very complementary w.r.t. capabilities and diagnostics -> collaborative studies of special importance
- New wiki website to collect detailed info about the various PMI facilities, maintained by FZ Jülich

Session II: recent research highlights

Demostration of Transient heat load (ELMs and Disruption)	High heat flux experiments
Nd:YAG laser (PISCES) (~80 $MJm^{-2}\ s^{-1/2}$) W, He damaged W Be coated W (Be-W alloying formation Threshold energy to remove Be coating) (J. Yu et al.)	H/He neutral beam (GLADIS) 10-15MW/m^2, long pulses, surface temp. 600-200°C He irradiation → nanocone structure (H. Greuner et al.)
e-beam (FZJ) -Steady state heat load: flat tile, monoblock design (neutron radiation effect) -Thermal shock load: Cracking depending on base surface temperature , orientation and size of grain (WUHP, WTa5, W-1.1TiC by Dr. Kurishita) (Th. Loewenhoff, J. Linke et al.)	Helicon source (NAGOYA-III type) (MAGPIE) Deuterium retention in Graphite and Diamond W(He irradiation – blistering) W 1%LaO (C. Corr et al.)
Laser (FZJ) W-UHP, ITER-grade at RT, 400 °C (Cracking pattern is similar to that of e-beam exp.) (A. Huber, B. Unterberg et al.)	

Session II: recent research highlights

Erosion (re-deposition) and Surface modifications
Investigate the influence of W on the erosion of EUROFER at energies close to W sputtering threshold Reduction of sputtering yield of EUROFER due to enrichment W near the surface (temperature dep.) (J. Roth, R. Doerner et al.)
Effects of neutron damage on nanofuzz formation using 1-30keV W self ions; He damage depending on crystal orientation Incident angle dependence and dual exposure for nano fuzz formation pre-damaged W (50dpa) →no difference for nano fuzz formation (F. Meyer et al.)
Collaboration between LANL IBML energetic ions to simulate neutron damage of PWM and PISCES-A Plat damage profile obtained by different energy Cu+ ion beam 3ω method thermal conductivity He damaged sample → low conductivity 30% reduction of ion damaged W (0.2 dpa) (R. Doerner et al.)
Demonstration of liquid target (Sn with W mesh) in PSI-2 linear device and TEXTOR tokamak Difference of erosion rate depending on droplet formation in tokamak (B. Unterberg et al.)
Li coating lifetimes in Li- coated graphite and TZM Mo Li target is demonstrated in MAGNUM-PSI Observed Li sputtering yields << Langmuir evaporation in vacuum (T. Abrams et al.)

Session III – Diagnostics for PMI facilities

- Thomson scattering systems (van der Meiden, DIFFER)
  - Advanced TS system: spatially variable (target or source); $0.07\ \text{eV} < T_e < 35\ \text{eV}$, $n_{e\ min} \sim 10^{17}\ \text{m}^{-3}$, 2 sec temporal, 2 mm spatial resolution
  - Collective TS system designed: Ion temperature measurements, plasma flow velocity; should be operational this year
- Laser induced florescence diagnostic developed for DIII-D originally (Scime, UWV)
  - 3 methods were developed: perpendicular, counter propagating and conformal (which is the most compact)
  - Measurements in Kr and H helicon plasmas show differing ionization fractions and neutral density depletion profiles, possible to measure H isotope mixtures, wall loading effects
- Digital holography as erosion monitor (Thomas, 3DT)
  - Measurements accuracy of a few microns for ITER (dual laser system down to 100 nm), spatial resolution of mm; frame rates on order of kHz
  - System in use at LTX SGI, vibrations in system subtracted
- Diagnostics plans for MPEX: OES, LP-Probes, RFA, filter scope, TS, LIBS, IR (Biewer)
- Action: create database of diagnostic capabilities, develop diagnostic collaborations

Session IV – Theory & modeling for PMI facilities

- Drift fluid modeling of intermittent cycles, comparison to NAGDIS (Reiser, FZJ)
  - Spiraling vortices observed and lead to radial expulsion of particles in quasi-periodic modes
  - Reduced model to 3 scale lengths: pressure, potential, temperature
  - Compare to NAGDIS measurements
- Transport simulations in linear configurations (Owen, ORNL)
  - Increasing model complexity – 2 point models, 1d fluid plasma/kin. neutrals, 2d fluid plasma/kin.neutrals
  - MPEX device modeled – power, gas fueling, target and source with pumping included, B-field ripple
  - Simulated puff and pump experiments: plasma viscosity effects could enhance density at target
- ERO modeling of erosion (Borodin, Reiser, FZJ)
- Tungsten crack formation modeling for ELM-like heating pulse (Araksheev, Budker)
  - Model includes: thermal expansion, elasticity, plasticity, brittleness and DBTT
  - 3 conditions necessary for crack formation: temperature exceeds DBTT, max plastic stress exceeds ultimate tensile stress, residual stress exceeds ultimate tensile stress
  - Compared with JUDITH HHF damage database
- Actions: try to measure E-field profiles at several axial locations, dedicated runs to simultaneously measure all relevant parameters