Objectives

• Scope of main future European industrial procurements in the NB and EC areas
• Specific technologies involved
• Near term opportunities for Industry
• Future opportunities for Industry (hints)
Sharing of the EC Heating and Current Drive

<table>
<thead>
<tr>
<th></th>
<th>EU</th>
<th>IN</th>
<th>JA</th>
<th>RF</th>
<th>US</th>
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<tbody>
<tr>
<td><strong>Power Supplies Source</strong></td>
<td>8 sets</td>
<td>5 sets</td>
<td></td>
<td></td>
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<tr>
<td><strong>Source</strong></td>
<td>8 MW</td>
<td>2 MW</td>
<td>8 MW</td>
<td>8 MW</td>
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<tr>
<td><strong>Tx. Line</strong></td>
<td>24</td>
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<td></td>
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<tr>
<td><strong>Launchers</strong></td>
<td>4 (UL)</td>
<td>1 (EL)</td>
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</tr>
</tbody>
</table>

The specifications for ITER go beyond state-of-art gyrotrons (170 GHz, 1 MW, CW)

A design and R&D programme is on-going in EU

EC Power Supplies & Sources

Call for Tenders to be launched in a near future:

- **EC Power Supplies**: CfT 2013 Q1
  
  Contract Duration 68 months (all PS sets)
  
  First acceptance 30 months after signature

- **1st Superconductive Magnet (He-free)**: CfT 2013 Q2

On a longer term:

- EU is responsible to procure 8 units of 1 MW Gyrotron Tubes + Superconducting Magnets + Auxiliaries

- **Functional specs**

- Main Contract signature (tubes & magnet) - **2016**
Overview of the HV EC Power Supplies

- Functional specifications: 8 sets (1 MHVPS + 2 BPS)
- Universal PS (suitable for different gyrotron types); accepted on dummy loads
- $\eta \geq 97\%$ in steady-state
- Full power modulation up to 1kHz - partial modulation up to 5kHz
- Demanding dynamic performances on output DC voltage (e.g. high accuracy $\pm 0.5\%$, fast switch-off <10$\mu$s)

$55kV, 50Ax2$

$35kV, 50mA$

$SS$ 2x

Universal PS (suitable for different gyrotron types); accepted on dummy loads

$\eta \geq 97\%$ in steady-state

Full power modulation up to 1kHz - partial modulation up to 5kHz

Demanding dynamic performances on output DC voltage (e.g. high accuracy $\pm 0.5\%$, fast switch-off <10$\mu$s)

Overview of the HV EC Power Supplies

$5NB$ and ECPS&S, Tullio Bonicelli, IBF13

1st He Free Superconductive Magnet

- Warm Bore Diameter = 240 mm

Nominal on axis magnetic field (B-field) value at 0.5m is $B_0 = 6.77T$. 

Nominal magnetic field distribution along the magnetic axis of the magnet.
The ITER Heating Neutral Beam System

Two HNB Injectors at 1 MV accelerating voltage and injecting 16.5 MW each into the plasma

HNB Procurement Sharing (% credits)

<table>
<thead>
<tr>
<th>PP</th>
<th>Title of PA</th>
<th>EU</th>
<th>JA</th>
<th>IN</th>
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<tbody>
<tr>
<td>53.P1</td>
<td>Assembly and Testing (Functional)</td>
<td>100</td>
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<tr>
<td>53.P2</td>
<td>Beam Source and Bushing (BtP)</td>
<td>41</td>
<td>59</td>
<td></td>
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<tr>
<td>53.P3</td>
<td>Beam Line components (BtP)</td>
<td>100</td>
<td></td>
<td>0</td>
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<tr>
<td>53.P4</td>
<td>Pressure Vessels/Shielding (BtP and DD)</td>
<td>76</td>
<td>24</td>
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<tr>
<td>53.P5</td>
<td>ACCC (DD/BtP)</td>
<td>100</td>
<td></td>
<td></td>
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<tr>
<td>53.P6</td>
<td>NB Power Supplies (Functional)</td>
<td>31</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>53.P9</td>
<td>NB Test Facility (various)</td>
<td>65</td>
<td>33.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Large scientific/technological step from existing NB systems ➔ A full scale Neutral Beam Test Facility is needed (NBTF/PRIMA).

The test facility is located in Padova (Italy) hosted by the Consorzio-RFX

NB and ECPS&S, Tullio Bonicelli, IBF13

7

NB Test Facility

MITICA Megavolt ITER Injector & Concept Advancement

NB and ECPS&S, Tullio Bonicelli, IBF13

8
HNB System

**NBTF Procurements**

- Six main contracts have already been tendered

<table>
<thead>
<tr>
<th>Component</th>
<th>Spec</th>
<th>Cft (exp.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MITICA Vessel</td>
<td>DD/BtP</td>
<td>2013Q2</td>
</tr>
<tr>
<td>MITICA AGPS (+ 2 HNBs)</td>
<td>FS</td>
<td>2013Q3</td>
</tr>
<tr>
<td>MITICA Cryogenic Plant</td>
<td>FS</td>
<td>2013Q3</td>
</tr>
<tr>
<td>MITICA Beam Line Components</td>
<td>BtP</td>
<td>2013Q3</td>
</tr>
<tr>
<td>MITICA Beam Source</td>
<td>BtP</td>
<td>2014Q2</td>
</tr>
<tr>
<td>MITICA Residual Magnetic Field Coils</td>
<td>BtP</td>
<td>2014Q2</td>
</tr>
<tr>
<td>MITICA SF6 Plant</td>
<td>FS</td>
<td>2014Q4</td>
</tr>
</tbody>
</table>

MITICA Cryopump ➔ see A Teissier (Cryoplant and Fuel Cycle Team)

NB and ECPS&S, Tullio Bonicelli, IBF13

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MITICA Vessel

- AISI 304L vacuum vessel
- Host the Beam Source and Beam Line Components (BLCs);
- composed of the following parts:
  - BSV (Beam Source Vessel);
  - BLV (Beam Line Vessel);
  - The vessel support structure;
- Design (for NBTF) compliant to ASME VIII, div.2 (2010 edition)
- Quality class 2

For ITER compliant to RCC-MR
Quality class 1

NB and ECPS&S, Tullio Bonicelli, IBF13
AGPS and GRPS (MITICA + 2 HNBs)

Acceleration Grids Power Supplies (AGPS) are shared btw EU and JA

5 inverters:
- Out Voltage 6.5 kV
- Current: ca 1.5 kA

Contract: detailed design, manufacture, factory testing, transport, on-site installation and commissioning

Ground Related Power Supplies (GRPS)

Electrostatic Residual Ion Dump PS (MITICA + 2 HNBs)
- Voltage = 25 kV
- Current = 60 A

Correction Coils PS (HNBs)
- 7 Units
- Voltage btw 0.5 kV and 1.4 kV
- Current = 650 A

Residual Magnetic Field Coils PS (MITICA)
- 6 Units
- Voltage btw 150 V 550 V
- Current btw 275 A and 1100 A

AGPS and GRPS (MITICA + 2 HNBs)

=> Acceleration Grids Power Supplies (AGPS) and
=> Ground Referenced Power Supplies (GRPS)

Step-down Transformers

NB and ECPS&S, Tullio Bonicelli, IBF13
**NBTF Cryoplant**

→ Provides cryofluids to the MITICA cryopump

### Cryopanels circuit
- ScHe @ 4.5 K - 0.4 MPa(a)
- Max Flow rate: ~50 g/s
- **Max heat load: 900 W**

### Thermal Shields circuit
- GHe @ 80 K - 1.75 MPa(a)
- Max Flow rate: ~310 g/s
- Max heat load 21kW

### Operations
- Steady state operation
- Beam pulse operation
- Max beam duration 3600s
- 100 K regeneration
- Room temperature regeneration under UHV
- Duty cycle ¼ (typ 300s/900s)

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**MITICA Injector Components**

![Diagram of MITICA Injector Components](image)
**Beam Line Components (BLCs)**

- Actively cooled - 2.4 MPa water pressure
- Water cooled OFHC copper (Max power density≈ 0.5 MW/m²)
- Water cooled Panels or tubes in CuCrZr (Power density > to 1MW/m²)
- Case and piping manifold made of AISI 316 LN

- Calorimeter (14MW/m²)
  - 18MW - 7tons

- Electrostatic Residual Ions Dump (6MW/m²)
  - 19MW - 5 tons

- Neutraliser - (0.5 MW/m² to 3MW/m² leading edges)
  - 5.5MW - 15 tons

**MITICA Beam Source**

**Functions**
- Produce H-/D- ions
- Accelerate negative ions up to 1MV in 1280 beamlets

**Challenges**
- High voltage holding
- HHF components up to 20MW/m²
- HP water cooling (2.4MPa)
- Tight tolerances for grids alignment
- Precise and adjustable source positioning
MITICA Residual Magnetic Field Coils
- RMFC

RFMCs are used to simulate the residual magnetic field inside the injector.

- 3 pairs of coils
- 500 A each
- actively cooled copper coils with glass fiber reinforced epoxy insulation
- Coil Section from 100x30 to 120x100
  (alternative designs being considered)

SF6 Gas Handling Plant

SF6 gas is used as an insulating medium for the 1 MV components of the PS system.

- 32 T gas SF6 @ 6 bar
- 48 hours recovery time 32 T gas SF6 @ 6 bar
- Vacuum level 20 mbar
- Storage in liquid form in a set of tanks

- Diode and Filter Tanks ➔ 19.1 tons
- Transmission Line TL1/TL2 and HV Bushing ➔ 8.4 tons
- Transmission line TL3 and HVD2 ➔ 3 tons

- Based as much as possible on standard industrial components
- On-site installation and commissioning included in the contract
The ITER Heating Neutral Beam (HNB) System

EU to procure (shared with JADA):
- 2 NB Injectors
- Power Supplies for the 2 Injectors

ITER HNB Contracts Summary

List of main HNB contracts for ITER HNBs to be launched

<table>
<thead>
<tr>
<th>Component</th>
<th>Specs</th>
<th>CfT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 lots: Vessel, (VVPSS Box, tbc) &amp; Drift Duct, Exit Scraper, Fast Shutter</td>
<td>BtP</td>
<td>2015</td>
</tr>
<tr>
<td>Absolute Valve</td>
<td>BtP</td>
<td>2015</td>
</tr>
<tr>
<td>ACC-Coils</td>
<td>BtP</td>
<td>2016</td>
</tr>
<tr>
<td>PMS Plates</td>
<td>BtP</td>
<td>2016</td>
</tr>
<tr>
<td>General Assembly of HNB1 &amp; HNB2</td>
<td>FS</td>
<td>2017</td>
</tr>
<tr>
<td>Beam Source</td>
<td>BtP</td>
<td>2018</td>
</tr>
<tr>
<td>Beam Line Components (3 lots - Neutralizer, Calorimeter, RID)</td>
<td>BtP</td>
<td>2018</td>
</tr>
</tbody>
</table>
ITER HNB components

The NBI Vessel
An extension of the primary vacuum confinement and of the primary safety barrier.

2 x 2 Stainless-Steel Tanks (Beam Line Vessel and Source Vessel) – SIC1 RCC-MR code –
Weight: BLV → about 40 tonnes
BSV → about 30 tonnes

Magnetic Active and Passive shieldings
Reduction of almost three orders of magnitude of the external Magnetic field to ensure a good beam transmission

-Steel (S235 tbc) Plates 75mm thick all around the vessels
- 2 x 6 Coils – Water Cooled Conductor in OFHC - Dimension about 3,3m x 3m - 92000 kA-turns to 200000 kA-turns – Coil Cross-section typically 400x200 mm²

ITER HNB components
(Front End components)

2 Drift Duct and (Vacuum Vessel Pressure suppression box, tbc)
– SIC1 – Stainless Steel – Double Bellows- Deep Drilled liner Copper alloy

Absolute Valve - Stainless Steel Casing SIC1 - High vacuum

Fast Shutter SIC1 - RH Mechanisms – Pressurised Bellows
• Activities for the development of NBI facilities under construction in Padova, V Toigo, RFX

• ISEPS status (Ion Source and Extraction Power Supplies), G Taddia, OCEM Energy Technology

• Supply of the Cooling Plant for MITICA etc., R Bozzi, DELTA-TI IMPIANTI SPA (in the Fuel Cycle parallel session)

• ELISE project, G Orozco, Trainee working within IPP NNBI-group

• Activities in the development of RF tubes for EC, IC and LH systems for ITER and the Fusion programme, S Bethuys, THALES ELECTRON DEVICES

For further information please contact us at industryportal-info@f4e.europa.eu

mentioning “Neutral Beam” in subject of your email

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