Status of RADI - a RF source size-scaling experiment towards the ITER source

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ITER Neutral Beam System: Requirements and Present Status of RF source

	ITER Requirement	IPP NNBI RF-Source			
		≤ 2002	2003	2004	**2005**
Cal. Current Density	**20 mA/cm² D⁻** **28 mA/cm² H⁻**	— 15	— 12	15 26	**23 mA/cm² D⁻** **33 mA/cm² H⁻** ✓
Extraction Voltage	**9 kV**	6 kV	6 kV	**9 kV** ✓	
Source Pressure	**0.3 Pa**	0.7 – 1	0.5	**0.3 Pa** ✓	
Electron Content (j_e/j_{H^-})	**1**	2 – 5	1 – 2	**< 1** ✓	
Pulse Length	**3600 s**	**< 10 s** (tech. limitations)			
Source Dimension	**1.5 x 0.6 m²**	**0.32 x 0.59 m²**			
Extraction Area	**2000 cm²**	**70 cm²**			
Uniformity	**± 10%**	**t.b.d.**			

→ **BATMAN test bed**
(see talks of E. Speth, H. Falter, P. McNeely)

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→ MANITU test bed, but only PINI size extraction (<390 cm²)
(see talk of W. Kraus)

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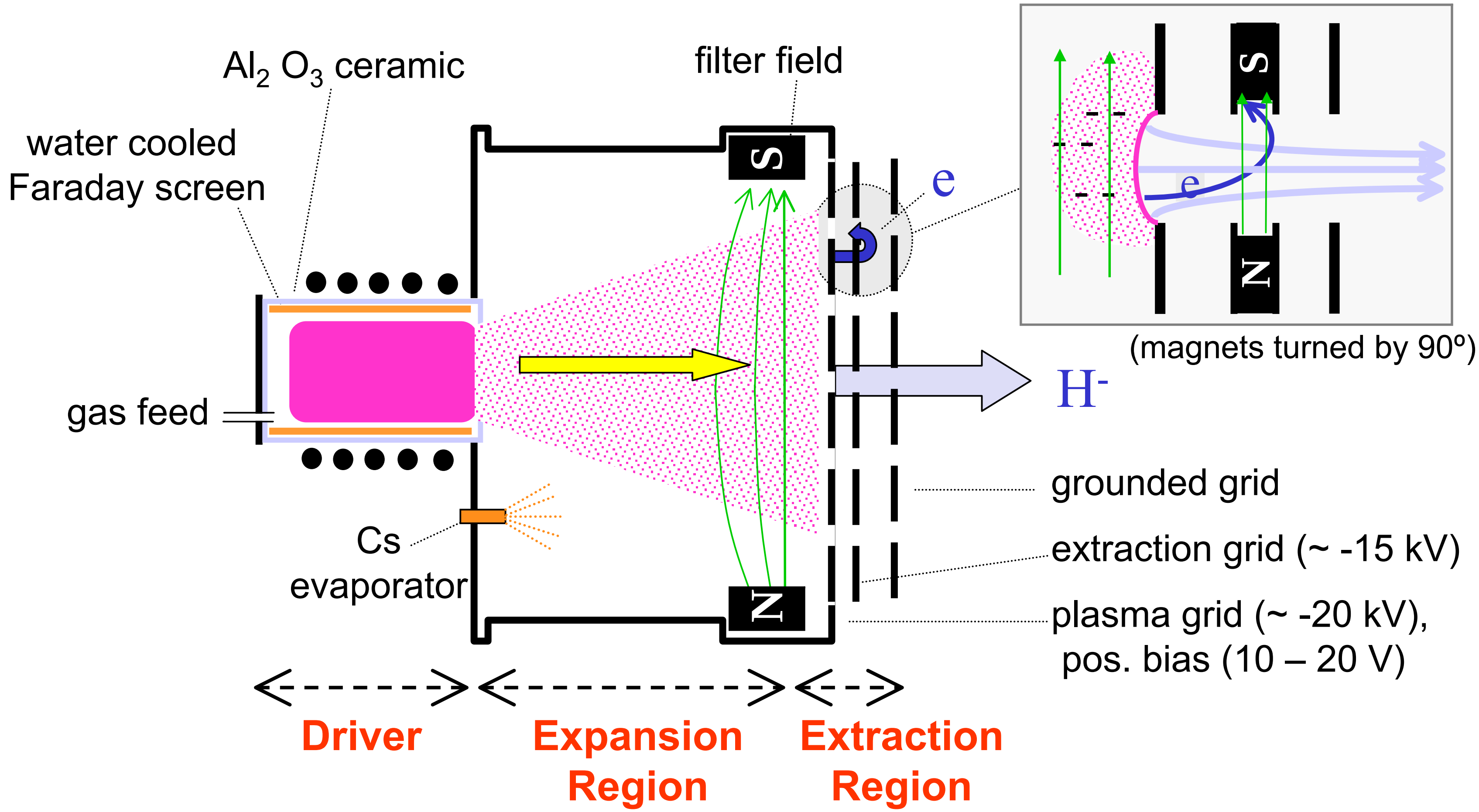
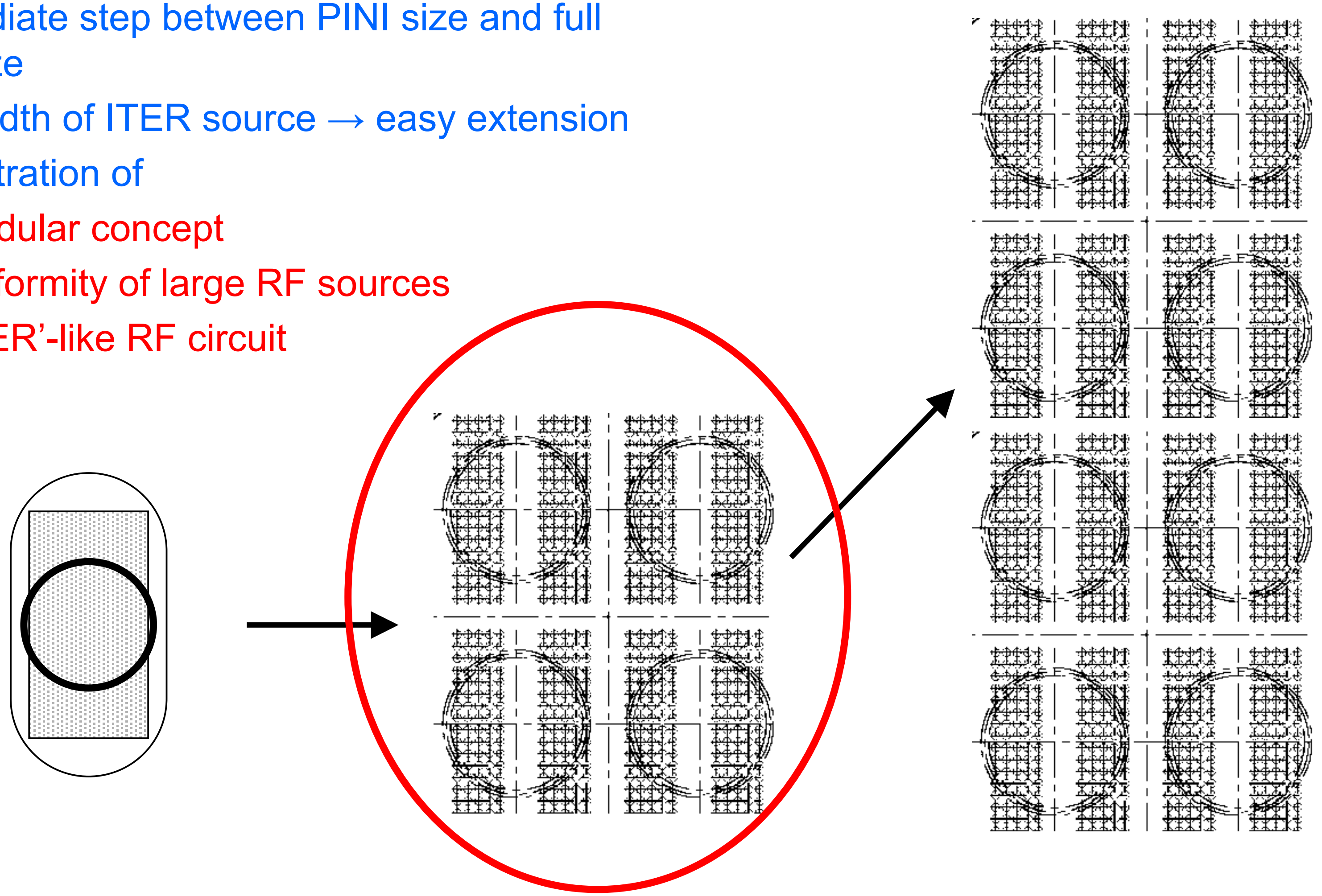
→ new test bed RADI, but without large area extraction

The IPP NNBI RF Source: Principle Design



Towards ITER:
‘½ size ITER source’

- intermediate step between PINI size and full ITER size
- same width of ITER source → easy extension
- demonstration of
  - modular concept
  - uniformity of large RF sources
  - ‘ITER’-like RF circuit



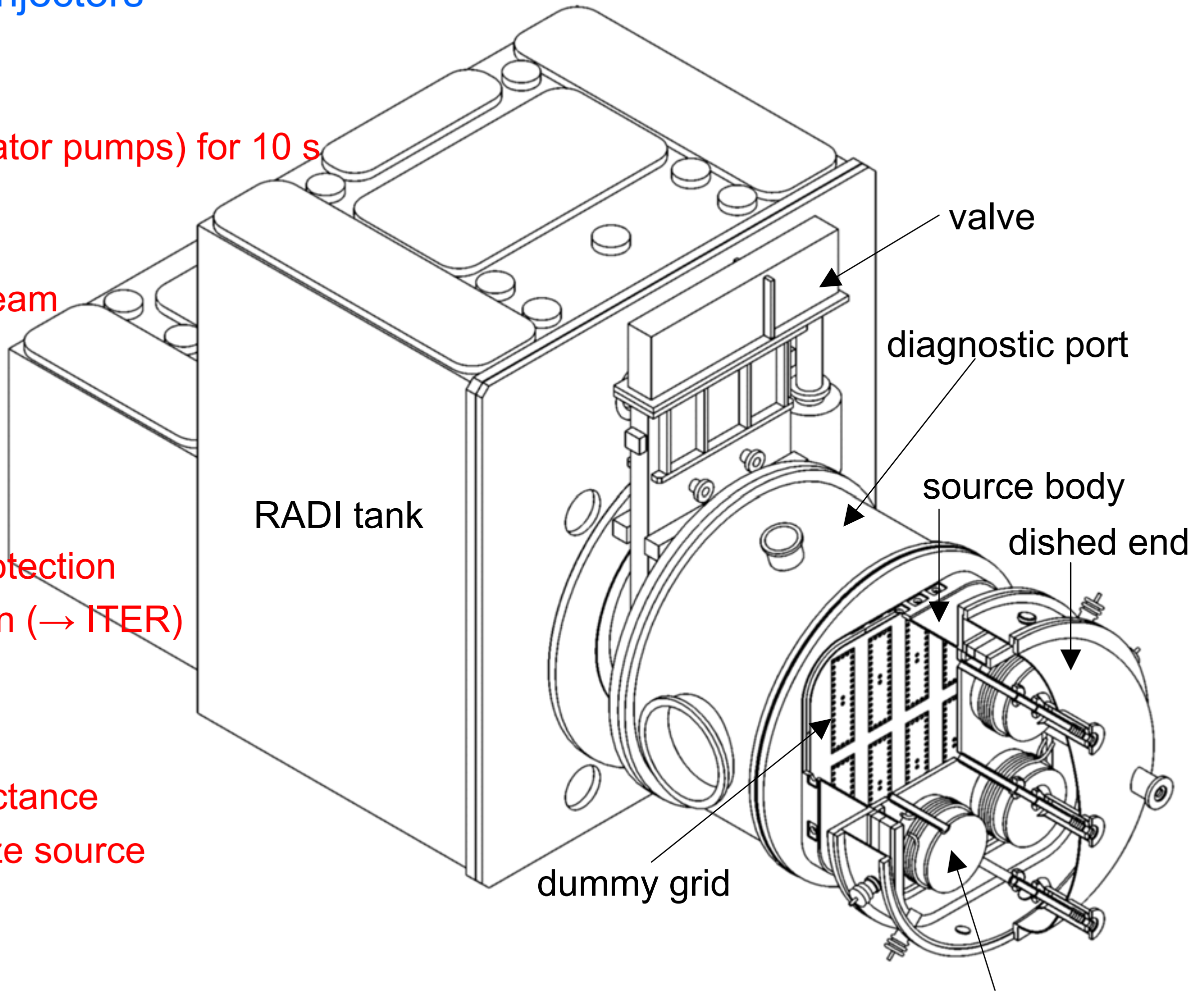
PINI (1/8) — **31x52 cm^2**

½ size ITER source — **80 x 70 cm^2**

full size ITER source — **160 x 60 cm^2**

½ size ITER source
RADI Test Bed

- re-use of one of the W7-AS injectors
  - no large insulator
    → no large scale extraction
  - vacuum system (Ti-evaporator pumps) for 10 s pulse
  - 500 mm valve
  - diagnostic port for downstream access
- plasma operation only:
  - source on ground potential
  - Deuterium w/o radiation protection
  - RF circuit: no HV separation (→ ITER)
- dummy grid with slits
  - adapted to SINGAP conductance
  - matching gas flow of full size source
- Status:
  - RF power supplies delivered and commissioned
  - commissioning summer 2005



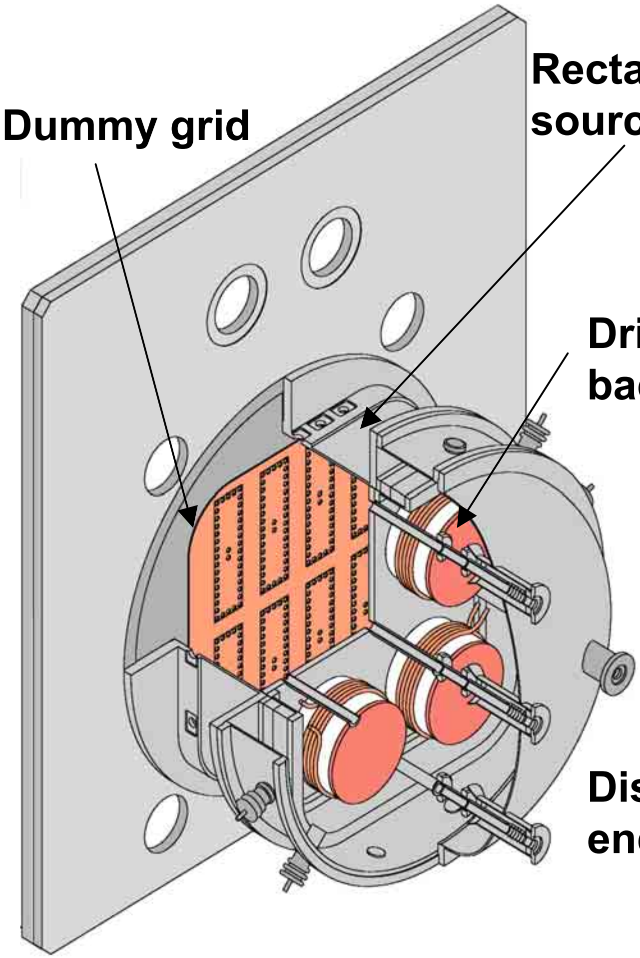
½ size ITER source
source design

- four parts:
  - rectangular source body
  - source back plate → drivers
  - drivers
  - driver back plates

- simulation of VIBS by dished end
  - also operation in air possible for commissioning by enforced back plate

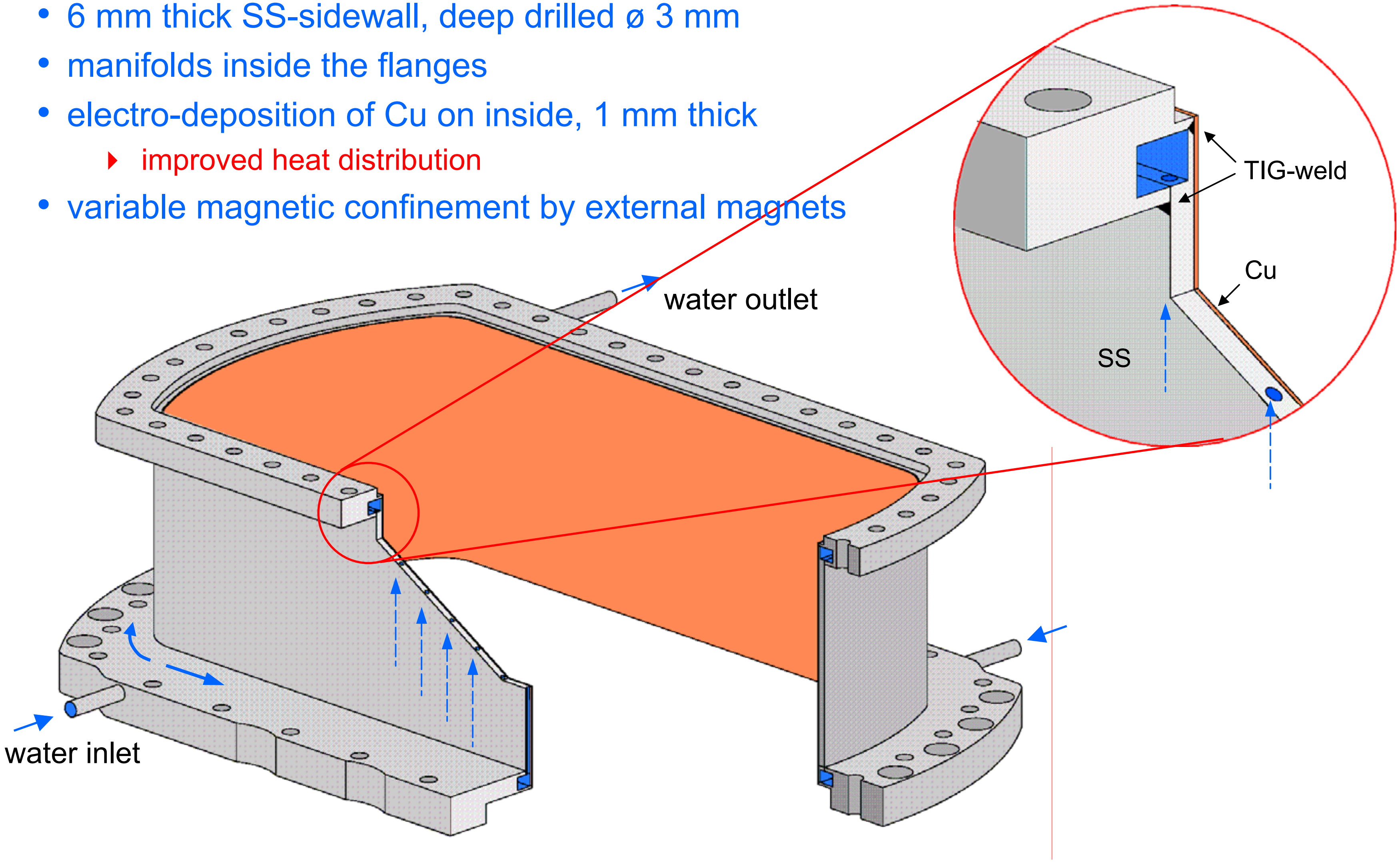
- variable source depth
  - spacers between source body and back plate
  - venting necessary
  - depth: 150 mm → 250 mm

- diagnostic ports:
  - 40 mm ø
  - 5 axial ports at back plate → Cs
  - 2 axial ports at driver back plate → gas, interlocks
  - 5 vertical & 3 horizontal ports, 1 cm distance from grid → diagnostics



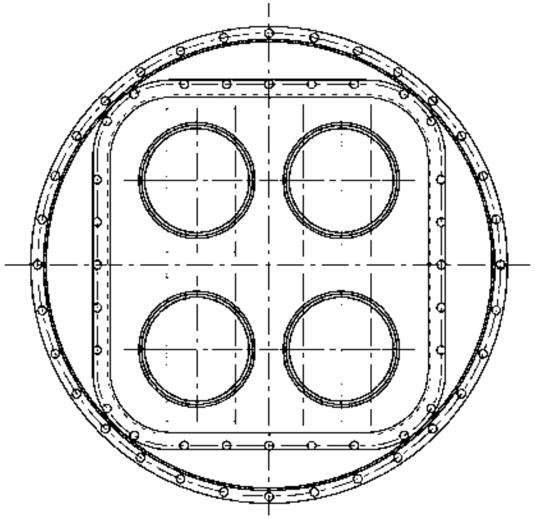
½ size ITER source
source body

- 6 mm thick SS-sidewall, deep drilled ø 3 mm
- manifolds inside the flanges
- electro-deposition of Cu on inside, 1 mm thick
  - improved heat distribution
- variable magnetic confinement by external magnets



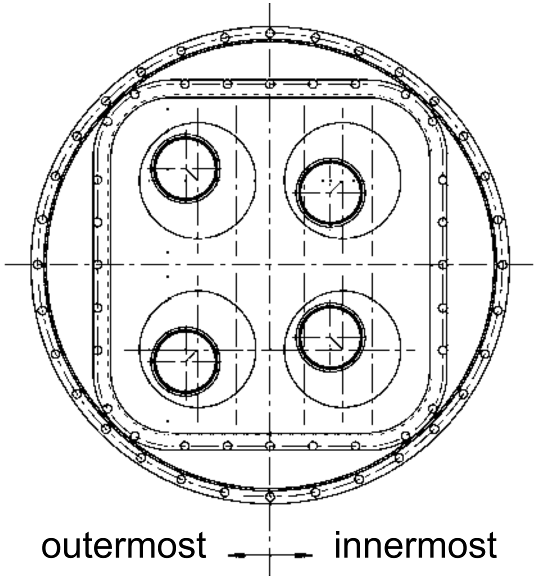
½ size ITER source
Driver Configurations

4 x 24 cm ø



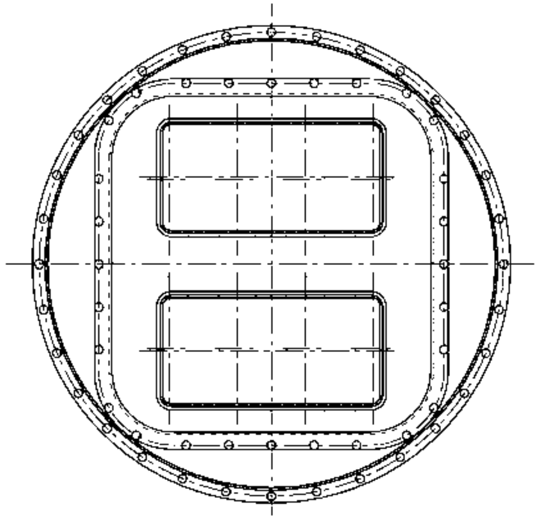
- standard driver
- can illuminate 150 – 200 cm^2 (MANITU)

4 x 15 cm ø



- same back plate
- eccentric flanges
- optimization of driver position

2 x racetrack



- new back plate
- similar to AUG PNBI RF geometry

1 RF generator / 2 drivers
(ITER RF design scenario)

1 RF generator / driver

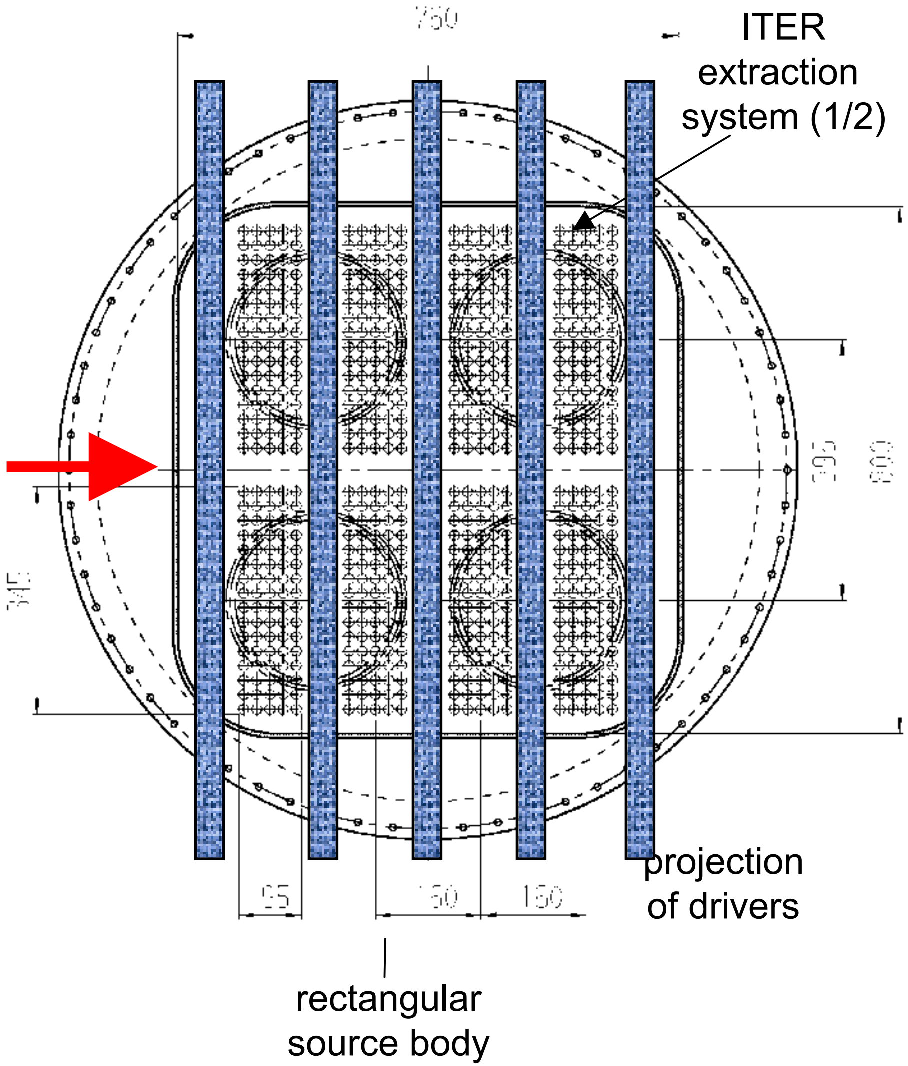
½ size ITER source
Auxiliaries

- Cs oven
  - 2 ovens, IPP design with 3 g each
- Plasma grid heating
  - electrical heating wires, controlled
  - 150 °C – 200 °C
- Bias
  - 50 V, 500 A power supply

- Filter field
  - ‘PG’ filter:
    - ➔ 5 kA current through PG (ITER)
  - ‘Rod’ filter
    - ➔ five water-cooled rods of magnets
    - ➔ similar to small sources
    - ➔ adapted to ITER grid segmentation

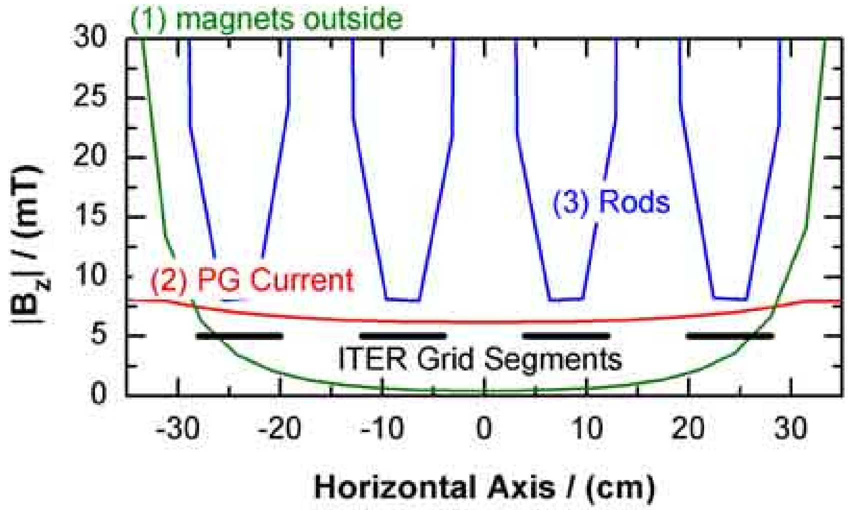
no extraction

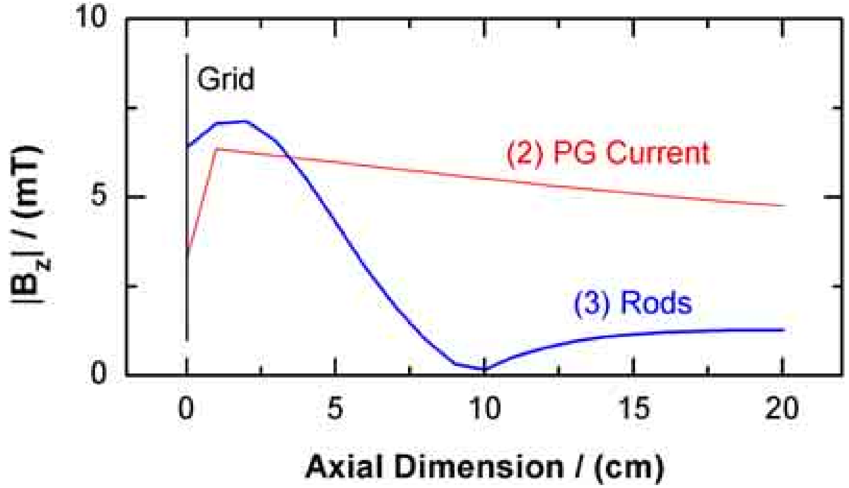
→ influence on plasma parameter !



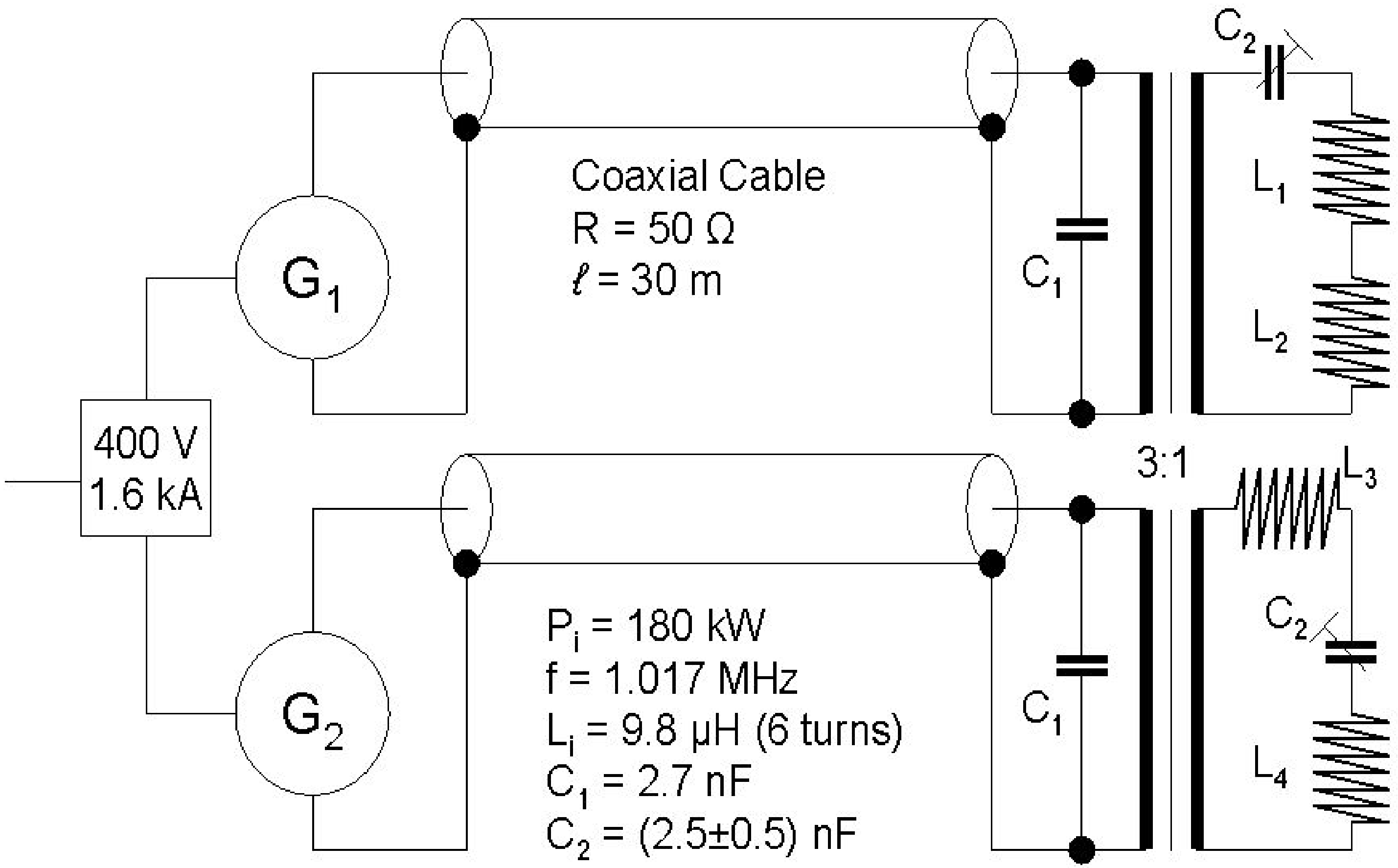
½ size ITER source
Filter field calculations

- magnets outside
  - no field in the center
- PG current
  - quite homogeneous across the grid
  - far reaching into source
- Rod filter
  - more localized at grid
  - variations across grid segments
- open questions:
  - combination of PG currents and rods
  - influence of magnets in extraction grid by dummy extraction grid





½ size ITER source RF circuit



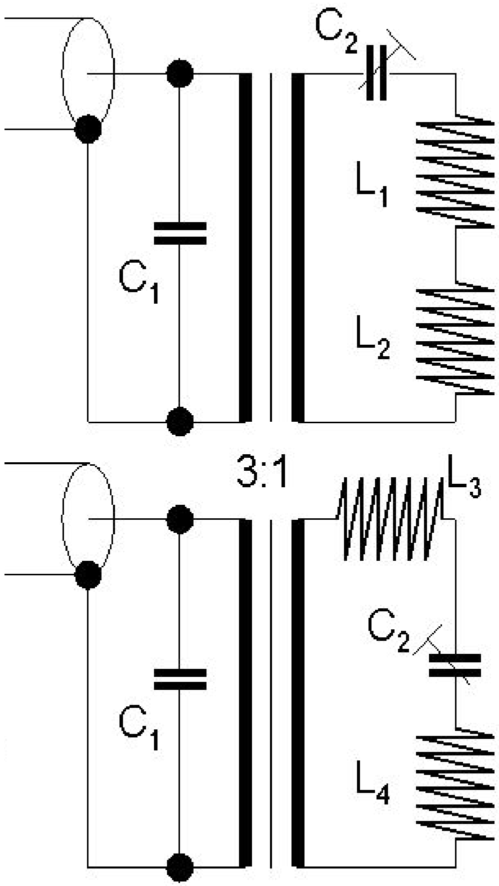
Similar to ITER RF design:

- RF generator and source at same potential
- 1 RF generators supplies 2 drivers

½ size ITER source
RF circuit

Open questions (→ ITER RF circuit design):

- distribution of the RF power into the source (FS, eddy currents in back plates, …)
- optimum number of coil turns
- operation without transformer
  - proof of principle at MANITU
- arrangement of C_2 with the drivers (‘CLL’, ‘LCL’)
- coil insulation
  - 4.5 kVpp for 90 kW between turns (1/2 for ‘LCL’)
  - 27 kVpp at coil ends for 6 turn coil
- mutual influence of the matching networks and of the possible different frequencies
- other means of variable matching
  - C_2 has to be located near the source
  - rather large → problems for ITER
  - control of frequency ? → redesign of generator



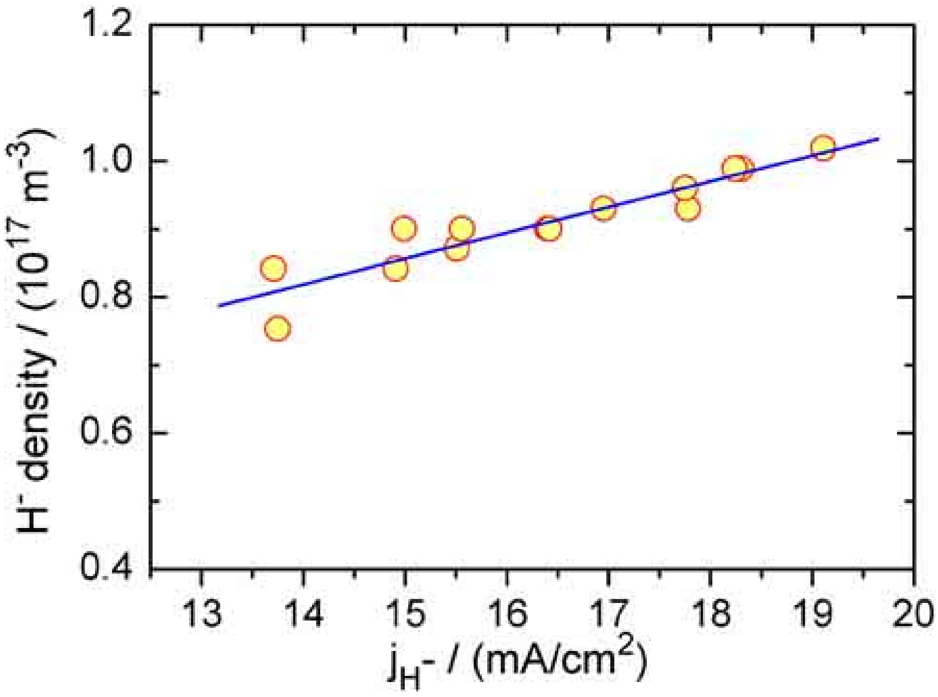
½ size ITER source
Diagnostics

no large scale extraction

→ no direct measure (current density, electron/ion ratio) of source performance

IPP strategy:

- diagnostic of plasma parameters
  → negative ion density
  → electron density
  → Cs density in the plasma
  → Cs coverage
  → …
- axial and horizontal / vertical profiles
  → uniformity
- calibrate plasma parameters to current density and electron/ion ratio at BATMAN / MANITU



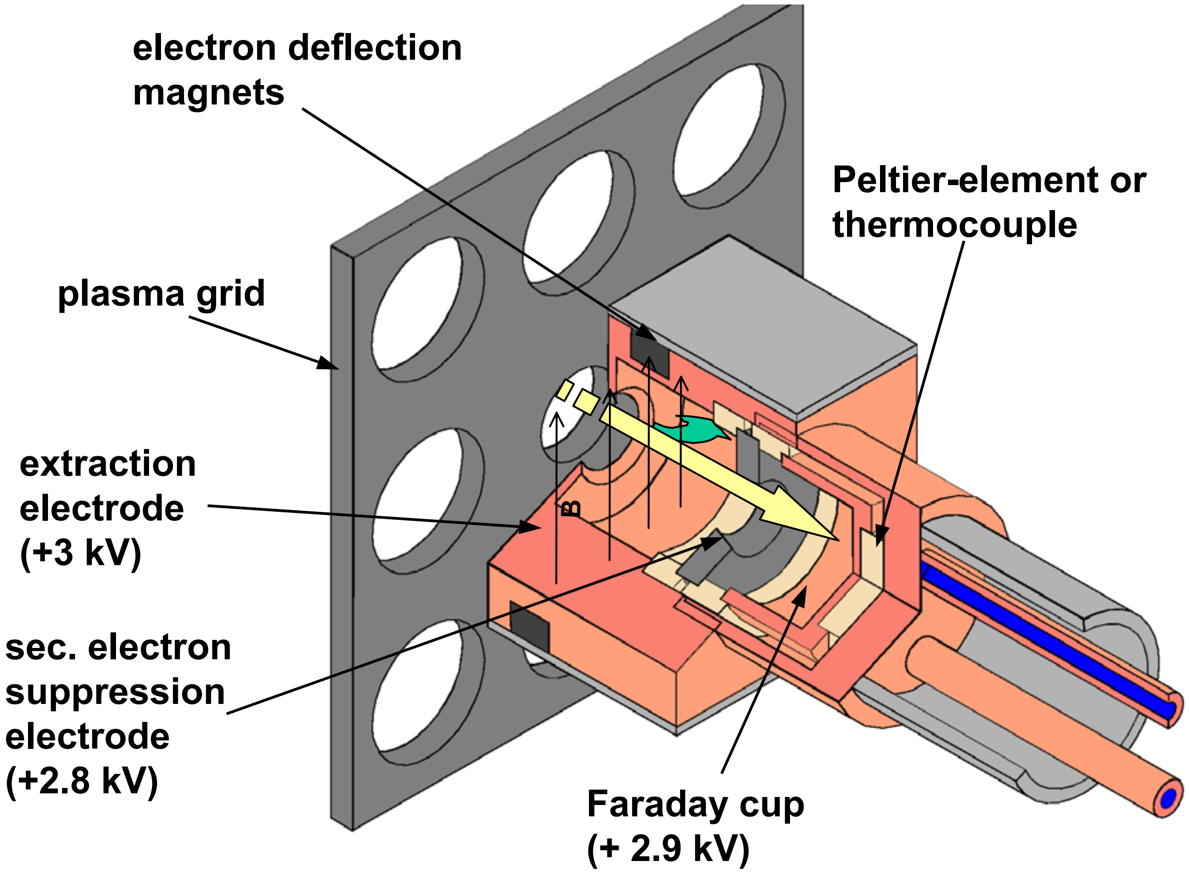
(see talk of U. Fantz)

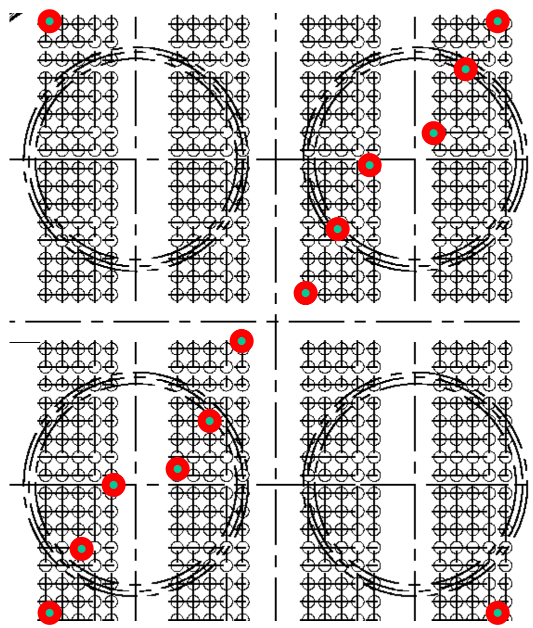
½ size ITER source
Diagnostics

(see talk of U. Fantz)

Diagnostic	*Parameter*	*Profiles*	*Comments*
Optical Emission Spectroscopy	n_e, T_e, **n_{H^-}**, n_{Cs}, n_{H°, Impurities	yes	already working on BATMAN, non-invasive 1 cm diameter of line of sight (optics) 2 three-channel spectrometer → tomography large ports (4 cm diameter) → axial profiles
Langmuir Probes	n_e, T_e	yes	problematic in RF environment, also installed in the plasma grid, important for spectroscopy collaboration with Charkov University
Work Function	Cs-coverage	no	in preparation white-light Hg-lamp, interference filters problems with RF noise, magnetic fields
Laser Detachment	**n_{H^-}**	yes	in preparation, relative measurement
Cavity Ring Down Spectroscopy	**n_{H^-}**	no	in preparation, absolute measurement
Local extraction with Faraday Cups	j_{H-}	yes	voltage too low for maximum performance

½ size ITER source
local extraction





- max. voltage (4 – 5 kV) determined by distances
- perhaps to low for optimum performance, but beam profile possible

½ size ITER source
Summary

- The IPP RF source has fulfilled or exceeded the ITER requirements regarding current density, source pressure and electron content, but for small sources

- In order to demonstrate the scalability and the modular concept of the IPP RF source, IPP is currently constructing a new test bed RADI
  - test of ½ size ITER source → same width, ½ of the height
  - no large scale extraction → performance via plasma parameter
  - test of 'ITER'-like RF circuit
  - variable design for optimisation:
    drivers, confinement, filter field, source depth, RF matching, …
  - diagnostic tools for negative ion density developed / in preparation,
    calibration against current density under way

- commissioning summer 2005, first results October 2005
  - direct impact on full size source design / RF circuits at Padua

- mid term: large scale extraction ?
  - upgrade of test bed → calorimeter on HV
  - more significance of results