# Plug-in Modules in 7-8 Status report

P. Strubin on behalf of AT-VAC

Extent of the problem in 7-8
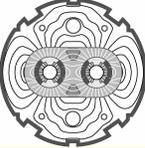
o **Quadrupole-Dipole interconnects in the DS**
  - o 15 PIMs were wrongly installed and cut out for replacement
  - o Of these, 7 PIMs had fingers buckled into the beam aperture
  - o These PIMs were all working outside their specified range

o **Q11-Connection cryostat in 8L (QQEI.11L8)**
  - o 2 fingers in the V2 line buckled into the beam aperture
  - o 8L was equipped with a standard SSS-MB PIM
  - o However, Q11 is 20% longer than a standard SSS, so the PIM was operating under different conditions to the arc

o **Quadrupole-Dipole in 26R7 (QQBI.26R7)**
  - o 1 finger in V1 line and 8 fingers in V2 buckled into the aperture
  - o This is a standard arc interconnect by design
  - o There were at least 2 particularities noted
    - o The installed length of the PIM was ~4 mm longer than nominal (magnet NC)
    - o The contact finger bending angles were out of tolerance

Courtesy D. Duarte & R. Veness

Failure example

QQBI.26R7 line V2
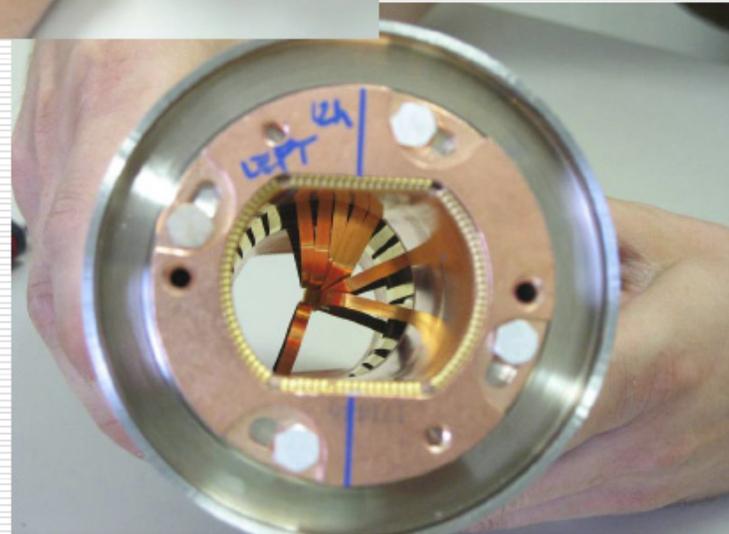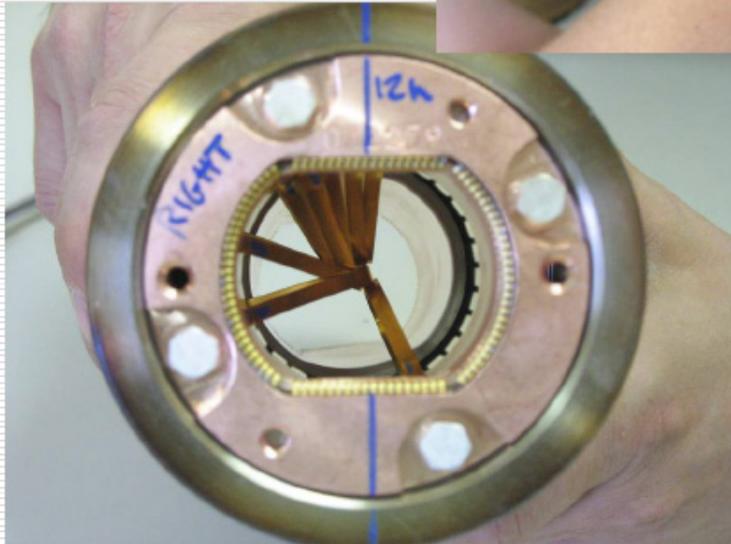
# QQBI.26R7 V2 Bends done by the copper tube

- ☐ Fingers have not come out of guiding tubes
- ☐ This implies that damage was done during warm-up

Courtesy D. Duarte
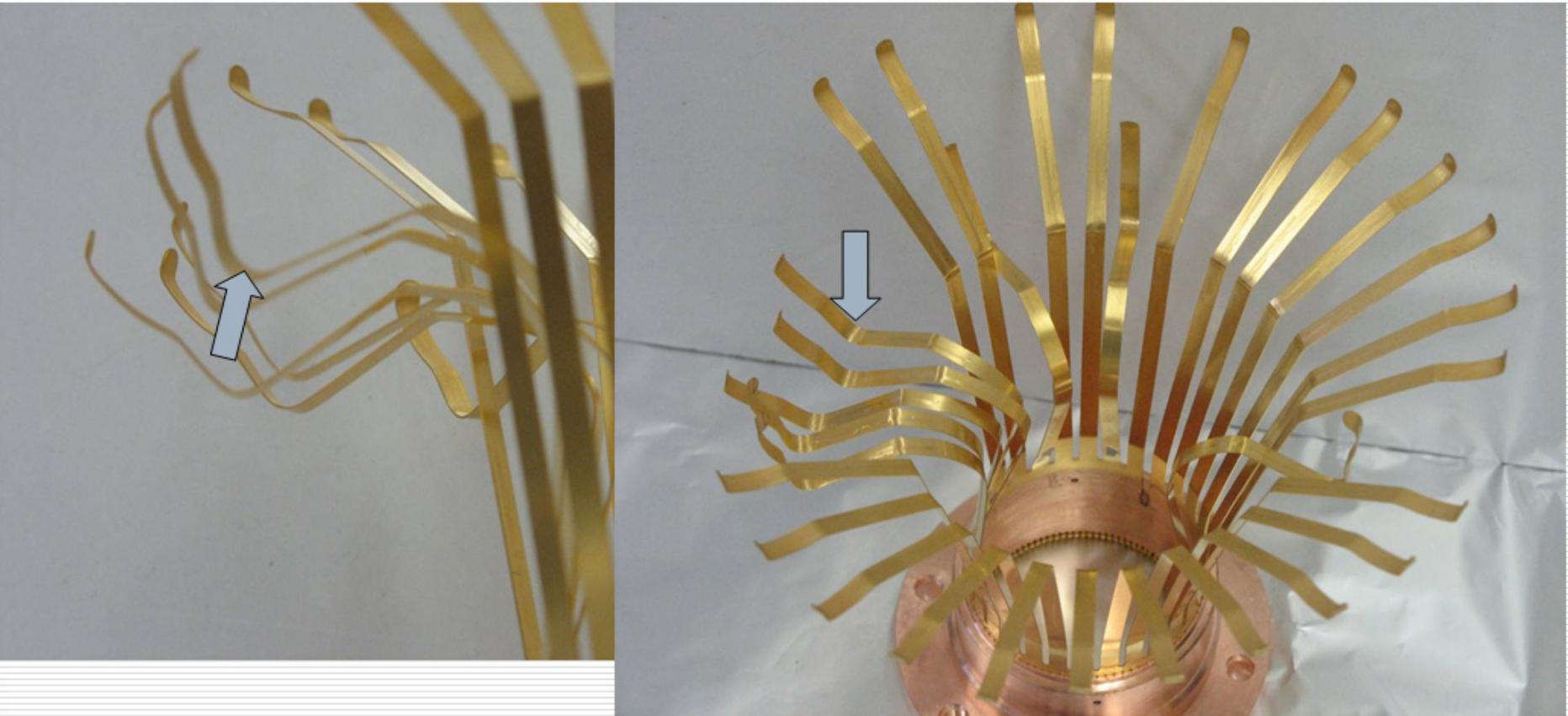
Failure reproduced in lab
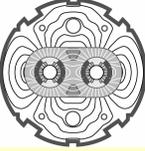
Same deformations as in sector 7-8
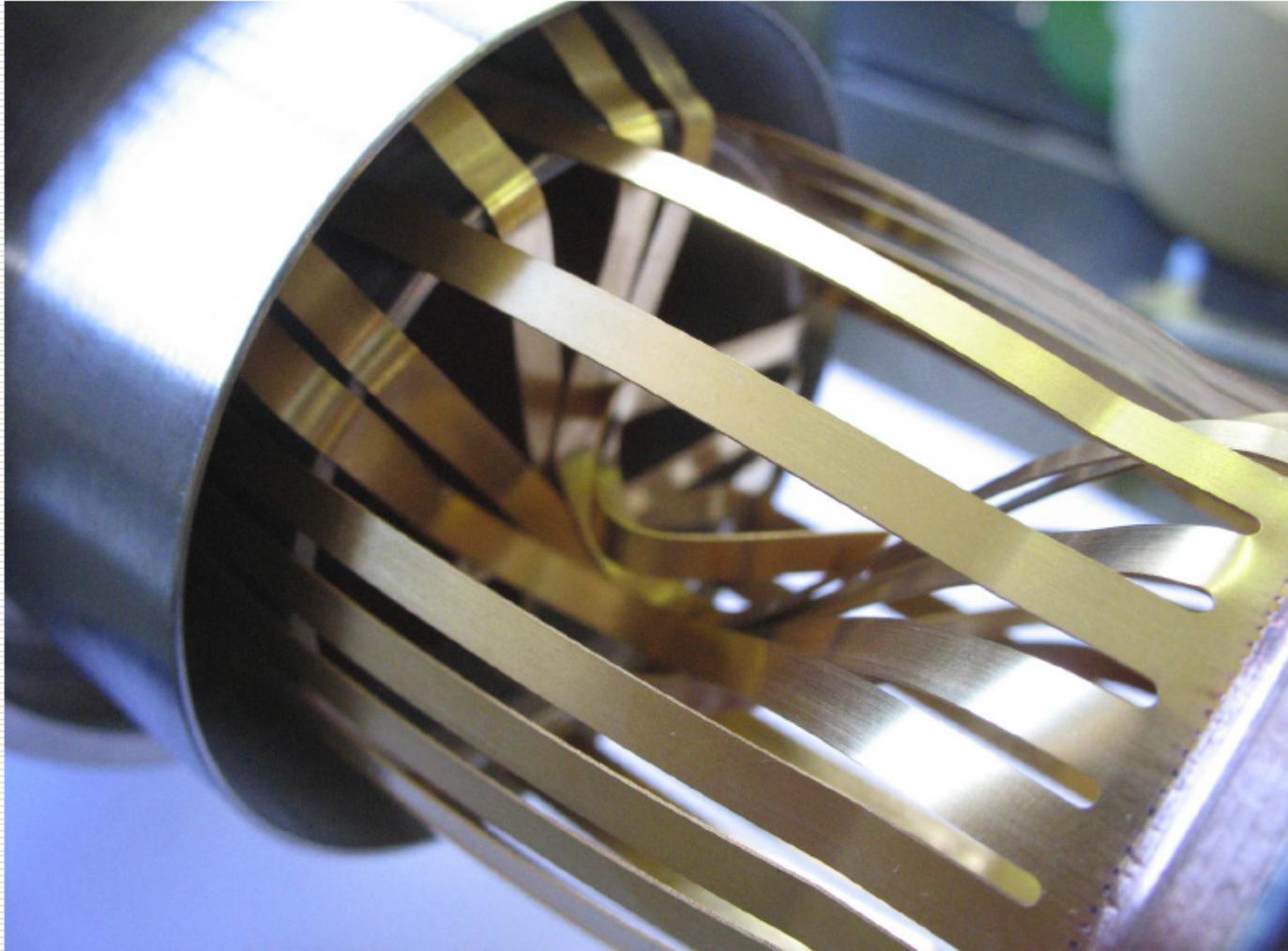
Statistics 30 August 2007
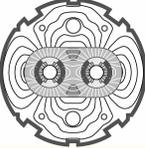
	PIM V1				PIM V2			
	Qty	Inspected	Not Ok	% Not Ok	Qty	Inspected	Not Ok	% Not Ok
IC type QQBI	45	24	1	4%	45	24	1	4%
IC type QBQI	46	22	0	0%	46	22	0	0%
IC type QBBI	92	44	0	0%	92	44	0	0%
	183	**90**	**1**	**1%**	**183**	**90**	**1**	**1%**

100 + 100 by 31 August 2007

	PIM V1				PIM V2			
	Qty	Inspected	Not Ok	% Not Ok	Qty	Inspected	Not Ok	% Not Ok
IC type QQBI	8	8	4	50%	8	8	3	38%
IC type QQDI	1	1	0	0%	1	1	0	0%
IC type QQEI	1	1	1	100%	1	1	0	0%
IC type QBQI	7	7	0	0%	7	7	0	0%
IC type QEBI	1	1	0	0%	1	1	0	0%
IC type QBEI	1	1	0	0%	1	1	0	0%
IC type QDQI	1	1	0	0%	1	1	0	0%
IC type QEQI	1	1	0	0%	1	1	0	0%
IC type QBBI	8	8	0	0%	8	8	0	0%
	29	**29**	**5**	**17%**	**29**	**29**	**3**	**10%**

Courtesy P. Fessia

Situation in DS

ZONE DS R7

QQDI.7R7		QQBI.7R7		QBBI.8R7		QBQI.8R7		QQBI.8R7		QBBI.9R7		QBQI.9R7		QQBI.9R7		QBBI.10R7

| DFBA | OK / OK | Q7 7.75 m | OK / OK | DIP 15.66 m | OK / OK | DIP 15.66m | OK / OK | Q8 7.75m | NOT OK / NOT OK | DIP 15.66 m | OK / OK | DIP 15.66 m | OK / OK | Q9 9.15 m | NOT OK / NOT OK | DIP 15.66 m | OK / OK |

QBQI.10R7		QQBI.10R7		QBBI.11R7		QBEI.11R7		QEQI.11R7		QQBI.11R7						

| DIP 15.66 m | OK / OK | Q10 7.75m | NOT OK / OK | DIP 15.66 m | OK / OK | DIP 15.66m | OK / OK | IC CR 13.7 m | OK / OK | Q11 7.75 m | NOT OK / OK | DIP 15.66m | | | |
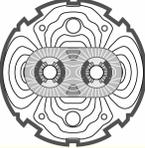
Only unexpected failure in DS

ZONE DS L8

				QBQI.12L8		QQEI.11L8				QEBI.11L8		QBBI.11L8		QBQI.11L8		QQBI.10L8		QBBI.10L8

| | | | | DIP 15.66m | OK / OK | Q11 7.75m | NOT OK / OK | IC CR 12.7m | OK / OK | DIP 15.66m | OK / OK | DIP 15.66m | OK / OK | Q10 7.75m | OK / OK | DIP 15.66m | OK |

QBQI.10L8		QQBI.9L8		QBBI.9L8		QBQI.9L8		QQBI.8L8		QBBI.8L8		QBQI.8L8		QQDI.7L8

| DIP 15.66m | OK / OK | Q9 9.15m | OK / NOT OK | DIP 15.66m | OK / OK | DIP 15.66m | OK / OK | Q8 7.75m | OK / OK | DIP 15.66m | OK / OK | DIP 15.66m | OK / OK | Q7 10.12M | OK / OK | DFBA |

Courtesy P. Fessia

One of the possible causes

QQBI.26R7 V1 bending angles out of tolerance

Approved manufacturing drawing
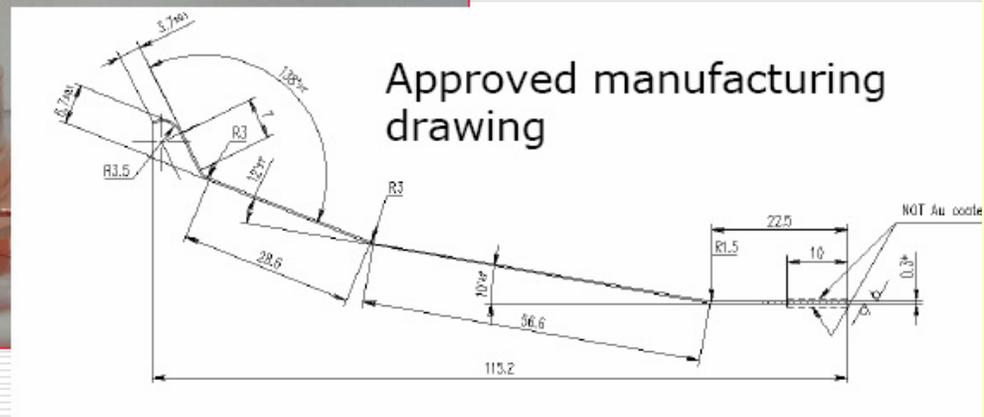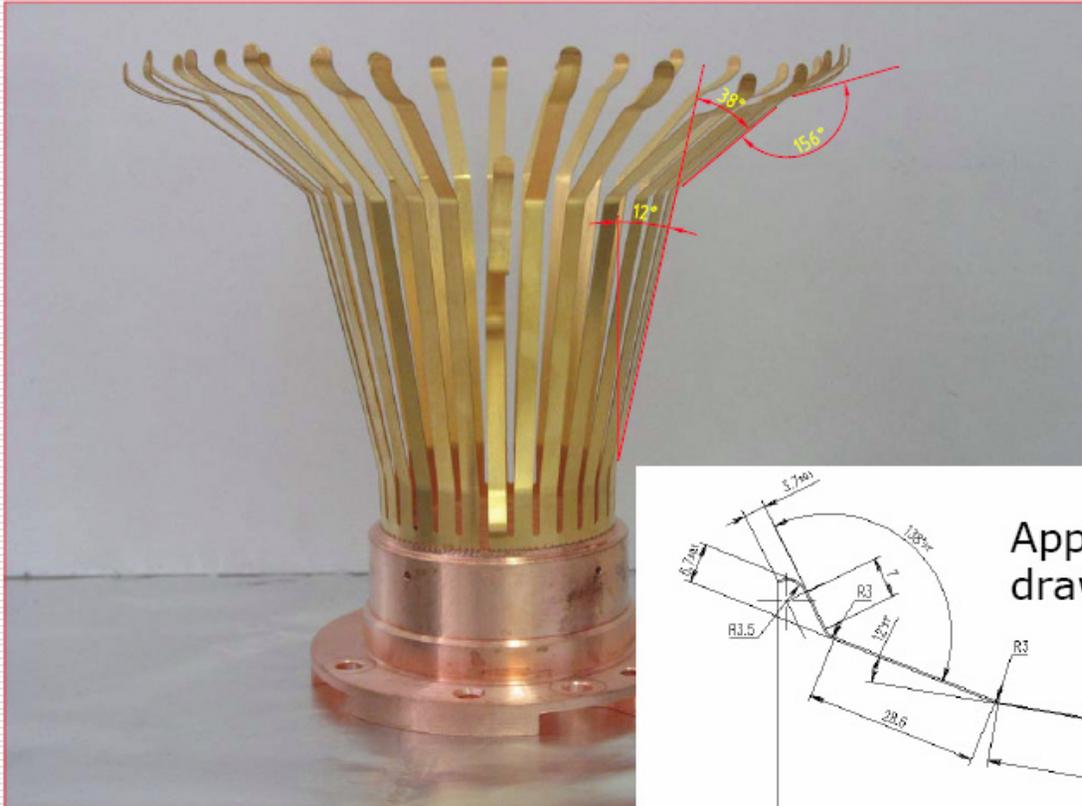
Actions underway
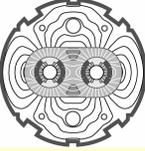
○ **Damaged PIMs**
  ○ Inspect and measure all mechanical aspects
    ○ Geometry of finger, surface and coating quality, etc.
  ○ Study solutions for repairs of non conform PIMs

○ **External effects**
 ○ In situ-measurement of real installation length
  ○ Correlation with calculated length
  ○ Cool-down and warm-up scenario

○ **Validation of design**
 ○ Agree on a model for FEM analysis
  ○ Compute safety margin against buckling for several configurations

○ **Explore means of detection**

Tool for Re-dressing contact fingers (in progress)

Thanks to D.Chauville

# FE Analysis Status
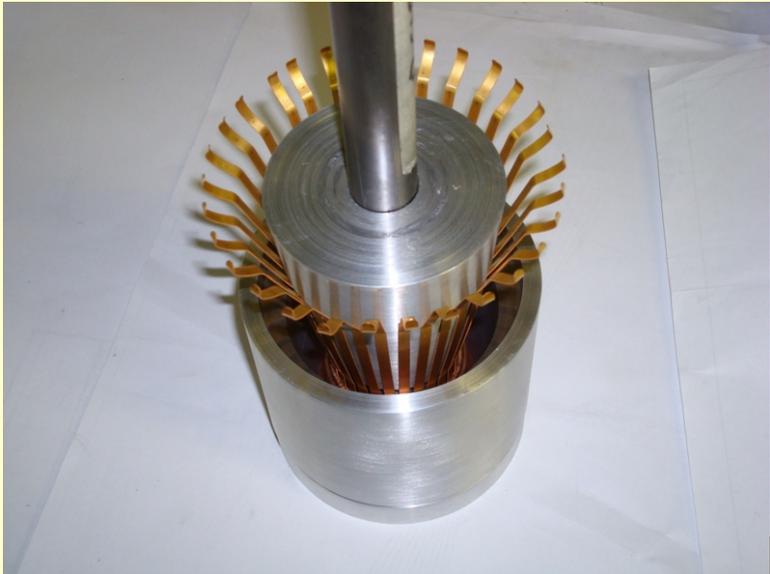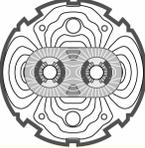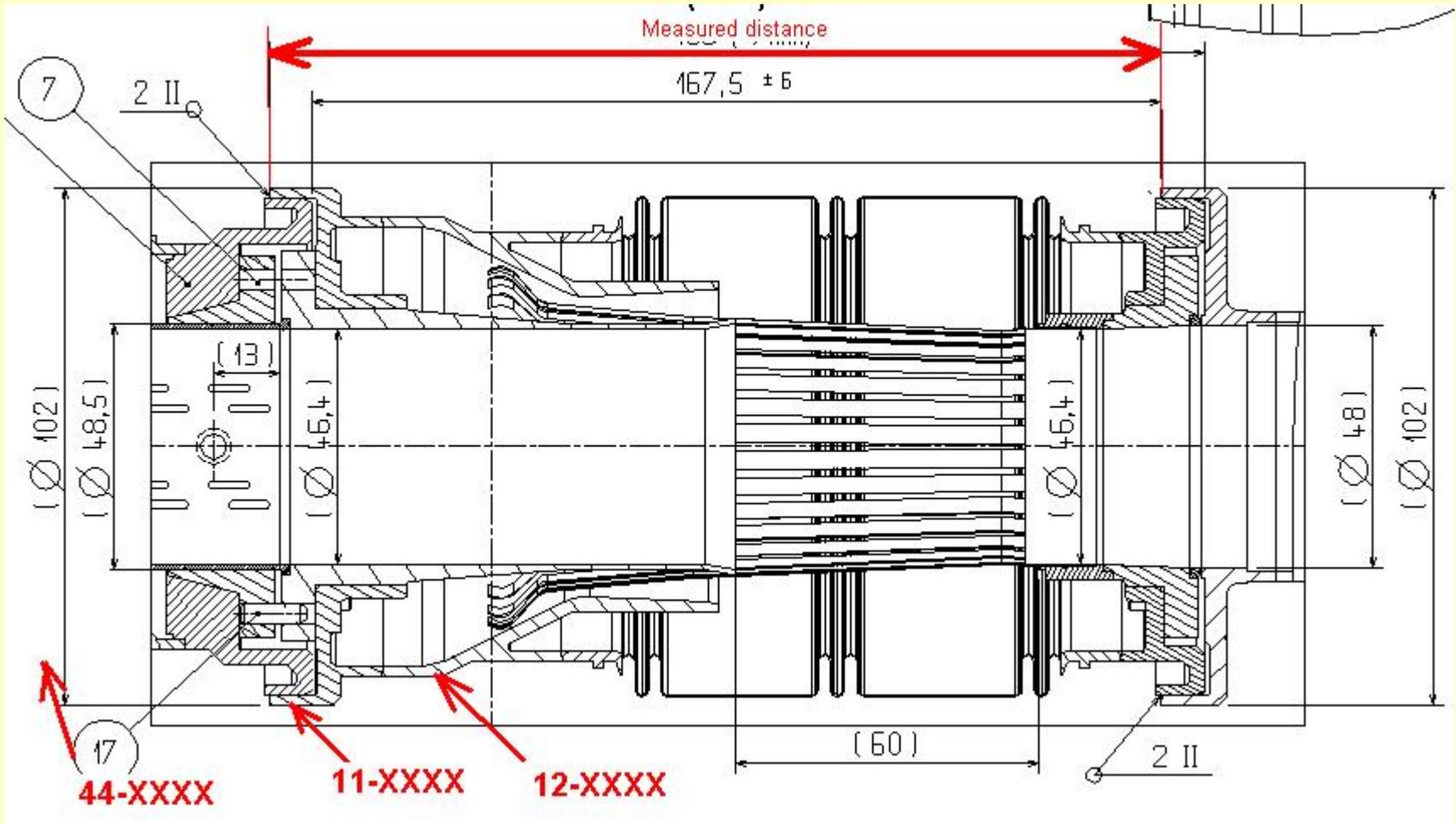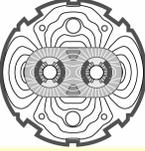
o **'Simple' model**
  - o **PLANE82 elements, (quadratic, 2-D with thickness, large deformation, linear-elastic material properties)**
  - o **8 elements through-thickness, 3200 along length (26912 total)**
  - o **Steps:**
    - o Model the 'free' shape of one contact finger
    - o Apply a deformation at contact points to produce cold-deformed shape
    - o Read the resultant normal force at contact points
    - o Apply friction coefficient to give lateral friction force
    - o Use this force as input for Eigen value buckling routine on deformed geometry
  - o **Can vary finger geometry and friction factor to give indications of sensitivity to various factors**

o **Next steps**
  - o **Elasto-plastic material properties**
  - o **Compare different element types (shell-type) and numbers**
  - o **Full model with contact elements and more complete PIM geometry**
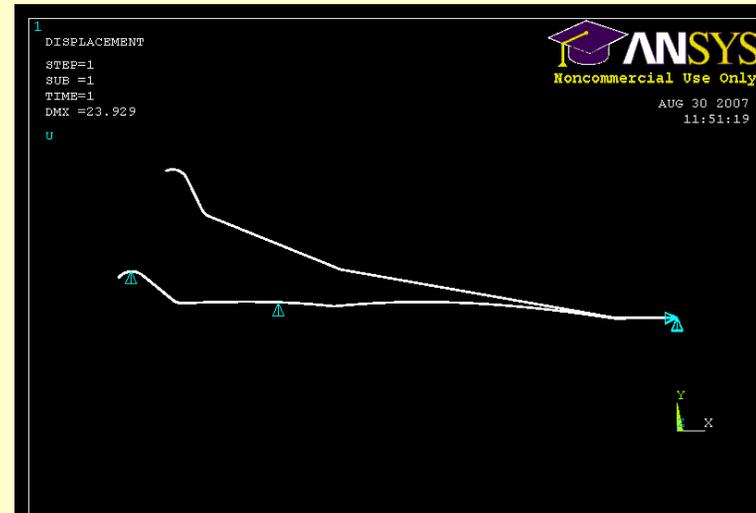
Nominal Design, Nominal cold position

Geometry from QQBI.26R7.V2, Nominal cold position

ICC 31 August 2007

Thanks to P.Lutkiewitz and C.Rathjen

Diagnostics
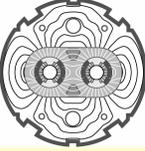
o **Methods looked into**

    o **Mole**

        o **A directly useable model has not yet been found**

    o **Reflectometry (validated)**

        o **Requires opening cryostat and beam vacuum every 200~300 m (min 5 weeks per sector)**

    o **X-ray (validated)**

        o **Requires opening of all ICs, (min 7~8 weeks per sector with existing trained teams)**

    o **RF probing via the BPMs ("BPM radar", under investigation)**

        o **The only proposed method that would work at cold**

   o **Interpretation of results not easy**

    o **Go-no-go gauge (under investigation)**

What to do in 7-8?
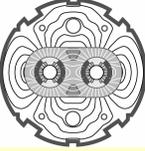
o **Considering that:**

- o It seems possible to identify the worse PIMs with the on-going X-ray campaign
- o The design is probably OK, even if improvements can be done
- o The tools to bring the fingers in conformity are being manufactured
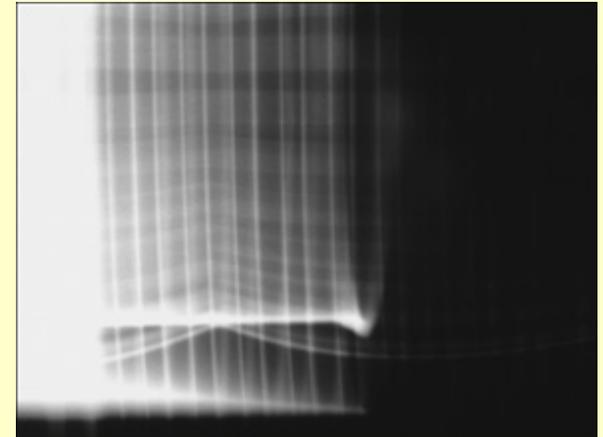
Do we replaced these PIMs?