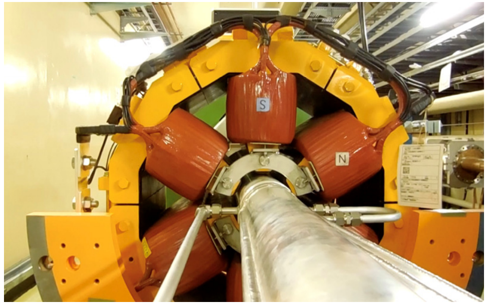
Chromatic x-y Coupling Correction by Tilting Sextupole Magnets in the SuperKEKB Positron Ring

Mika Masuzawa (KEK)



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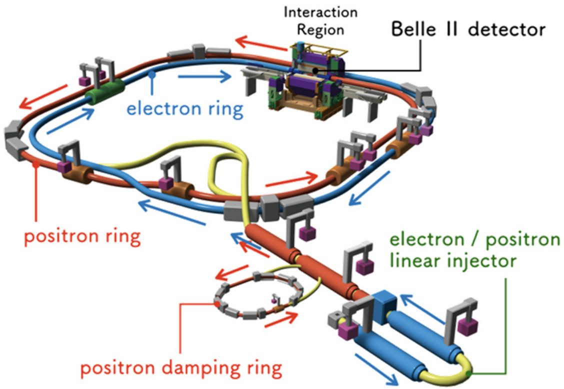
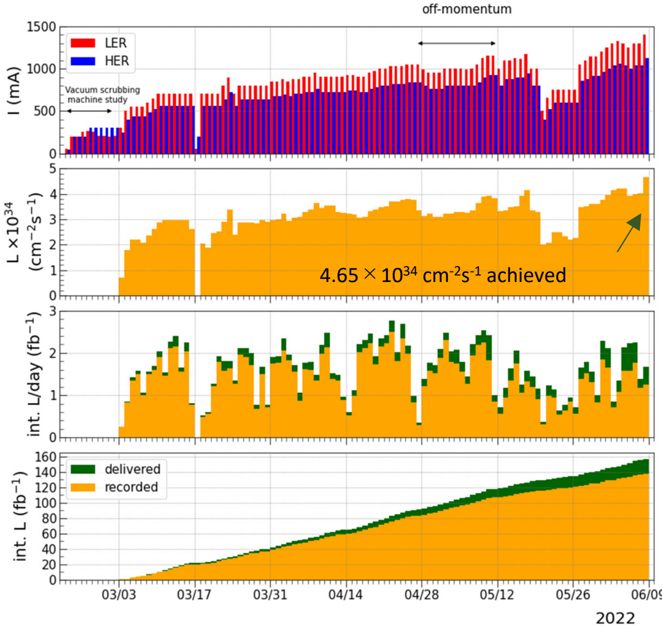
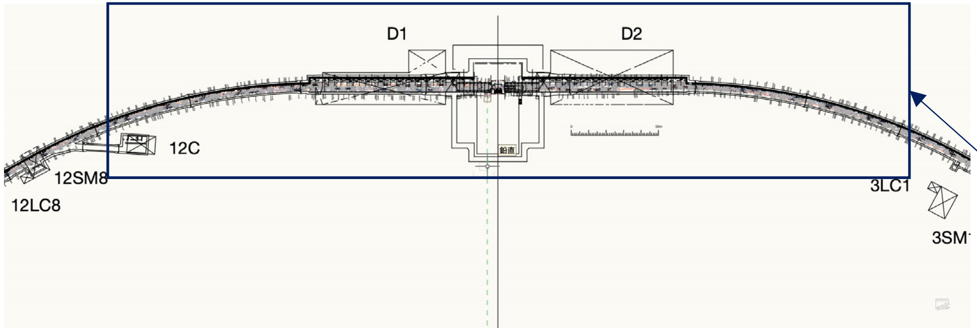
1. Introduction



SuperKEKB is an asymmetric-energy e+e- collider based on the "nanobeam scheme, where two low emittance beams collide with a large crossing angle at the IP.

Chromatic x-y coupling at the IP needs to be corrected in order to realize such low emittance beams.





Chromatic x-y coupling correction by rolling sextuple magnets in the LER located in this area are presented today.

2. Chromatic x-y coupling correction strategy: KEKB (predecessor accelerator)

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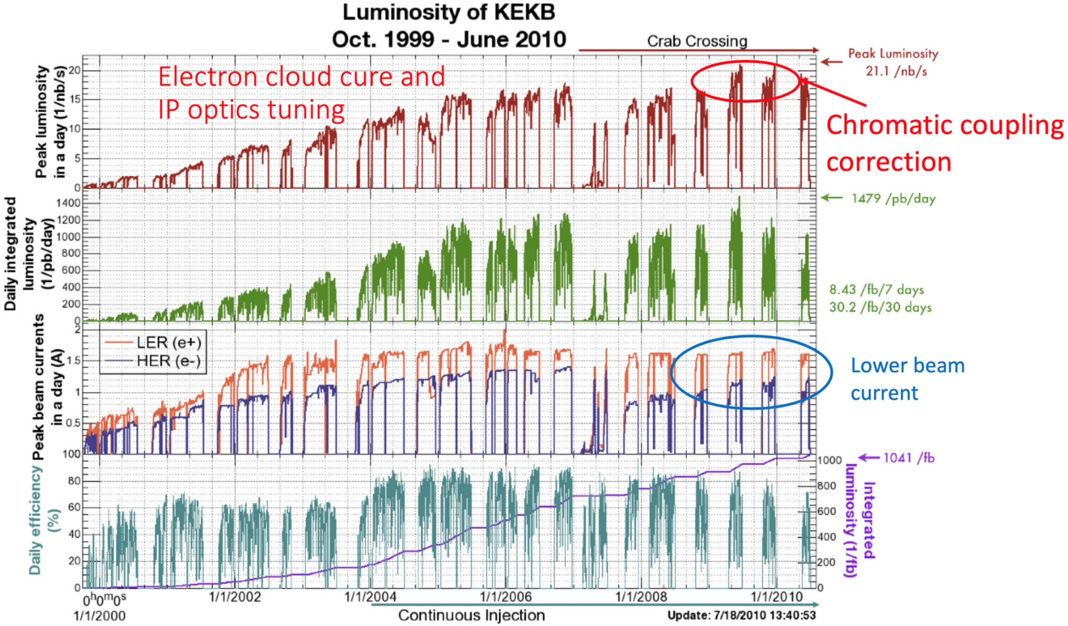
Chromatic coupling effect on luminosity : recognized @KEKB



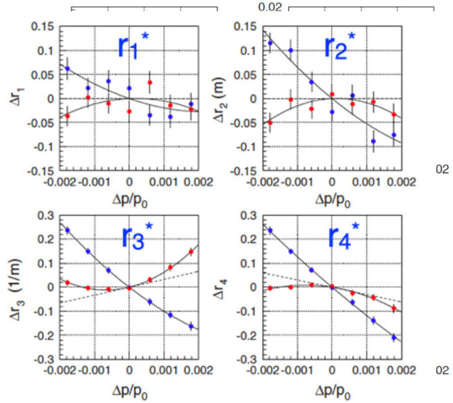
8 skew sextupole magnets

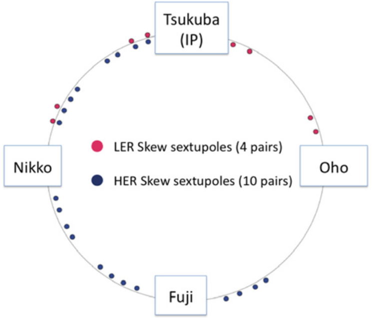
20 skew sextupole magnets were installed in 2009.

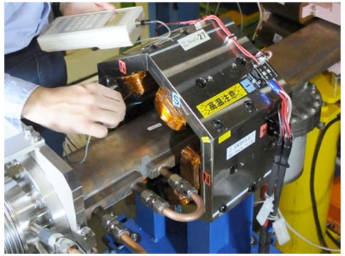
Measurement of chromatic coupling

- x-y coupling parameters are measured for RF freq shift.
- Blue and red is before and after correction.
- Luminosity increases 20% after the correction.

Y. Ohnishi et al., PRSTAB 12, 091002 (2009)

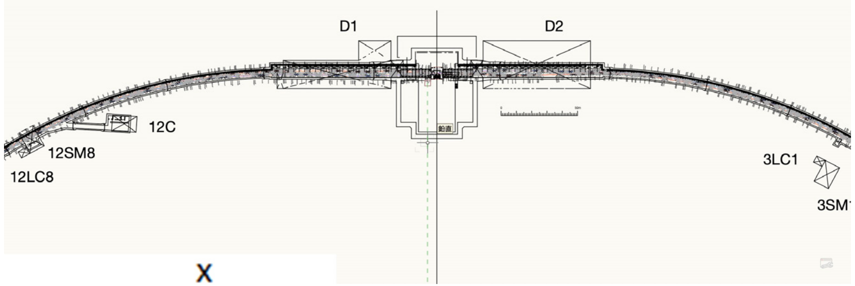


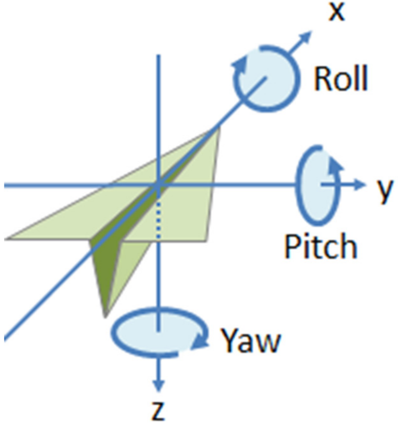




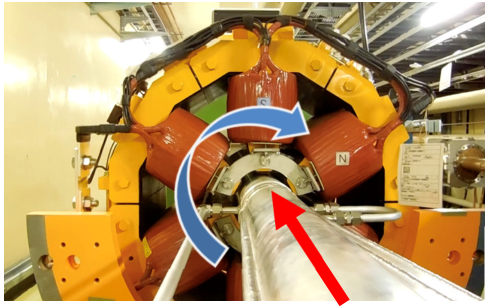
2. Chromatic x-y coupling correction strategy: SuperKEKB

We modified 24 sextupole magnet supporting tables in LER and make them “roll”.





Magnet “rolls”



e^+

Or support table “tilts”

2. Chromatic x-y coupling correction strategy: SuperKEKB

- Why LER ?
  - The final focus superconducting quadrupole magnet QC1(LER) is located closer to the IP than QC1(HER). The detector solenoid field is not cancelled at QC1(LER), while cancelled mostly at QC1(HER). This creates larger chromatic x-y coupling @IP and stronger (than KEKB) skew fields are needed.
  - Skew sextupole fields are needed for correcting this chromatic x-y coupling effects.
  - Dynamic aperture is more serious issue with LER. A pair of skew sextupole magnets with "–I" (non-interleaved) configuration is desirable.

- Why tilting magnets?
  - The best way to generate normal and skew fields at the same location would be to use superconducting sextupole magnets, but they are very costly.

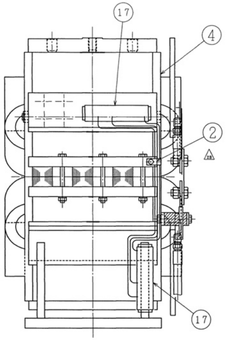
→So a set of sextupole magnets that roll was our choice.

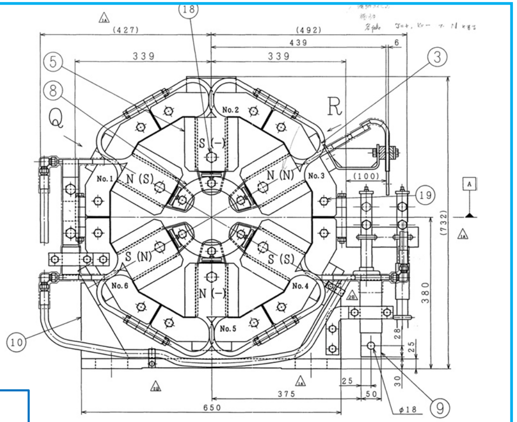
  - Change the roll angle to control the mixture of the skew to normal sextupole magnetic field components.
  - No need for installing an additional skew sextupole magnet and a power supply to generate skew magnetic field. "Two birds in one stone" scheme.

3. Tilting Mechanism

Magnet parameters

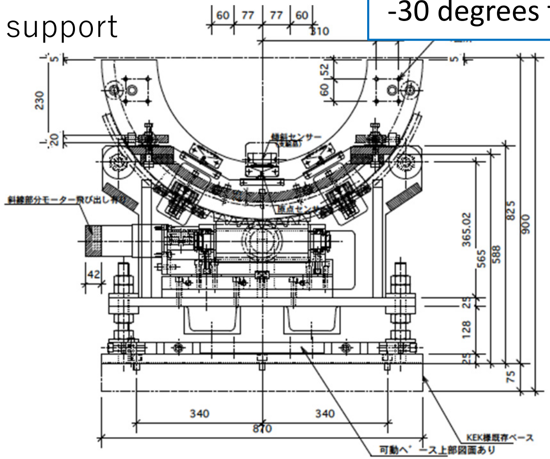
Parameter	Value
Bore radius	56 (mm)
Lamination length	300 (mm)
Magnet weight	~700 (kg)
Strength	340 (T/m^2)
Max. Current	425 (A)

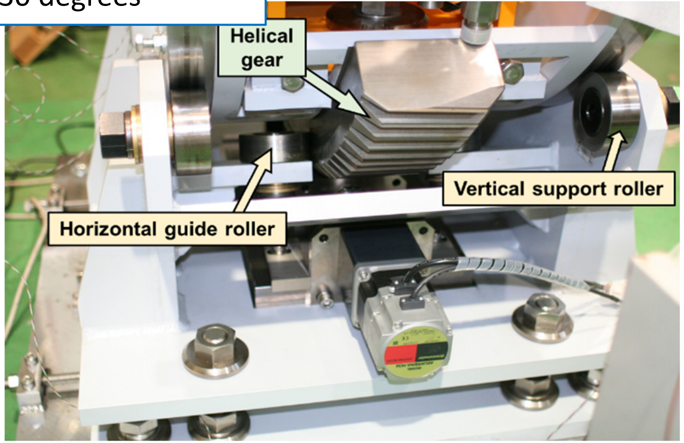




The roll angles can be varied from -30 degrees to + 30 degrees

New support

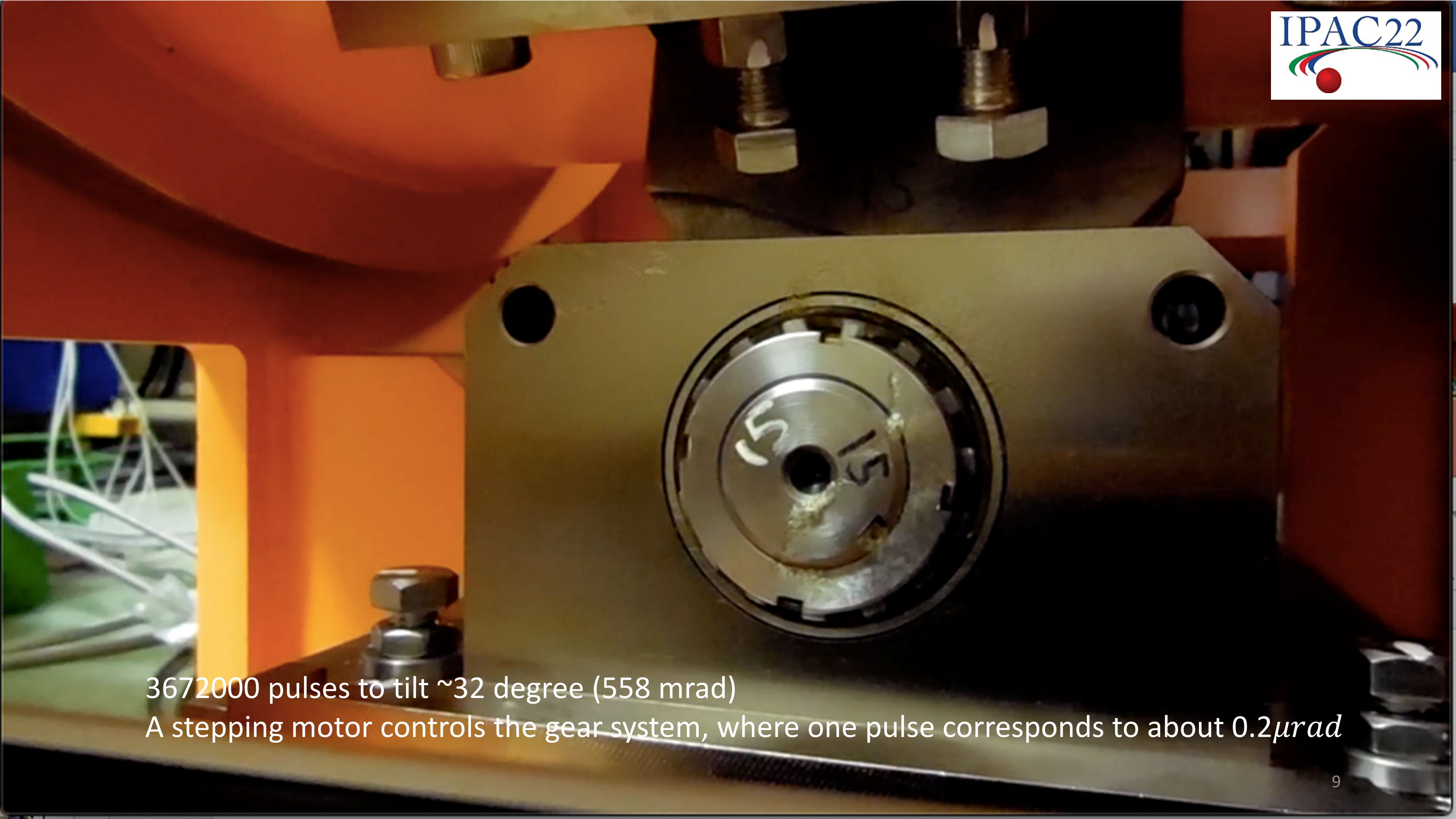




3. Tilting Mechanism

3672000 pulses to tilt ~32 degree (558 mrad)

A stepping motor controls the gear system, where one pulse corresponds to about $0.2\mu rad$



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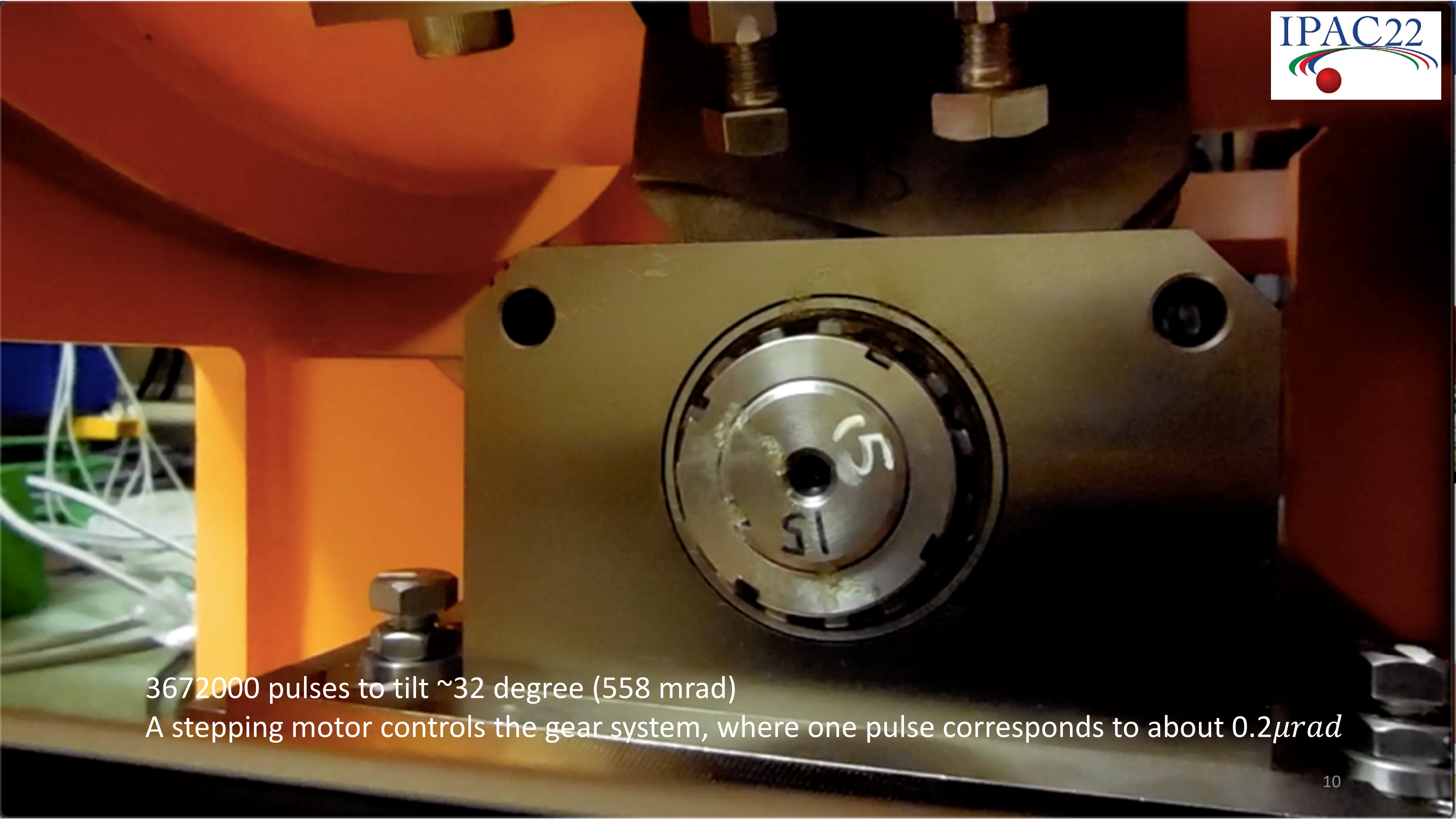

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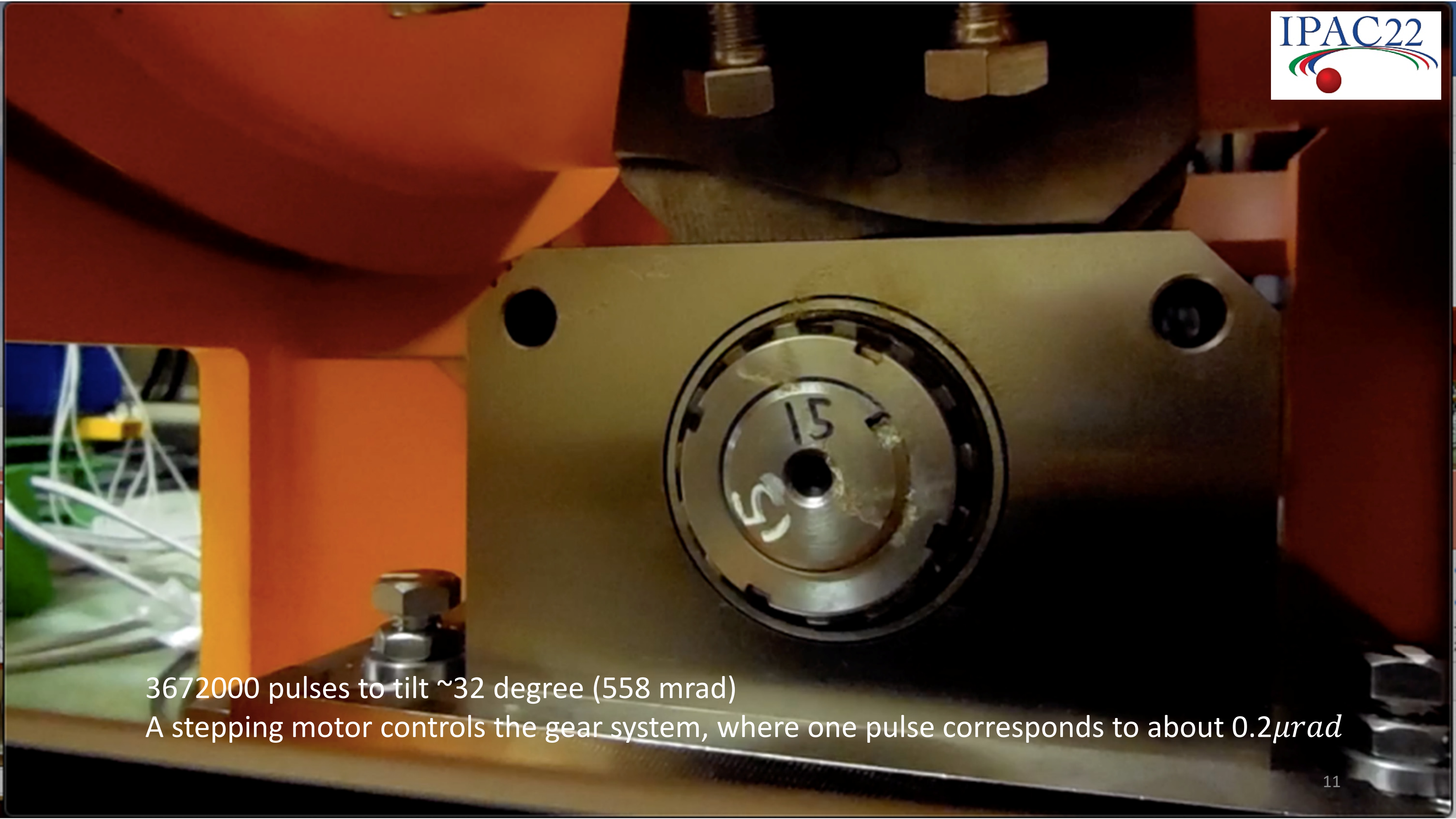

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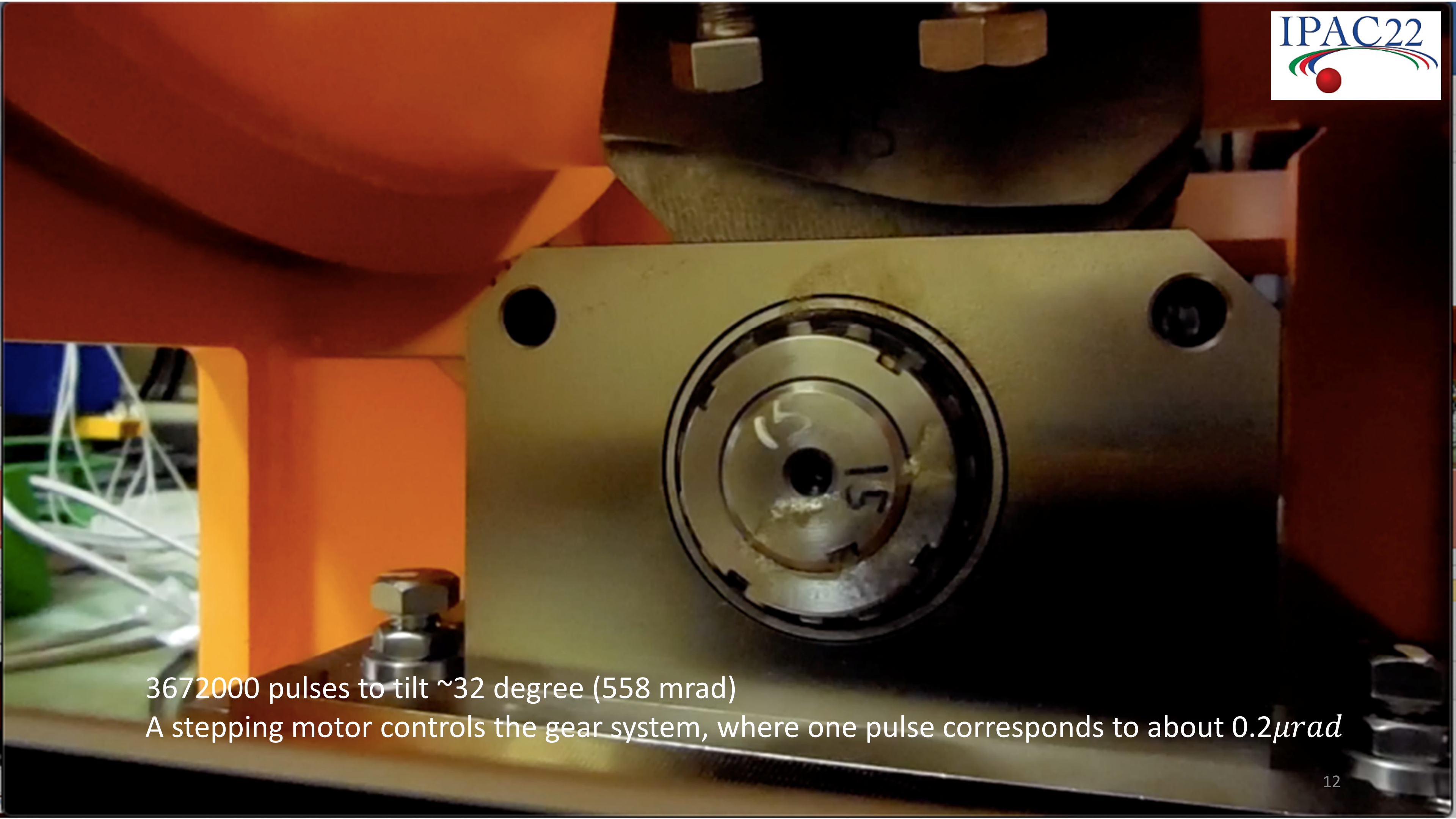

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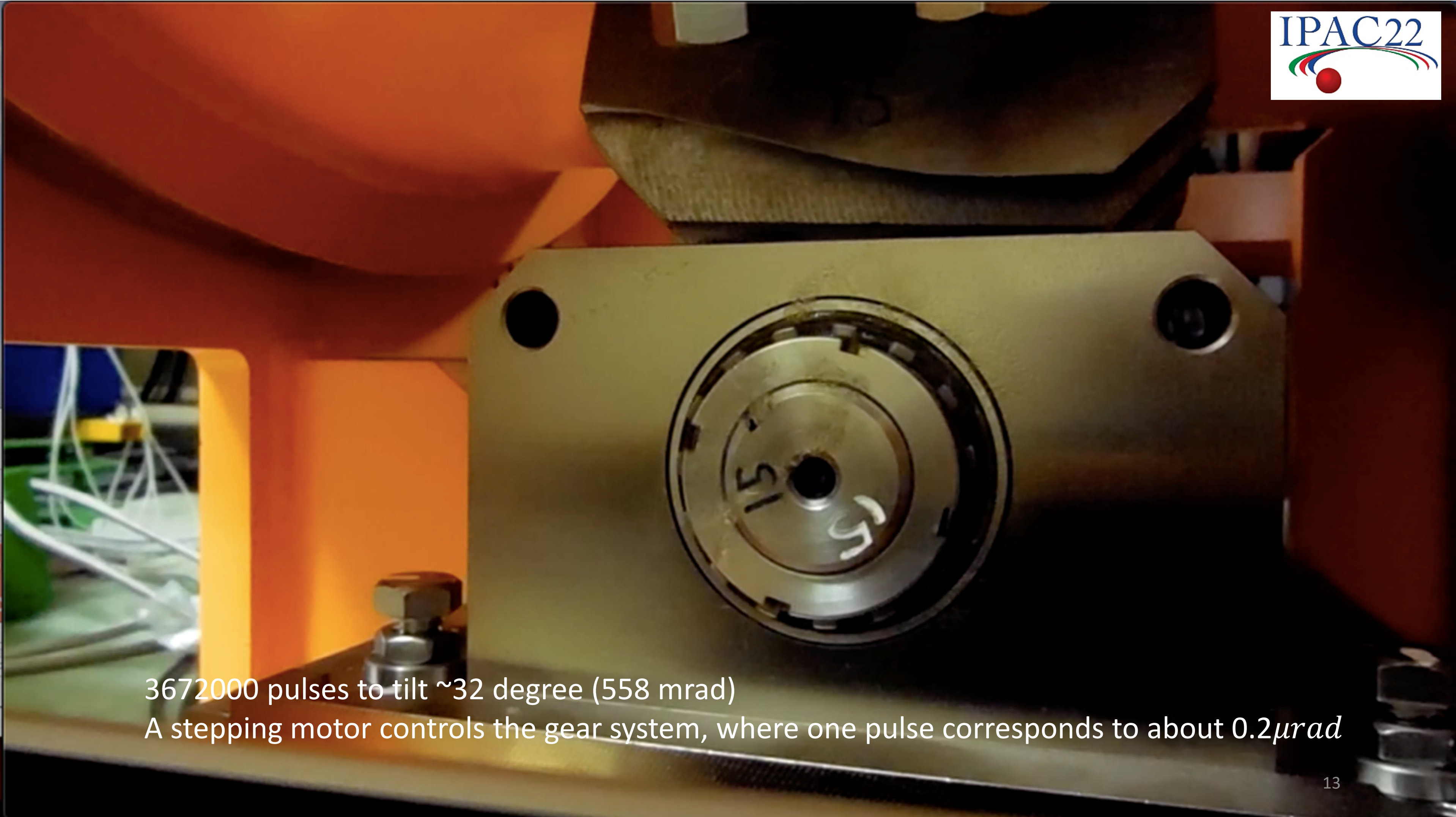

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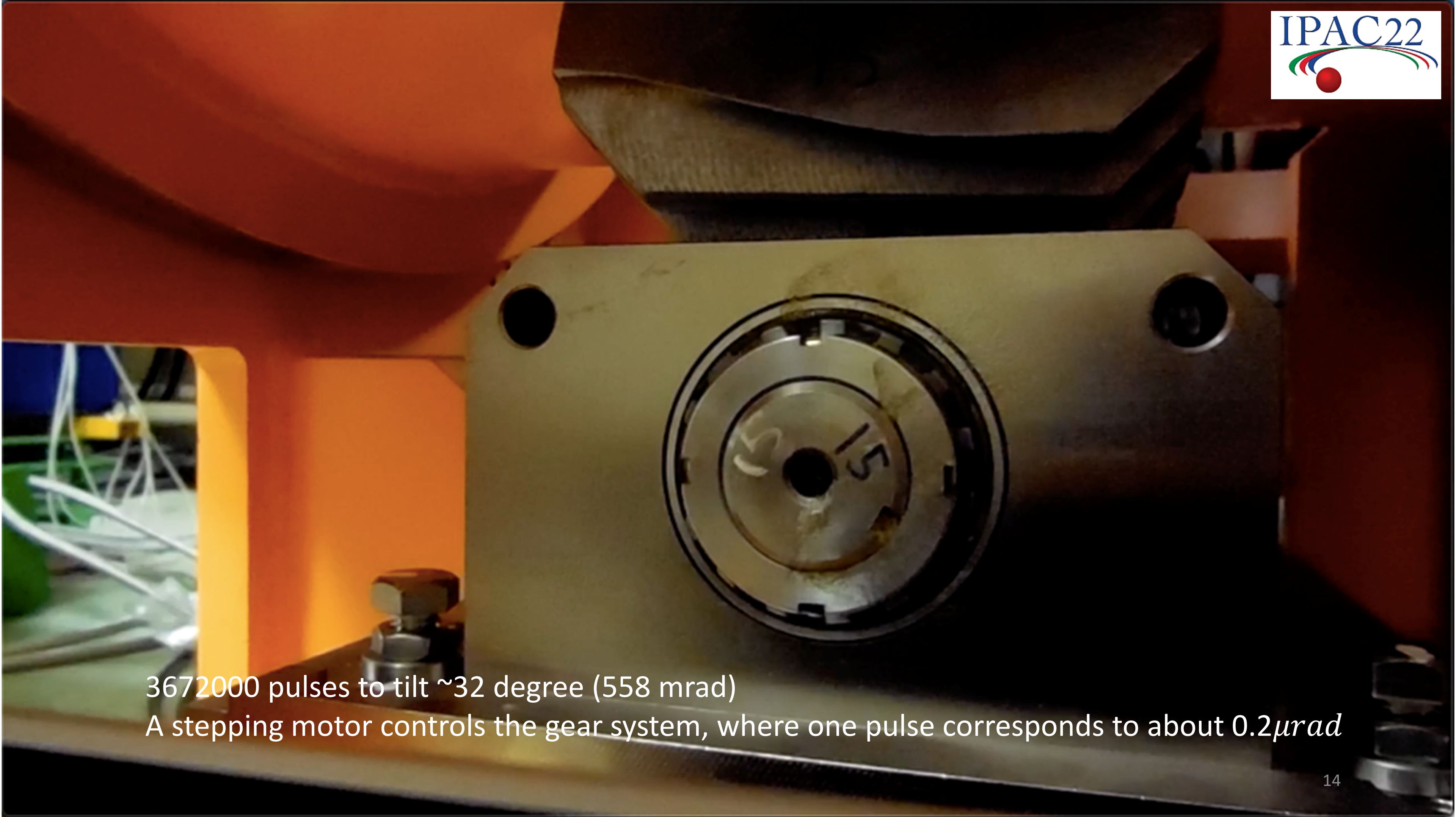

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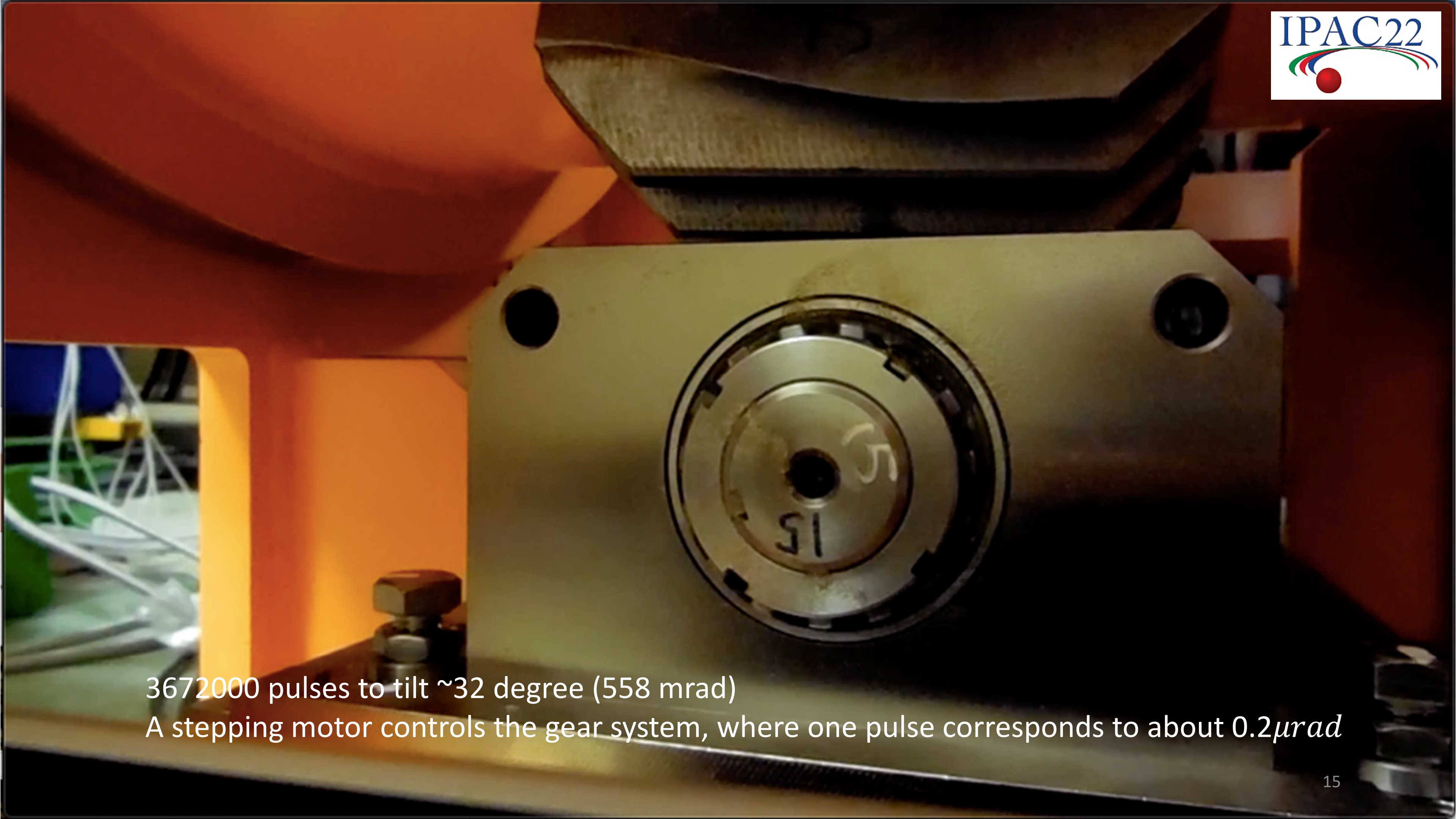

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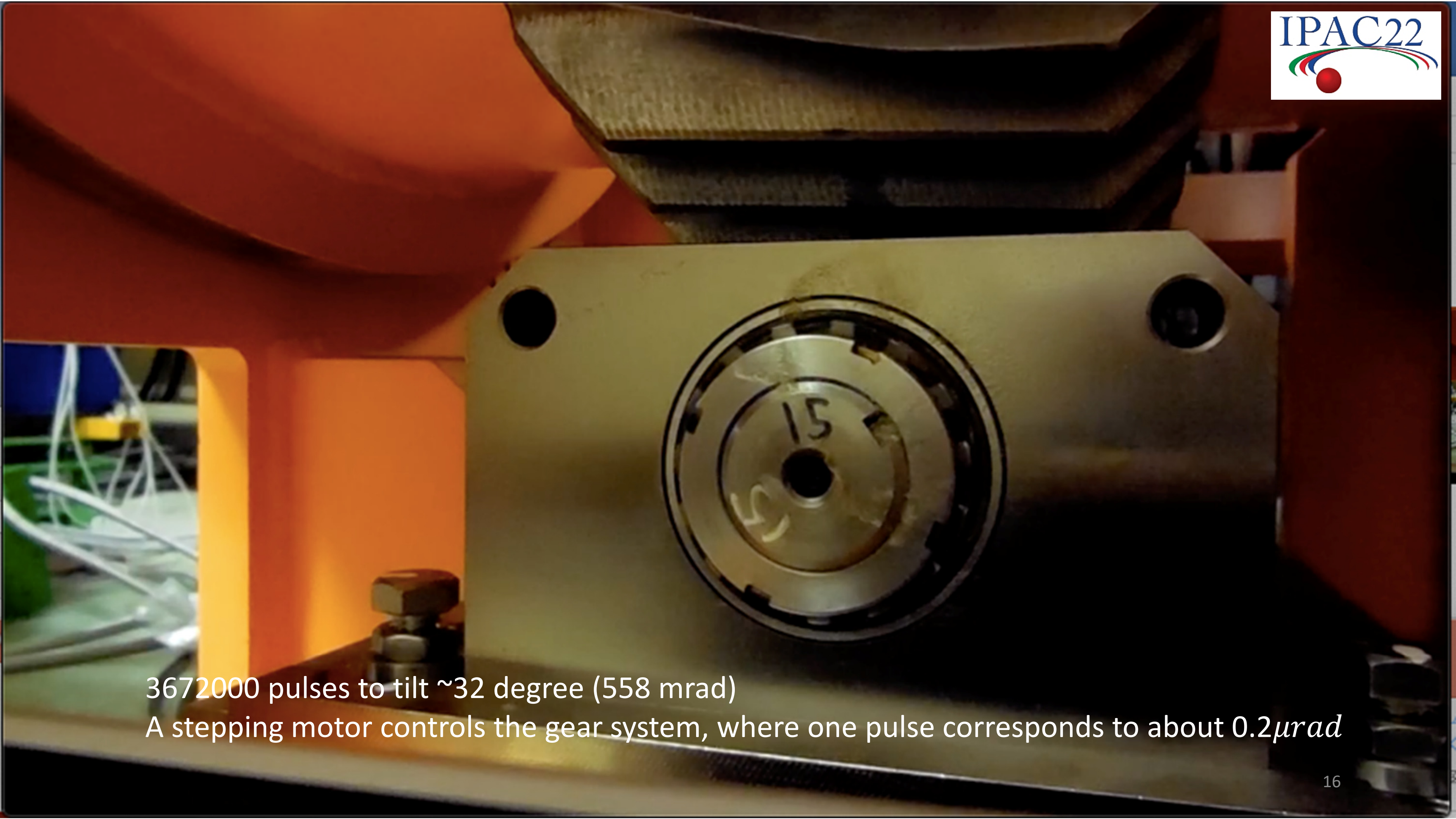

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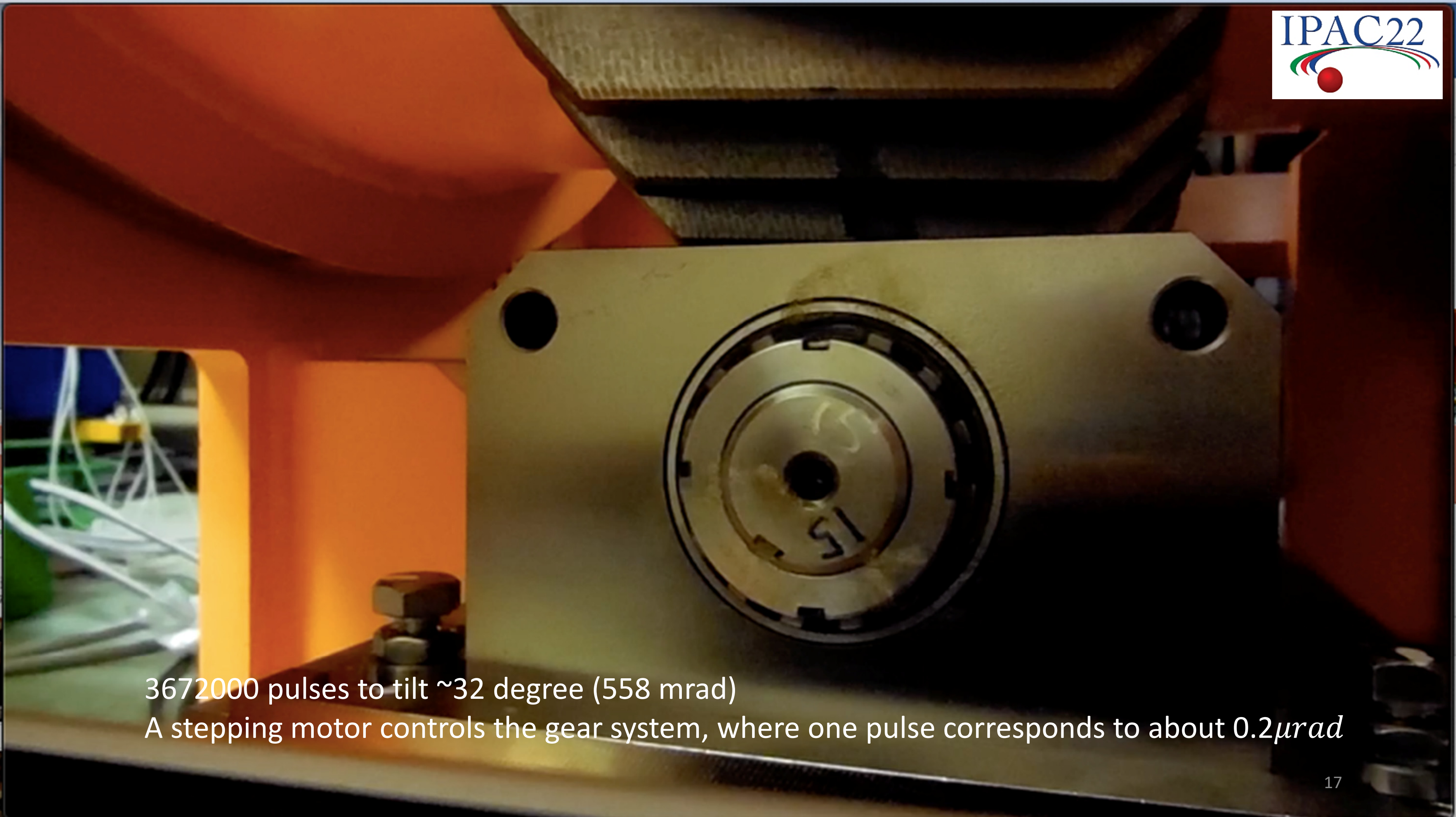


3672000 pulses to tilt ~32 degree (558 mrad)

A stepping motor controls the gear system, where one pulse corresponds to about $0.2\mu rad$

4. Test

Matching the magnet center with the tilt center

Tilting table with gears

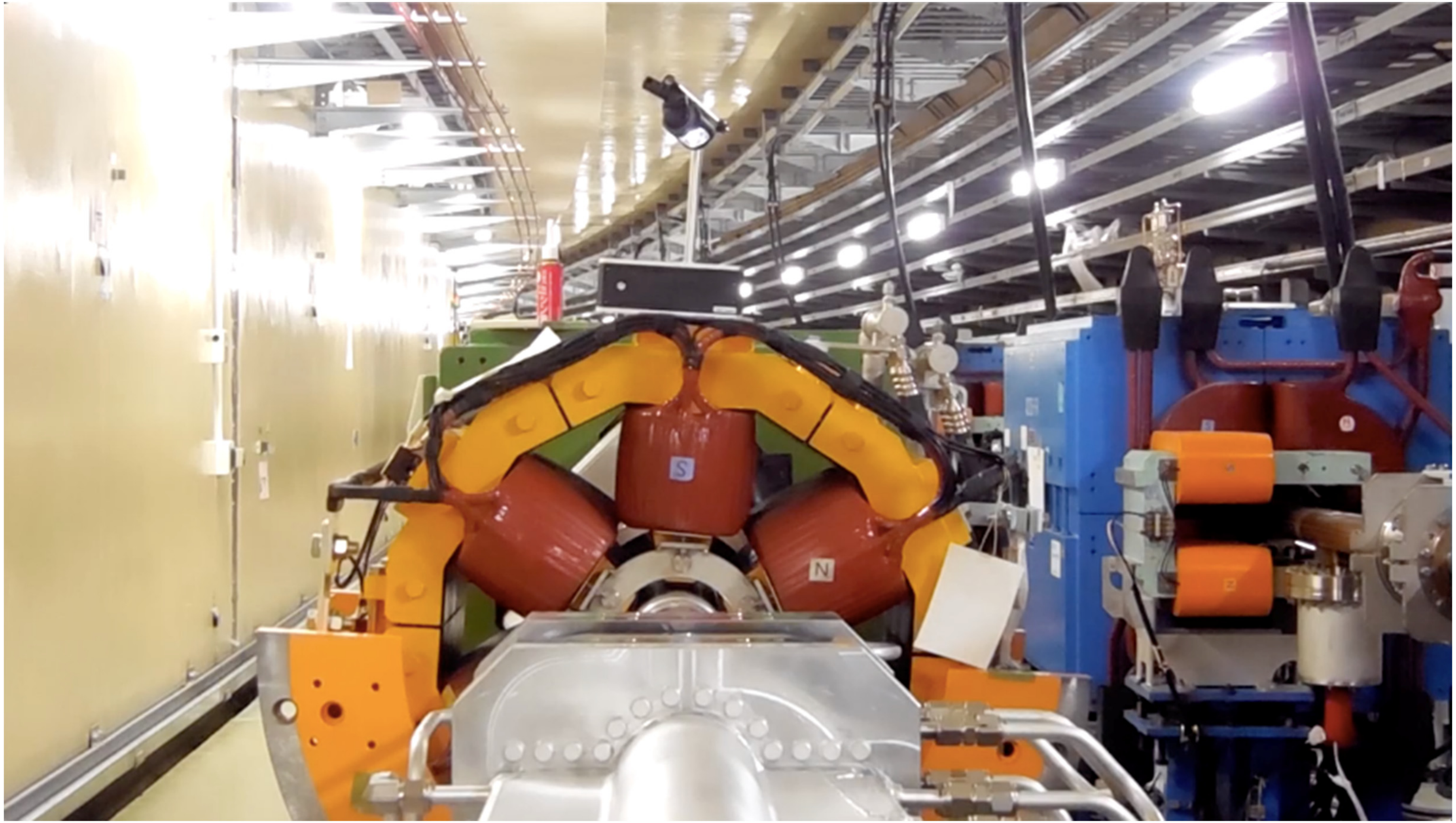
Procedure

Observe the wire crossing point (the magnet center) with an optical scope at various tilt angles.

Adjust the magnet position (with shim plates placed in between the magnet and the tilting table) until the magnet center and rolling center match.

4. Test

4. Test



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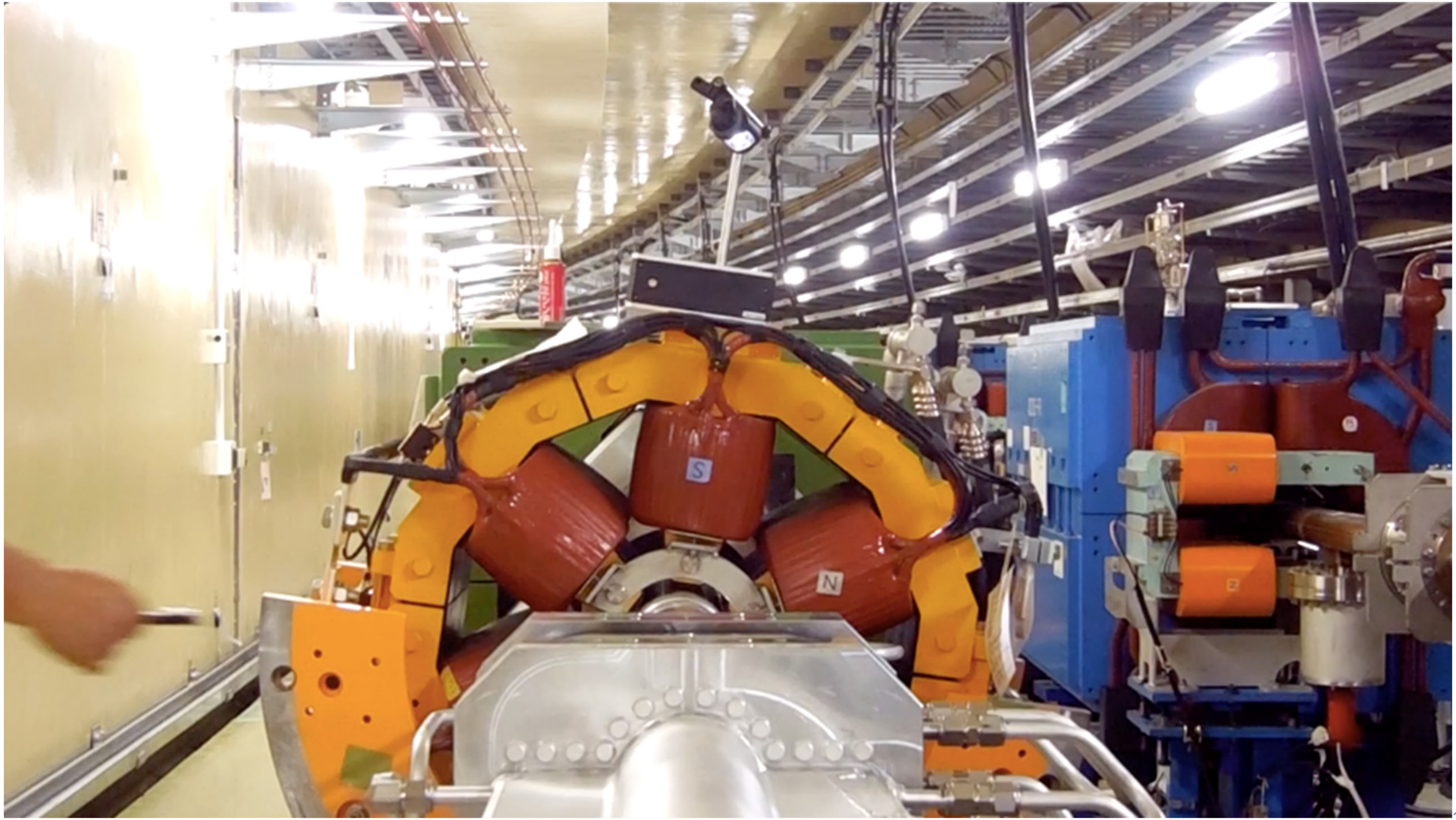

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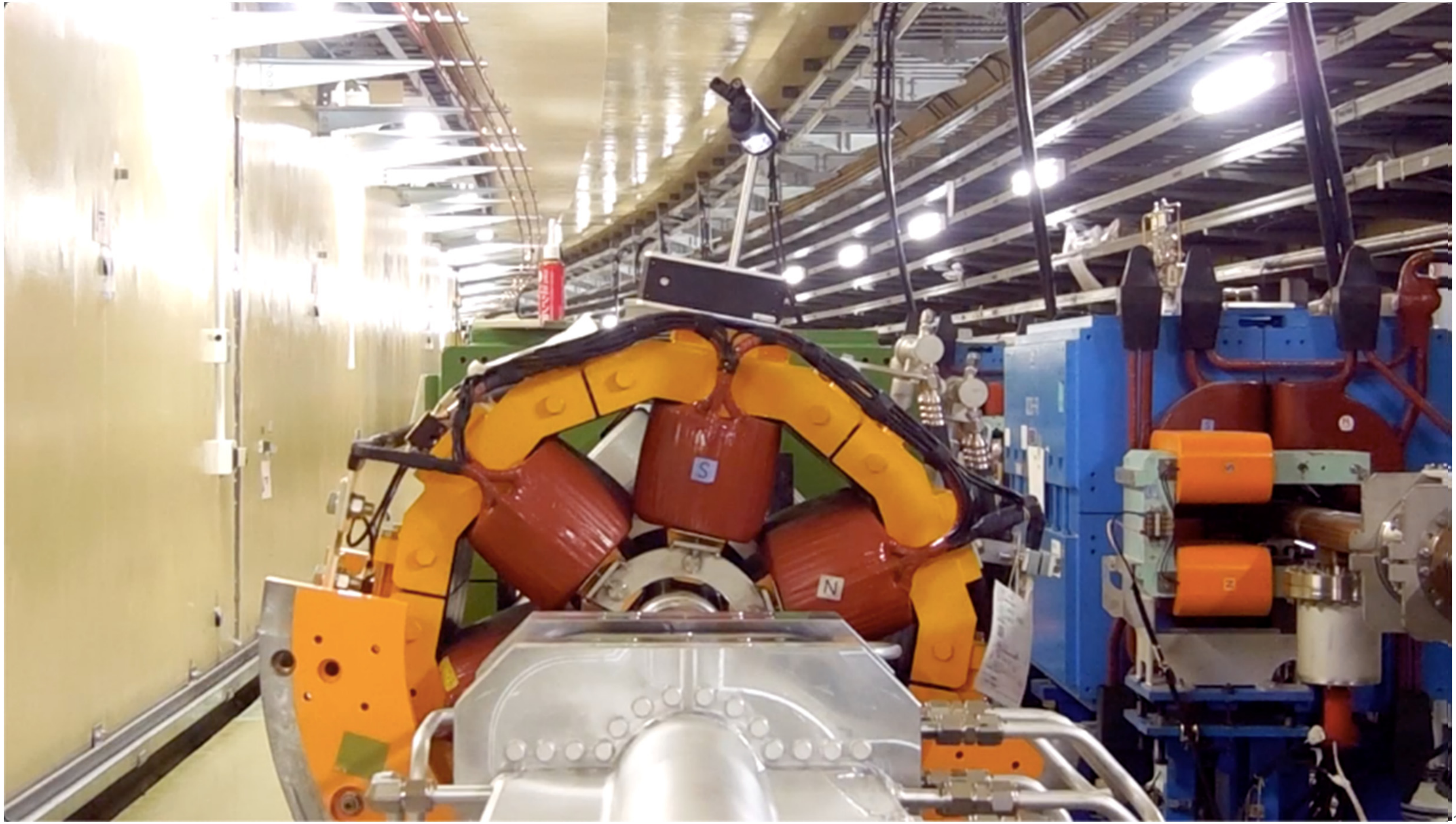

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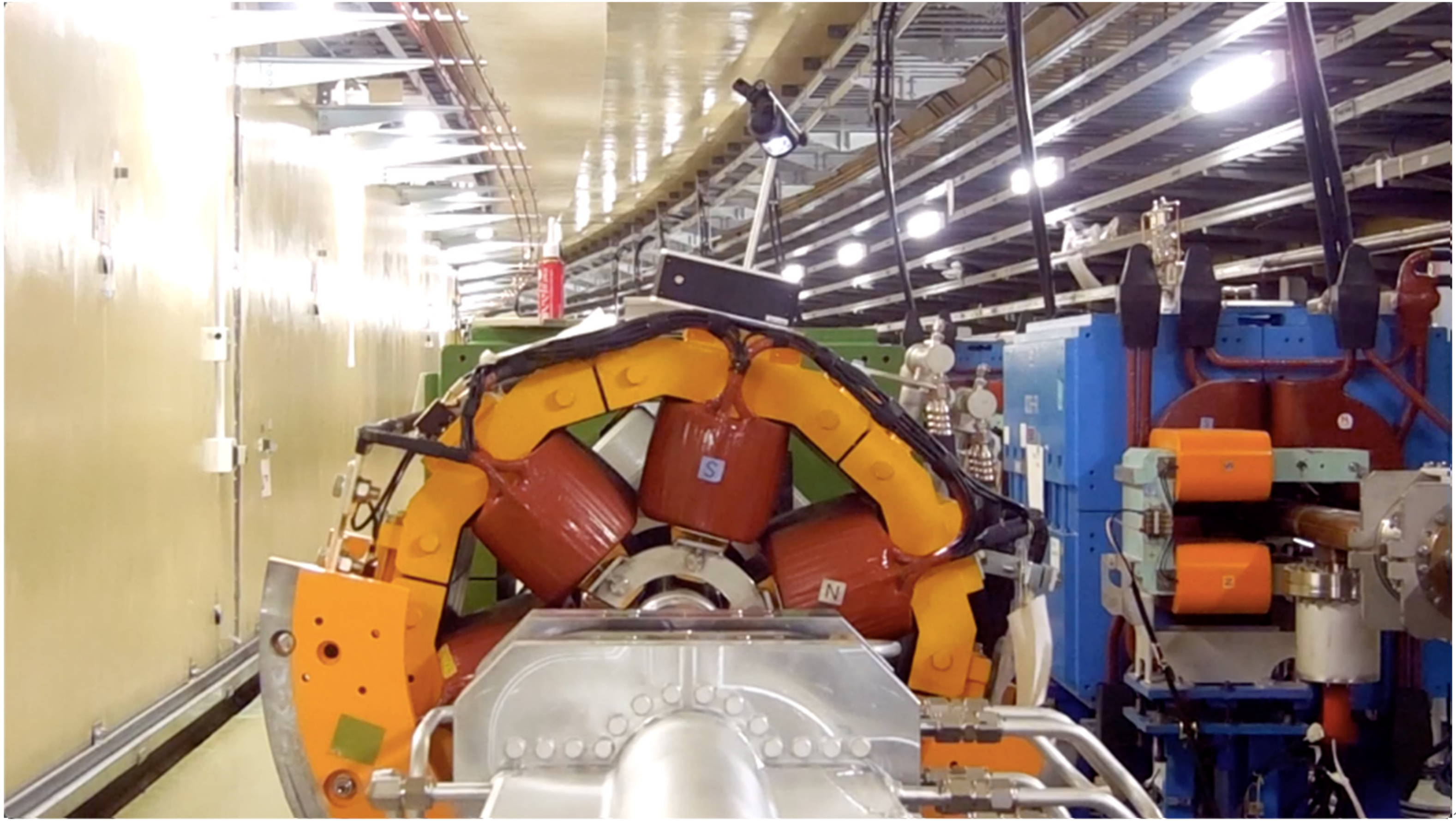

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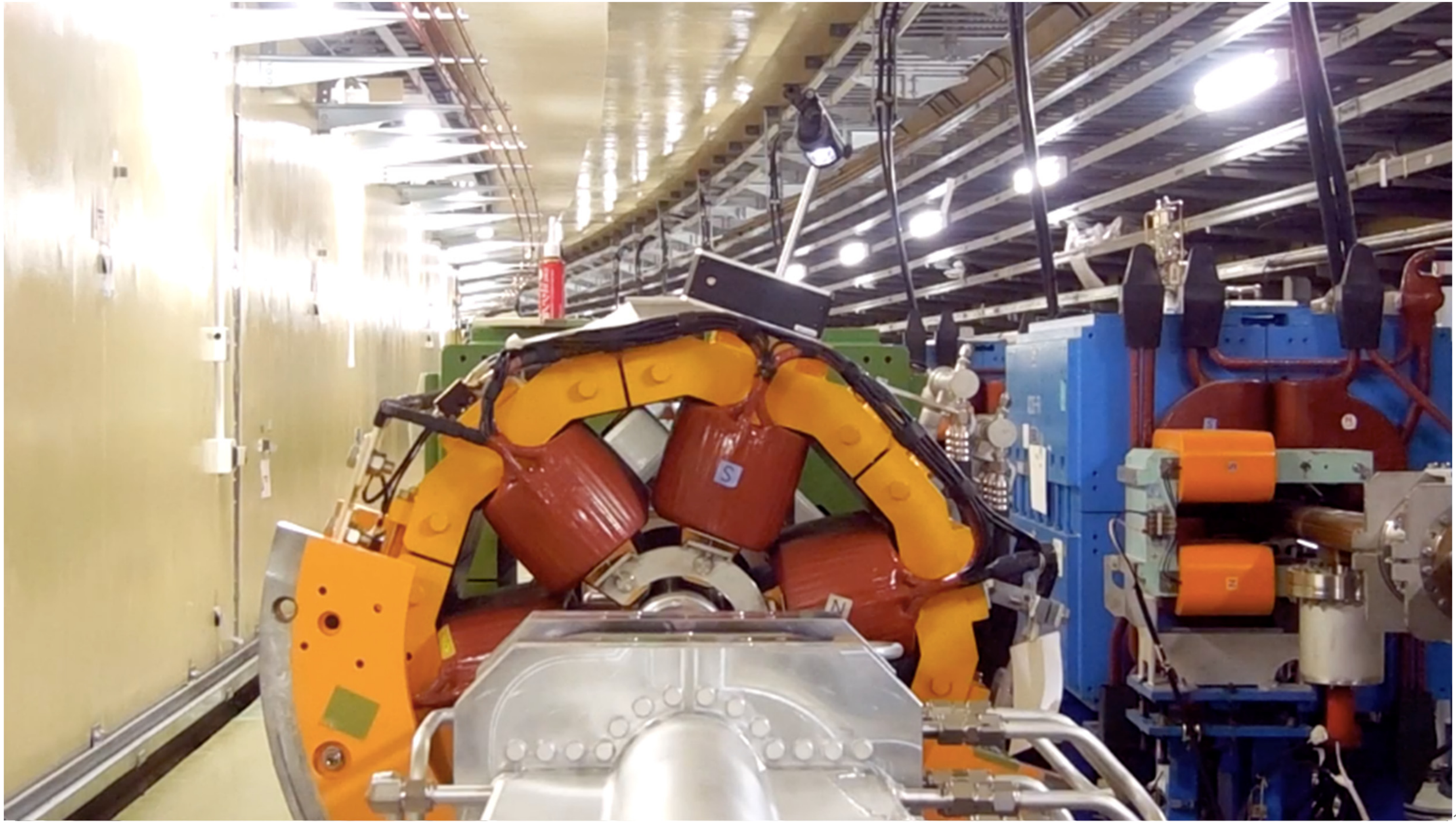


4. Test

5. Commissioning with $\beta_y^* = 1\ mm$ optics

One of the chromatic x-y coupling parameters R_1', was varied using the 24 sextupole magnets in the 2021autumn run.

We did tune survey with $\triangle R_1' = 0$

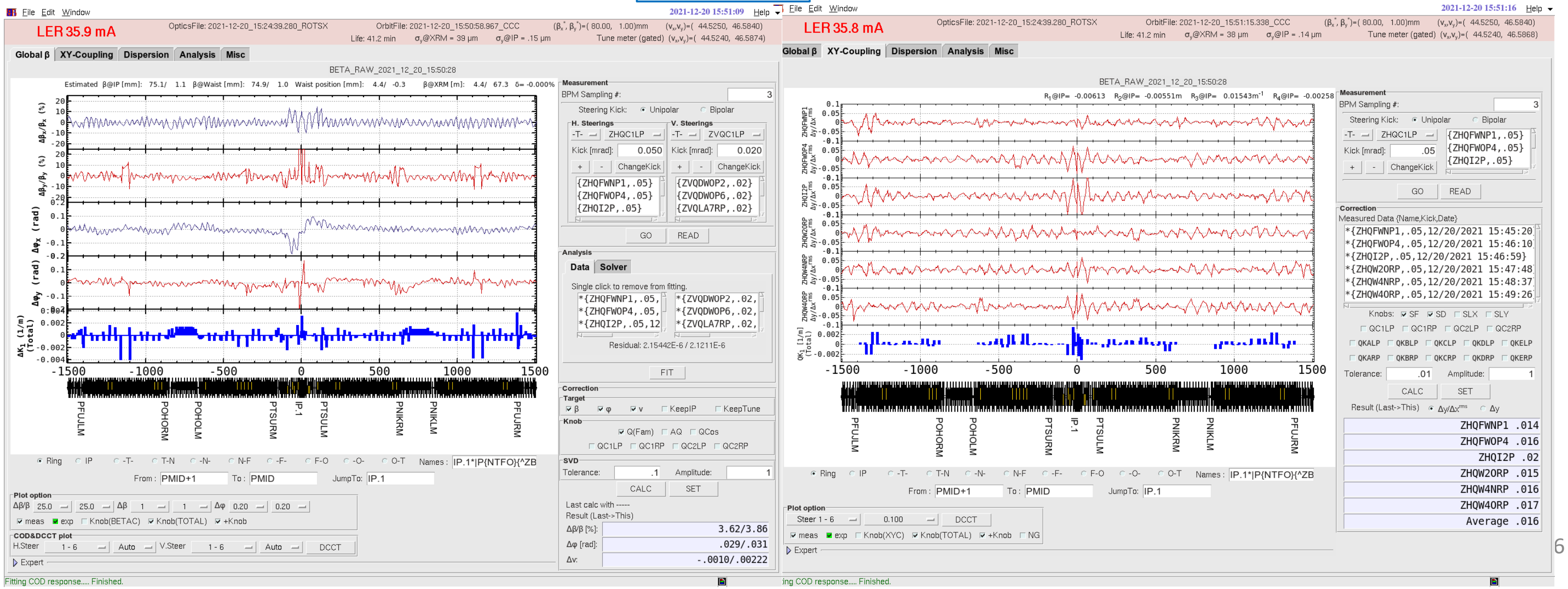
Then $\triangle R_1' = 1$ was set by rolling 24 magnets (next page)

We found

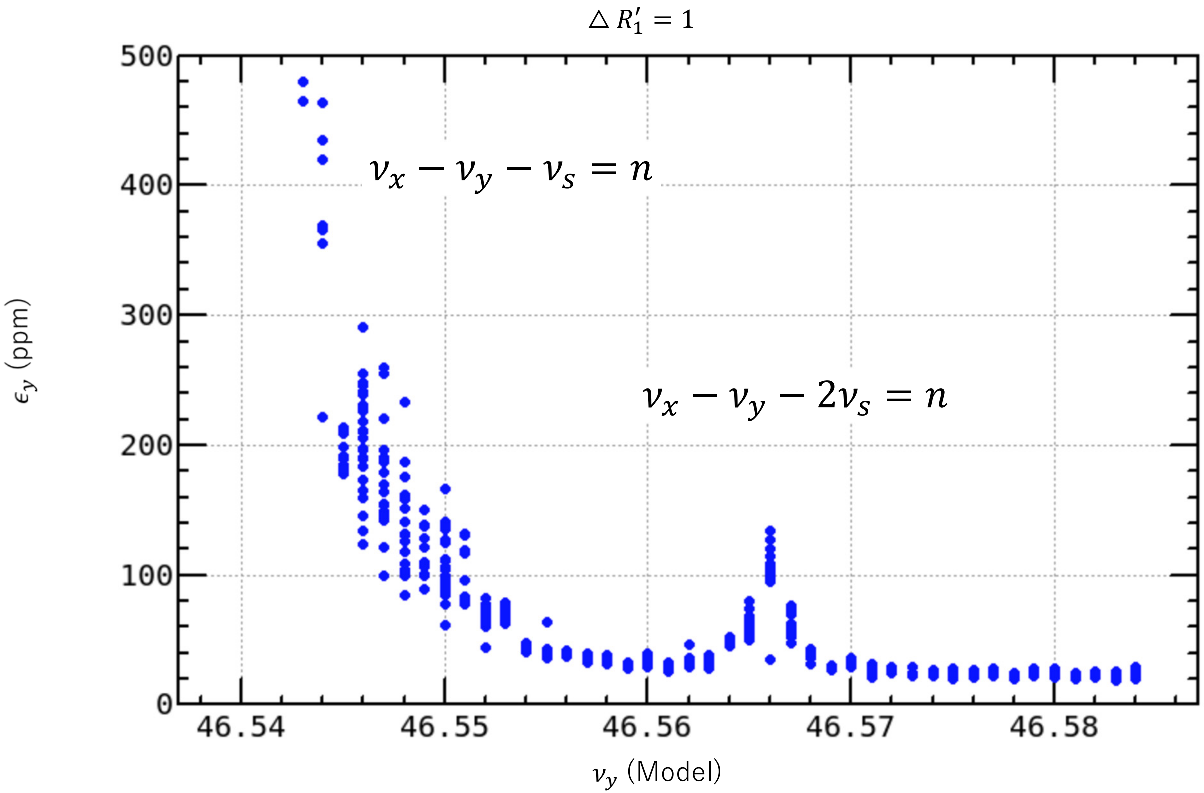
No problem with injection

No degradation in optics

$\beta_y^* = 1\ mm$



5. Commissioning with $\beta_y^* = 1\ mm$ optics



5. Commissioning with $\beta_y^* = 1\,mm$ optics

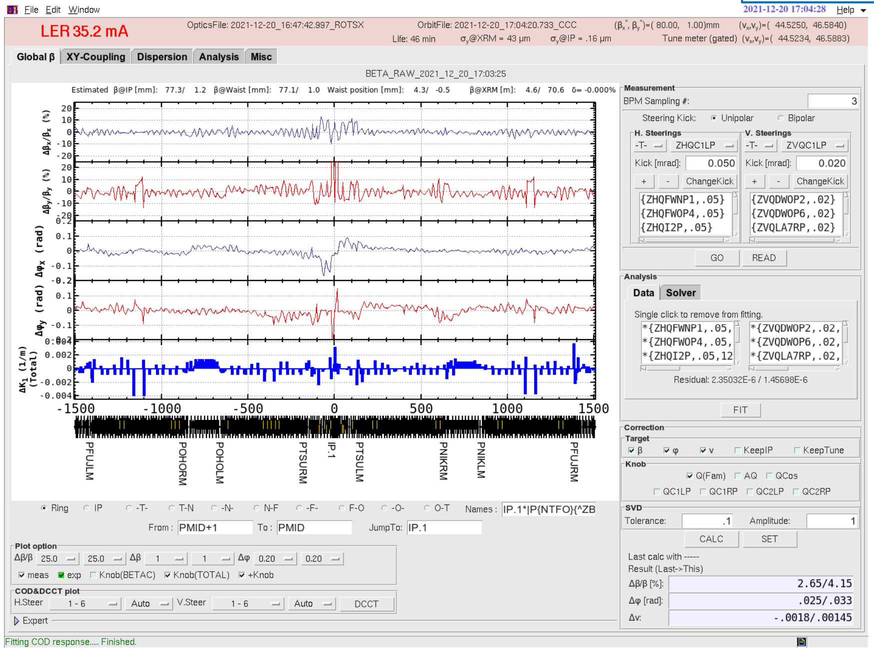
Then $\triangle R_1' = -1$

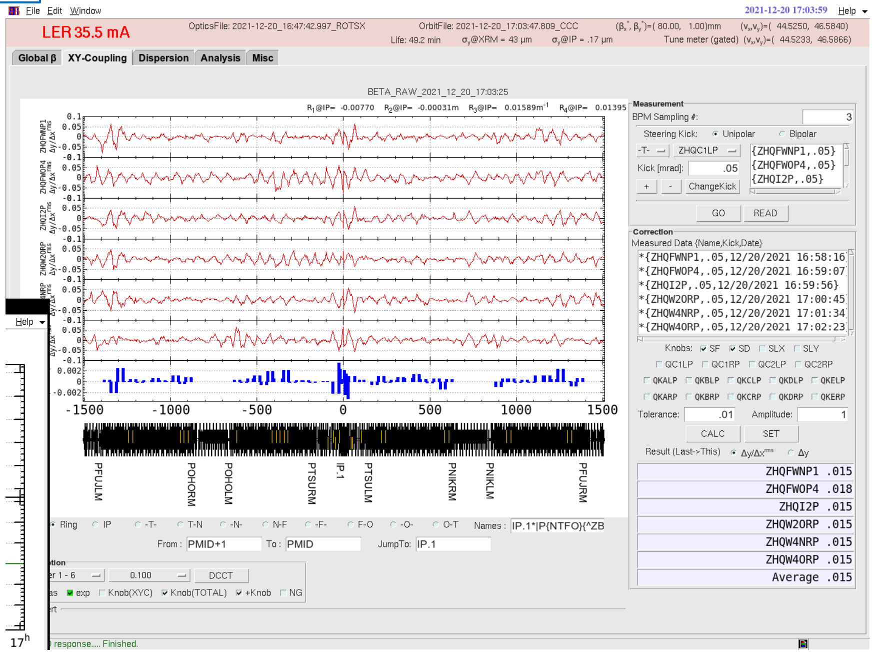
We found

No problem with injection

No degradation in optics

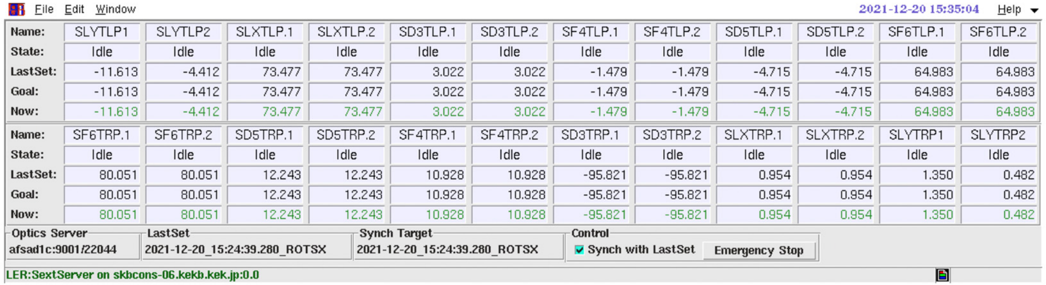
$\beta_y^* = 1\,mm$





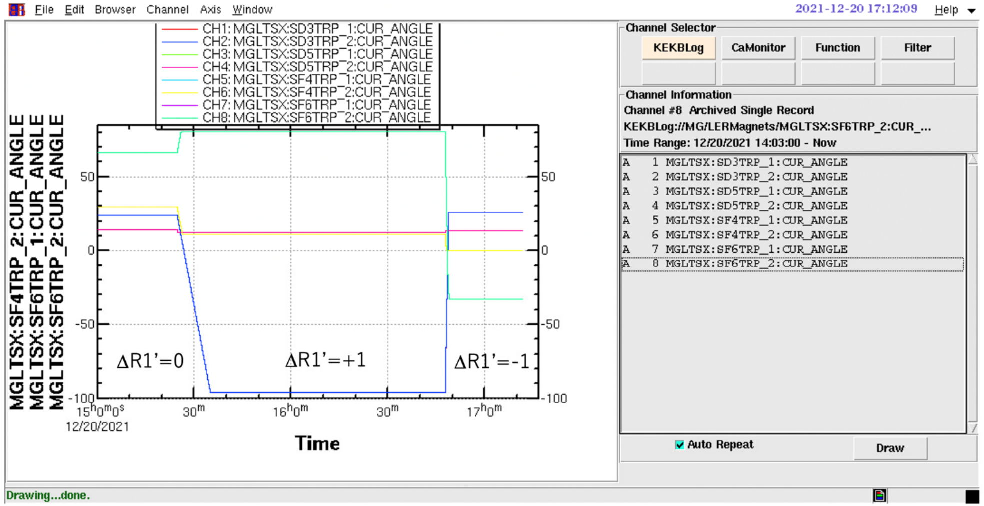
5. Commissioning with $\beta_y^* = 1\ mm$ optics

ΔR1'=+1



Name:	SLYTLP1	SLYTLP2	SLXTLP.1	SLXTLP.2	SD3TLP.1	SD3TLP.2	SF4TLP.1	SF4TLP.2	SD5TLP.1	SD5TLP.2	SF6TLP.1	SF6TLP.2
State:	Idle	Idle	Idle	Idle	Idle	Idle	Idle	Idle	Idle	Idle	Idle	Idle
LastSet:	-11.613	-4.412	73.477	73.477	3.022	3.022	-1.479	-1.479	-4.715	-4.715	64.983	64.983
Goal:	-11.613	-4.412	73.477	73.477	3.022	3.022	-1.479	-1.479	-4.715	-4.715	64.983	64.983
Now:	-11.613	-4.412	73.477	73.477	3.022	3.022	-1.479	-1.479	-4.715	-4.715	64.983	64.983
Name:	SF6TRP.1	SF6TRP.2	SD5TRP.1	SD5TRP.2	SF4TRP.1	SF4TRP.2	SD3TRP.1	SD3TRP.2	SLXTRP.1	SLXTRP.2	SLYTRP1	SLYTRP2
State:	Idle	Idle	Idle	Idle	Idle	Idle	Idle	Idle	Idle	Idle	Idle	Idle
LastSet:	80.051	80.051	12.243	12.243	10.928	10.928	-95.821	-95.821	0.954	0.954	1.350	0.482
Goal:	80.051	80.051	12.243	12.243	10.928	10.928	-95.821	-95.821	0.954	0.954	1.350	0.482
Now:	80.051	80.051	12.243	12.243	10.928	10.928	-95.821	-95.821	0.954	0.954	1.350	0.482

http://www-linac2.kek.jp/kekb/scrshot1/2021_12/20/2021_12_20_15_35_04.png



http://www-linac2.kek.jp/kekb/scrshot1/2021_12/20/2021_12_20_17_12_11.png

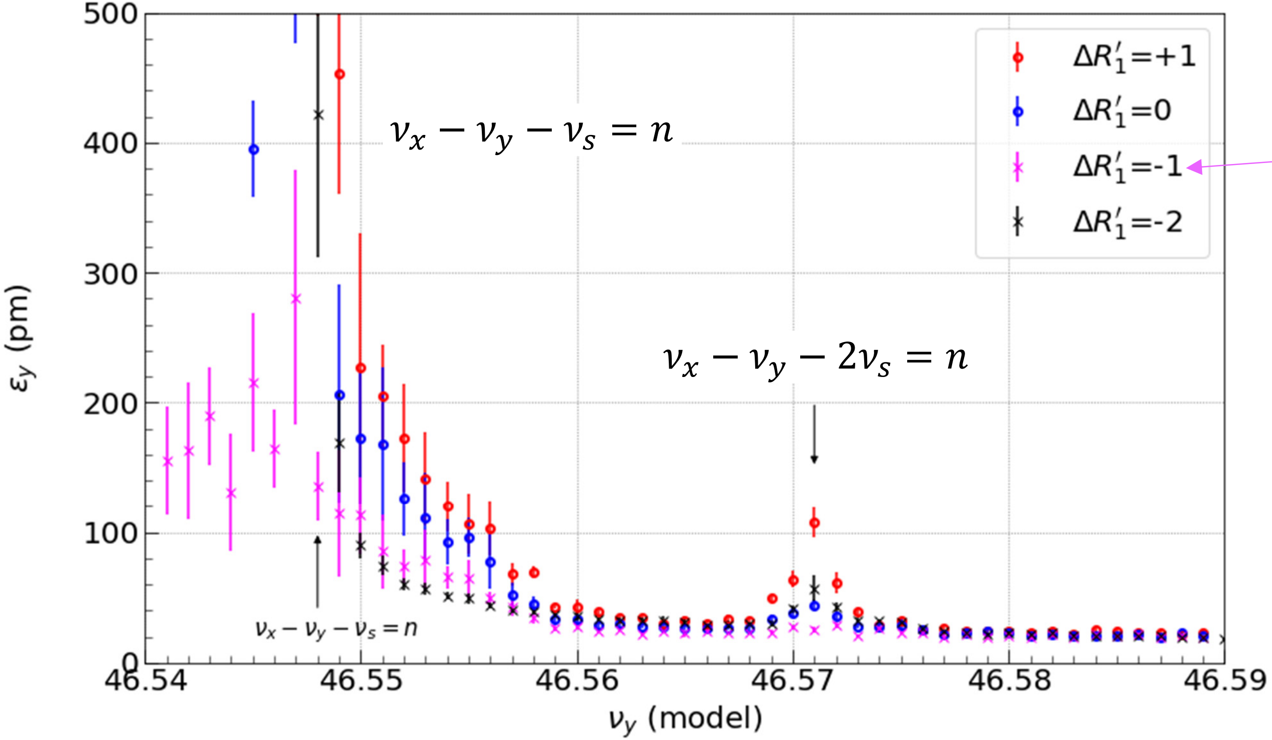
$\beta_y^* = 1\ mm$

24 magnets were tilted simultaneously.

Some magnets were tilted as large as 100 mrad.

We tested tilting the magnets with keeping the beam at the end of this study and found no problem (no sudden loss of the beam, no sudden change in the beam orbit and so on).

5. Commissioning :$\triangle R_1'$ Scan results



$\triangle R_1' = -1$
was the best

5. Commissioning

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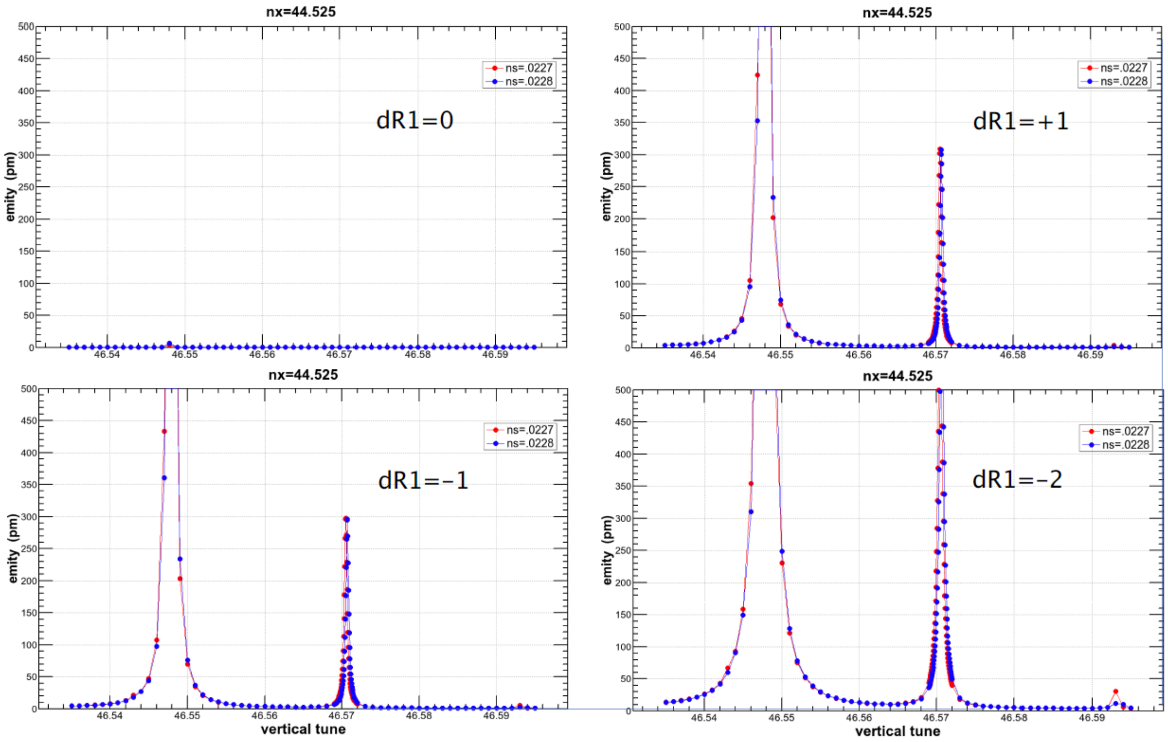
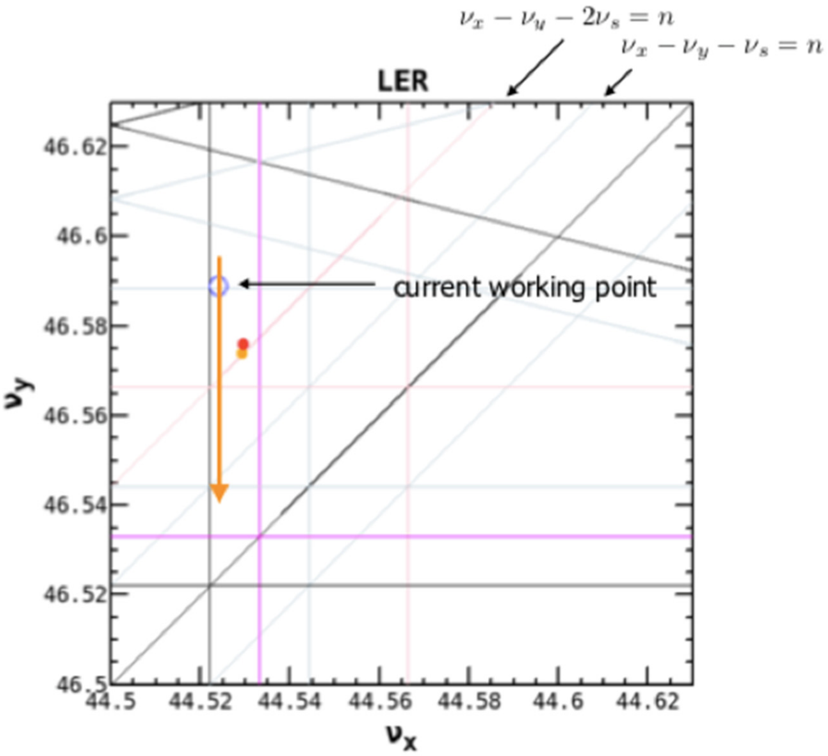
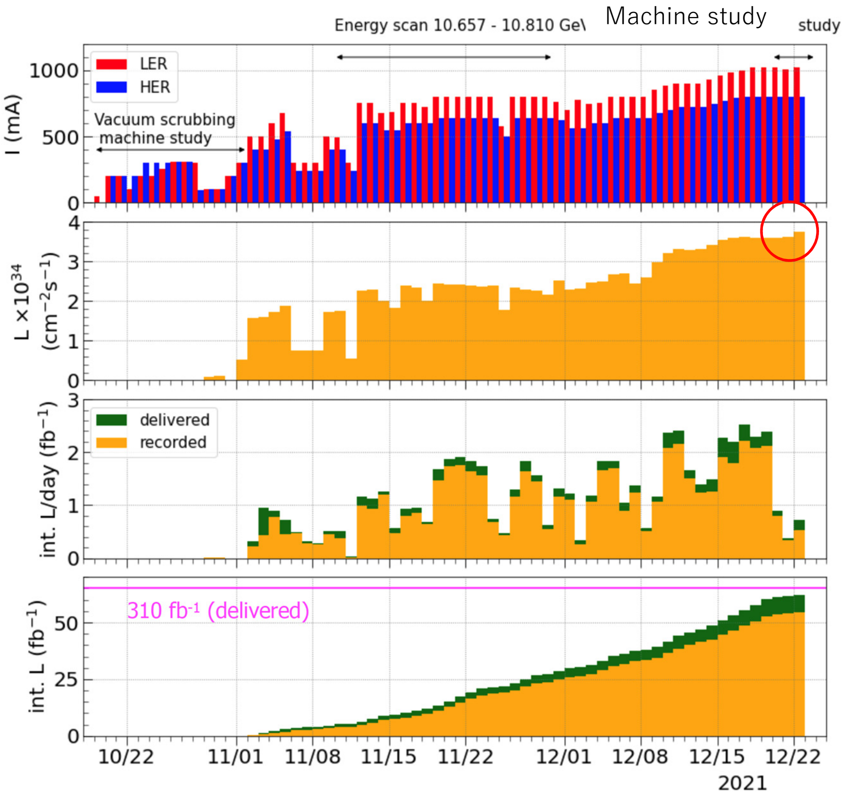
Comparison with simulation (H. Koiso)



5. Commissioning





Tilting the sextupole magnets successfully made the fist synchro-beta coupling resonance weaker, together with the second resonance. The vertical tune can now be set at lower value.

6. Summary

- Chromatic x-y coupling correction was carried out with the rolling sextupole magnets in the LER with $\beta_y^* = 1\ mm$ optics.

- No degradation with injection efficiency, optics observed.

- It was found that the emittance growth at the primary and secondary synchro-beta resonance lines can be controlled by tilting the sextupole magnets.

- Luminosity increase followed after optimizing a chromatic x-y coupling parameter R_1' and finding a better tune working point.

- We hope to do more study (effect of $\triangle R_2'$, $\triangle R_1'$ with $\beta_y^* = 0.8\ mm$) before LS1 (long shutdown which starts from next month).