Manufacturing the Largest Magnet in the World

The Newest Advanced Technology and Nurturing Young Engineers and Experts

Magnet Session in MIIFED

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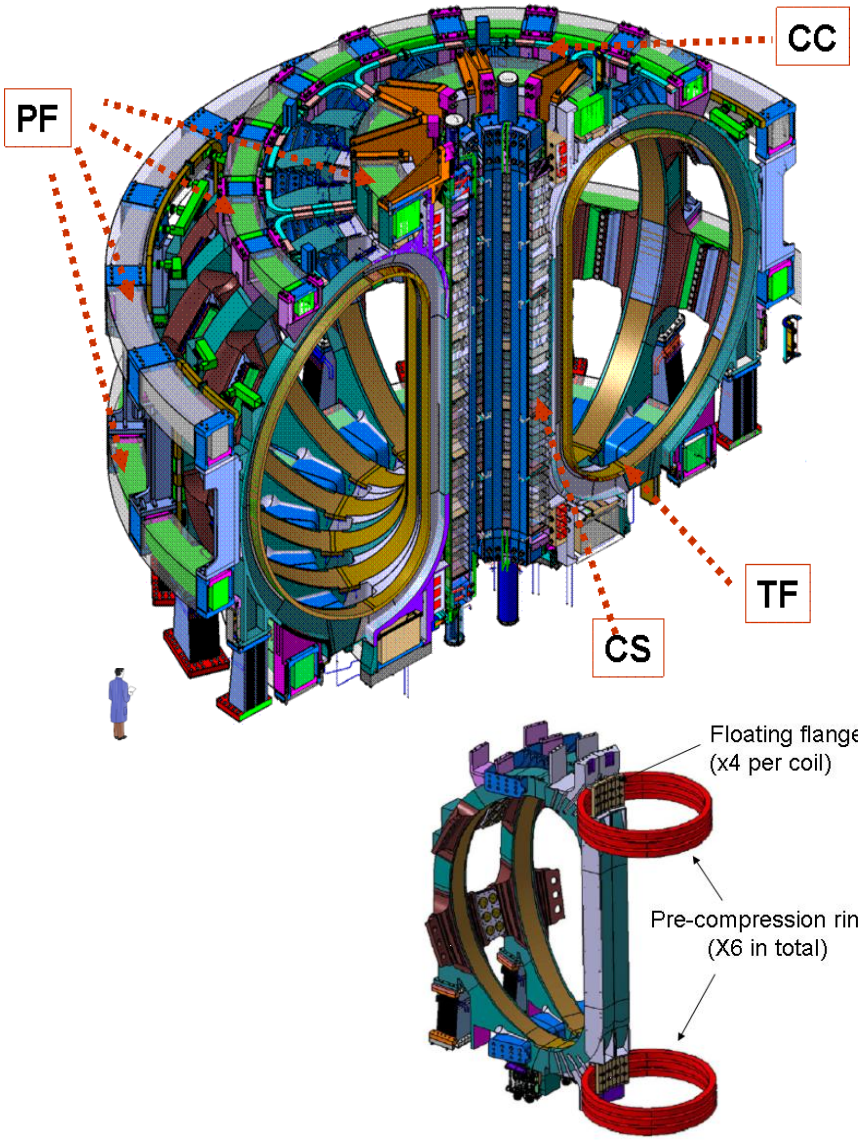
- F4E contribution to ITER magnets
- F4E strategy for TF coils
- F4E strategy for PF coils
- Technology development in F4E procurement
- Nurturing young engineers and experts: experience in F4E magnet team

F4E contribution to ITER Magnet System



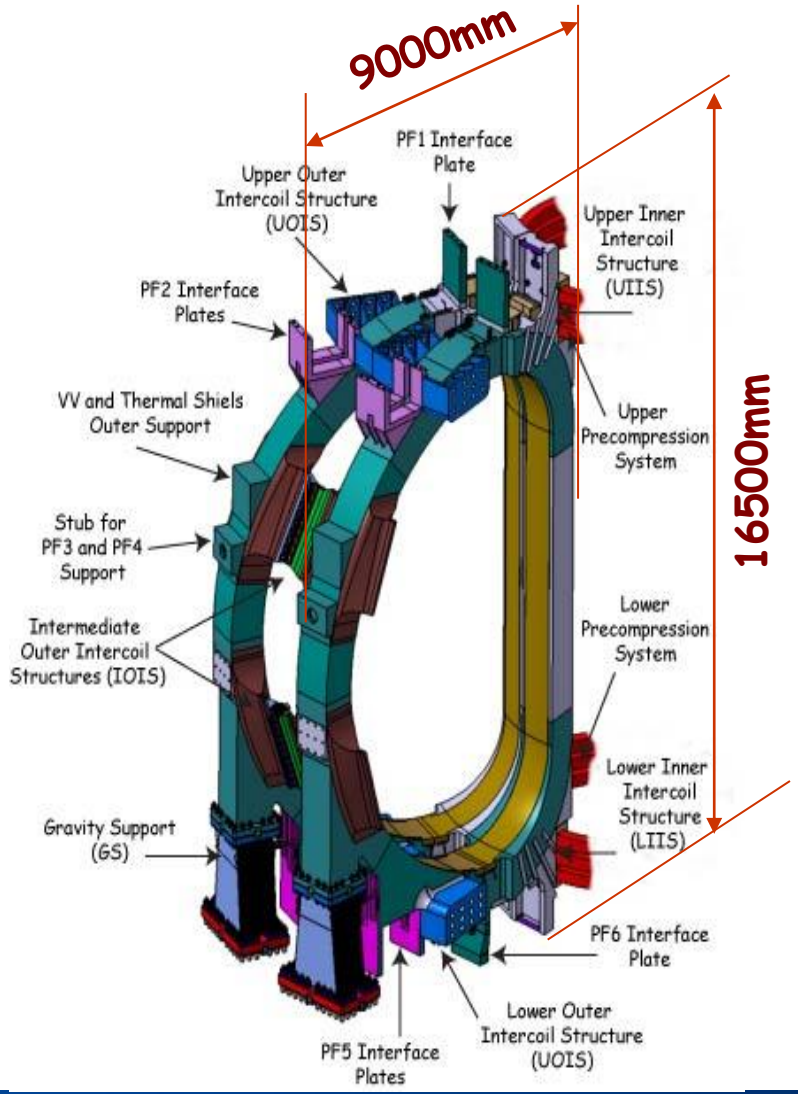
F4E contribution to ITER Magnets	
Component	N of units or % of total
TF Conductors	20% of total
TF Coils	10 coils
Pre-compression Rings	9 rings
PF Conductors	13% of total
PF Coils	5 coils

The ITER TF coils

Weight: 300tons/coil

Peak field 11.8T

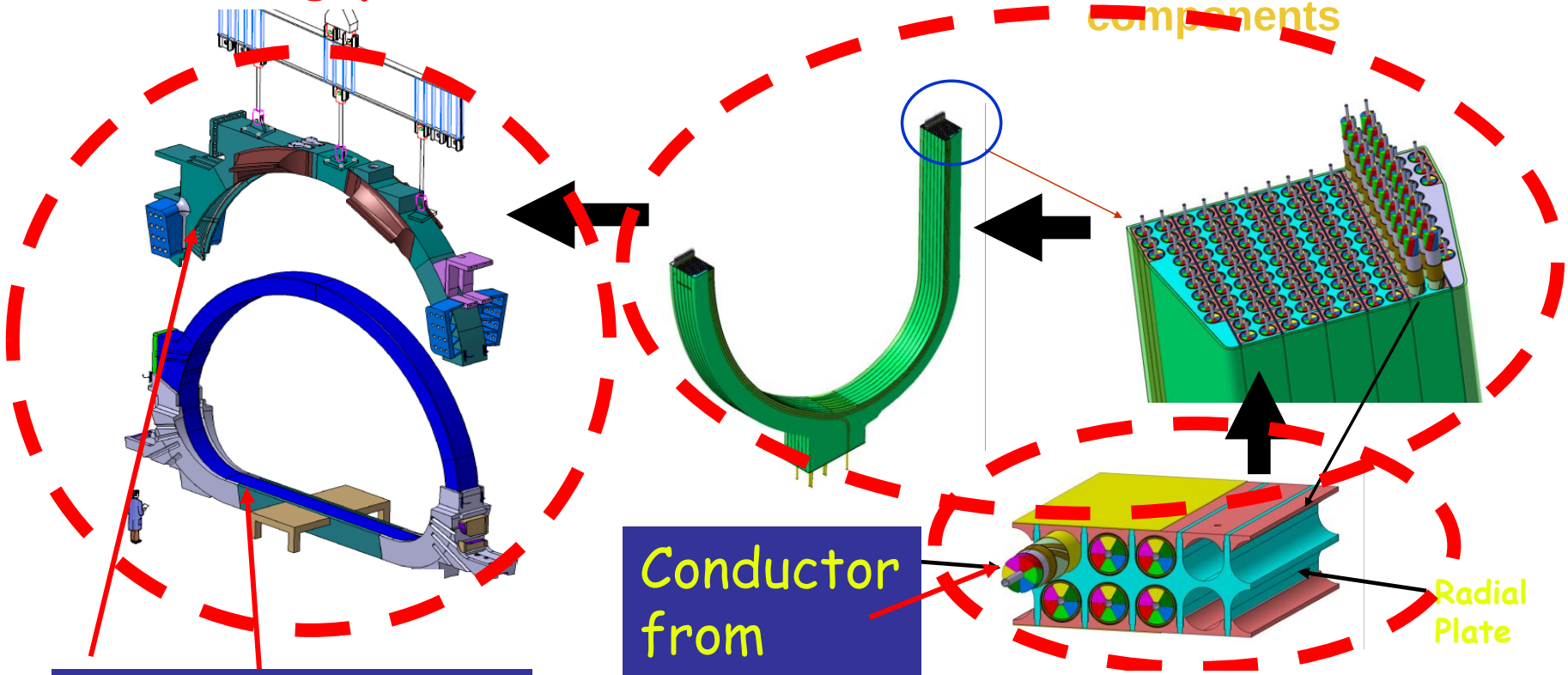
Constant Current 68KA



TF coils procurement split in 3 contracts

Completion of 10 TF coils (in tendering phase)

Manufacture of 10 Winding Packs (on-going)



Coil Case from JAEA

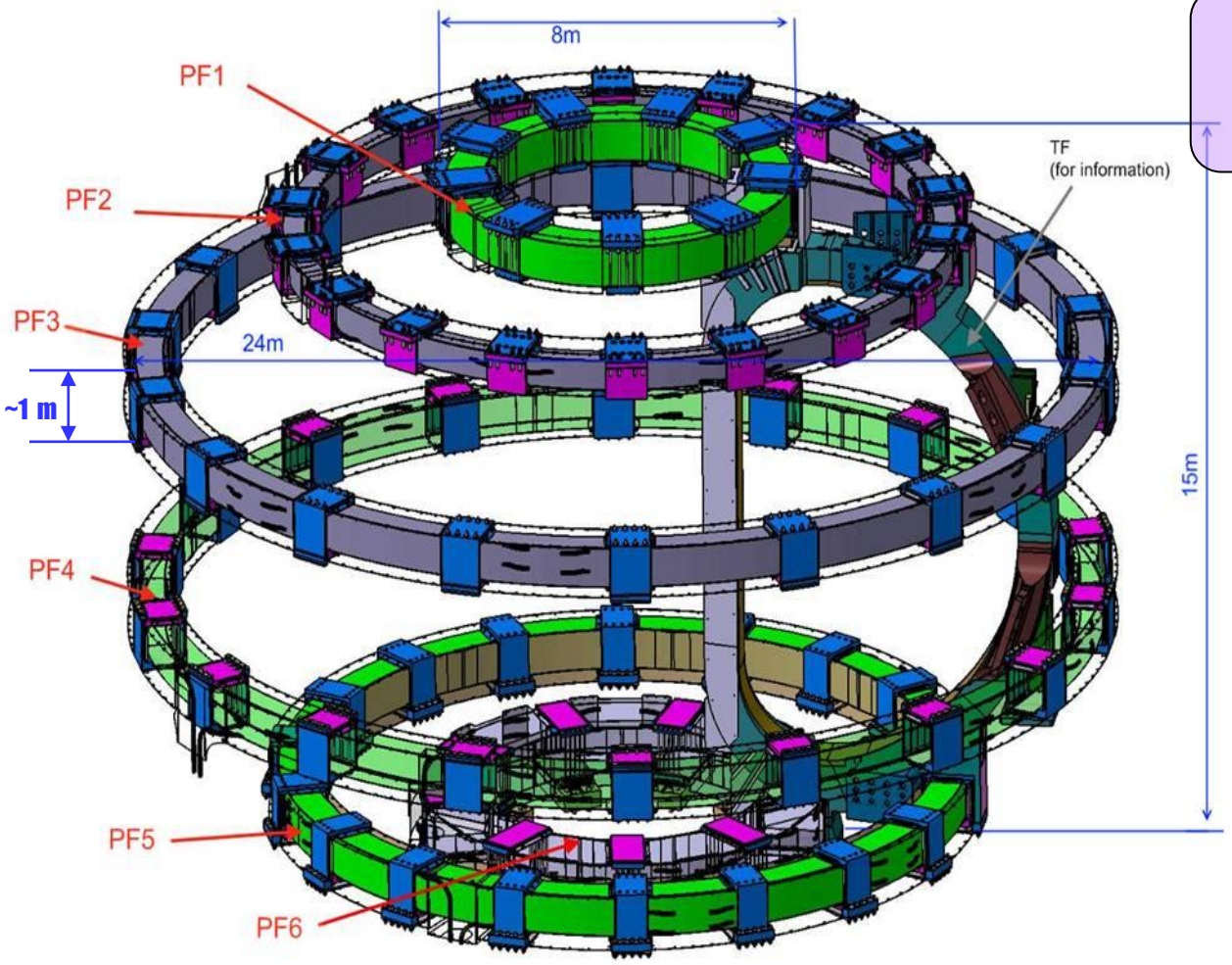
Conductor from EU,RF,CN & US

Manufacture of 70 Radial Plates (on-going)

Status of the T coils procurement

- Full Size Double Pancake Prototype wound and heat treated (by ASG / Iberdrola / Elytt)
- Series production started

Poloidal Field (PF) Coils



6 PF coils

RF: PF1
EU: PF2~PF6

Main Features:
- **Circular coils**
- **Supported on TF**
- **Made of DPs**

PF2-PF6 Manufacture configuration

Contracts	Main Scope	Call for tender	Expected Contract sign.
Engineering Integrator	Define manufacturing procedure and follow up construction	Over	Running
Winding Tools	Manufacture winding tool	Jul-2013	Mar-2014
Site & Infrastructure	Manage facilities	May-2014	Nov-2014
Impregnation and Additional Tools	Manufacture impregnation and mail lifting tools	May-2014	Nov-2014
Manufacturer	Manufacture PF2-PF5 in Cadarache	Jul-2014	Mar-2015
Cold Test facility	Design and manufacture cold test facility	Jul-2014	Mar-2015
PF6 – ASIPP	Manufacture PF6		Running

PF2-PF6 in CADARACHE

PF6 in China

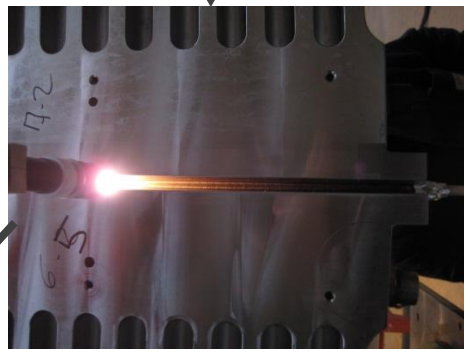
Technology development on F4E magnets

- Within the large cluster of F4E industrial contracts, many technologies are being utilized and pushed to their limit:
  - Material production
    - ITER Grade stainless steel Forging for TF radial plate sectors
    - Cold Drawing for TF cover plates with accuracy on shape of 0.1mm
  - Welding and bonding
    - Local Vacuum Electron Beam (to weld RP sectors)
    - Standard & Narrow gap GTAW (to weld RP sectors and piping)
    - Laser for welding of TF cover plates to radial plates
    - Explosion bonding (to bond copper to steel in electrical terminations)
  - Dimensional check
    - Laser tracker, Laser T-scan, to measure the TF conductor trajectory with tens of ppm accuracy
    - 0-1mm Gap measurement with camera
  - Machining
    - Machining with large Portal Machines (12x9m) with precisions of fractions of mm
  - Conductor bending
    - Bending of TF conductor on spiral D shaped trajectory with accuracy of tens of ppm
    - Bending of PF conductor over diameter of 24 m with accuracy of 1mm.

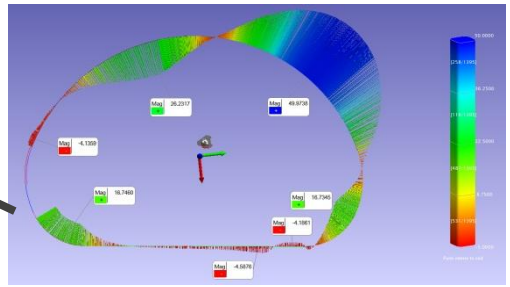
One example: The manufacture of the RPs

Forging of 6 sectors

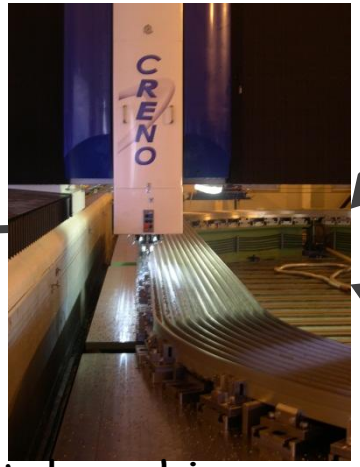
Machining leaving >5mm over-metal



Welding sectors by EB or GTAW



Measurement DP trajectory



Final machining with portal machine based on DP trajectory

REGULAR RADIAL PLATE PROTOTYPE FULLY MACHINED IN AUGUST 2011

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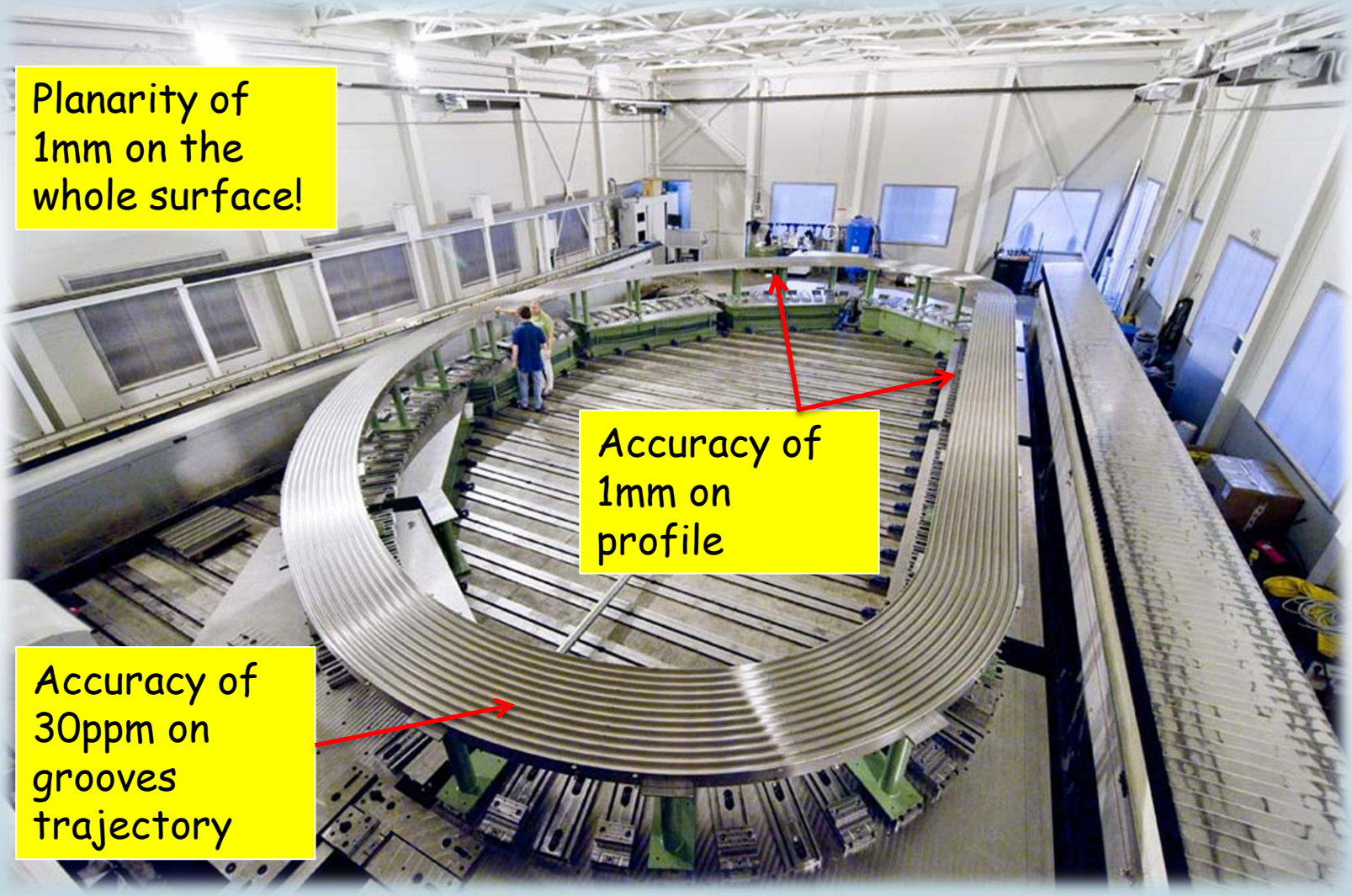
SIMIC S.p.A.



CNIM SIDE RADIAL PLATE PROTOTYPE
Machining completed in September 2011

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Nurturing expertise on FUSION long term project

- FUSION is a long term project, requiring a high level of expertise for many years. It requires a good balance between:
  - Very senior engineers (*present*)
  - Relatively senior engineers (*middle term*)
  - Young engineers (*long term*)

- Their main functions are:
  - Very senior engineers
    - To focus on the most strategic PRESENT issues
    - To coach rest of the team
    - To progressively give more responsibilities to "senior" engineers
  - Relatively senior engineers (future "very senior")
    - To manage the day-to-day activities, allowing the "very senior" to focus on most strategic issues
    - To develop expertise, taking over more and more responsibilities
    - To coach the young engineers,
    - progressively moving to the "very senior" roles
  - Young engineers (Future "relatively senior")
    - To progressively take over more and more tasks.

Nurturing expertise (II)

- In the long term, the balance between "very senior", "relatively senior" and young engineers is essential to:
  - Progressively nurture and bring young engineers to the right level of expertise in order to tackle effectively their tasks
  - Allow young team member to work on tasks adequate to own level of expertise, avoiding them to dealing with excessively difficult tasks that could bring to failure with consequent lack of self confidence.
  - Get each category to progressively move to the upper level of seniority.

- In F4E magnet team we have:

  - 7 over 45 years old engineers (very senior)
  - 8 between 35 and 45 years old engineers (senior)
  - 7 between 29 and 35 years old engineers (young)

- A good balance between the 3 categories, which should guarantee short and long term expertise, as long as steady flow of young engineers is assured to the team.

Thank you for your attention