TRIUMF

Canada’s national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire
et en physique des particules

Designing for Reliability

Using quality design and build practises

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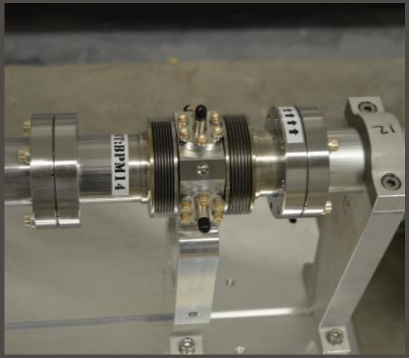


Dependencies Between Reliability and Quality

- Reliability
  - Equipment will perform it's function for a specified term, under known conditions without failure.
    - Design requirements drawn up and reviewed

- Quality
  - Equipment will work as designed after assembly
    - Manufacturing processes, standards followed, design requirements measured and met

Design Requirements

- Lay out objectives that **must** be met.
- Define in functional manner, but leave out implementation details.
- Give measureable details that can be used to determine the success of the final design.

Quality requirements

- Follow manufacturing standards
  - Quality control of parts being built
- Selection of appropriate equipment and materials
  - Look at environment the equipment will be placed in
- Commissioning documents written and completed
  - Ensures design requirements are met

Radiation Requirements

For most accelerator facilities radiation damage is a fact of life. While we can not eliminate the problems, designing around them is important.

Quantify the amount of radiation.

Pick radiation resistant materials.

Move equipment out of harm’s way.

Radiation index

TRIUMF is adopting the usage of Radiation Index (RI) of materials as a required design parameter.

It provides a simple method of comparing the radiation resistance of materials and determining the maximum dosage that can be absorbed by materials before significant degradation of physical integrity.

Material selection from R.I.

7.8	Epoxy, glass laminate
7.5	Polyimide (Kapton)
6.8	Polyesters/Polyurethanes
6.5	PEEK
5.8	Aromatic Polyamide (Nomex)
5.3	Polyethylene
5.1	Polyvinyl Chloride (PVC)
5.0	Silicone Rubber
4.6	Acrylic Rubber
4.5	Mylar
4.5	Teflon PTFE
3.5	Cellulose fibre (Rayon)
3.0	Teflon (FEP)

Moving equipment out of harm's way

Safety factors and redundancy

When designing equipment that has to be reliable both safety factors and redundancy must be considered.

Is it more appropriate to build something overly robust with a large safety factor built in or build redundancy into the system.

If a component fails can another component allow the system to continue to operate in a safe manner?

Ease of install or ease of service?

At installation often equipment is installed sequentially.

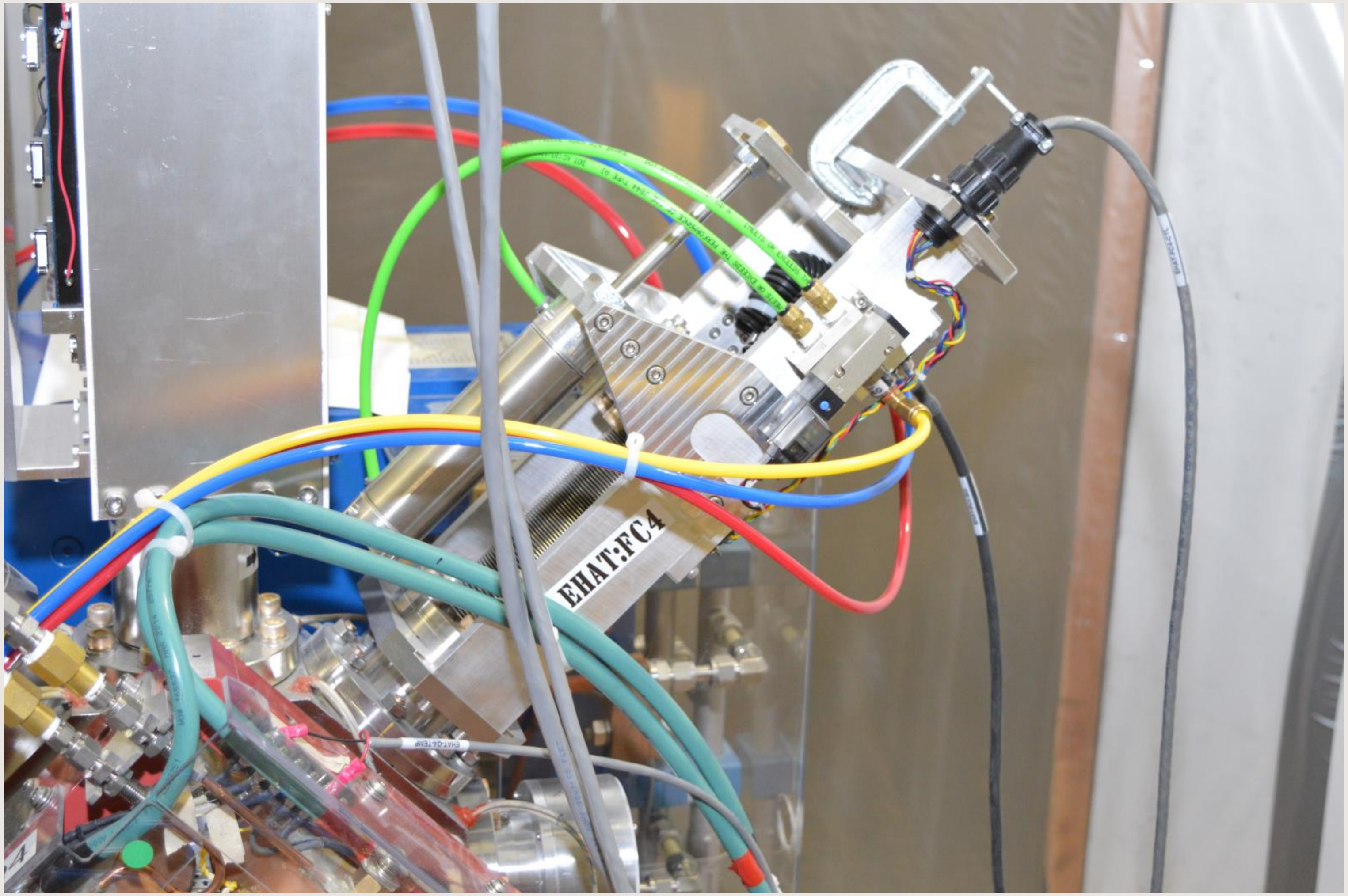
Servicing of equipment may require removal of surrounding equipment.

What else needs to be shut down to service equipment?

Easily identify services.

Don’t block other equipment.

Easy to identify services



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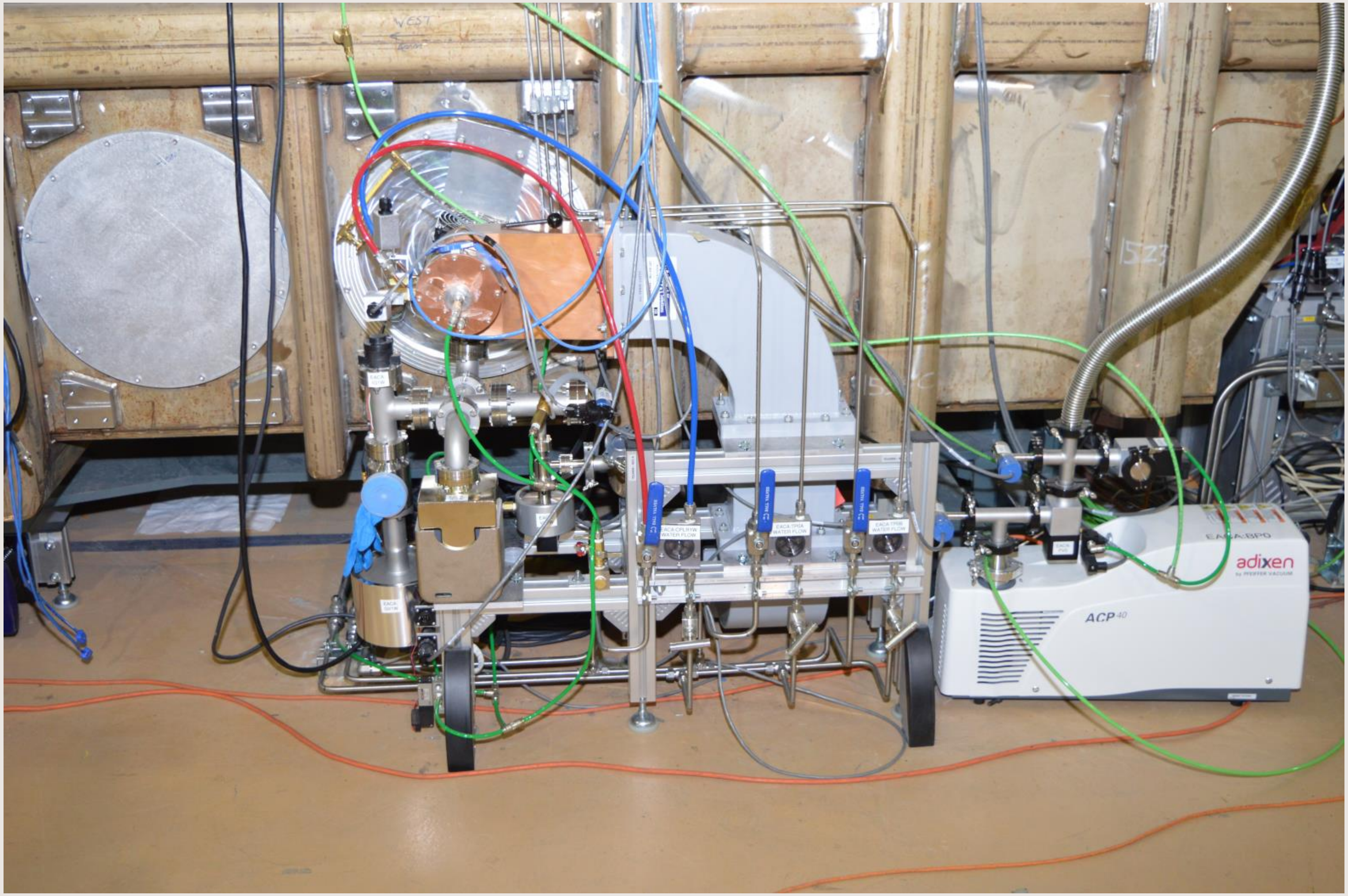
Blocking other Equipment

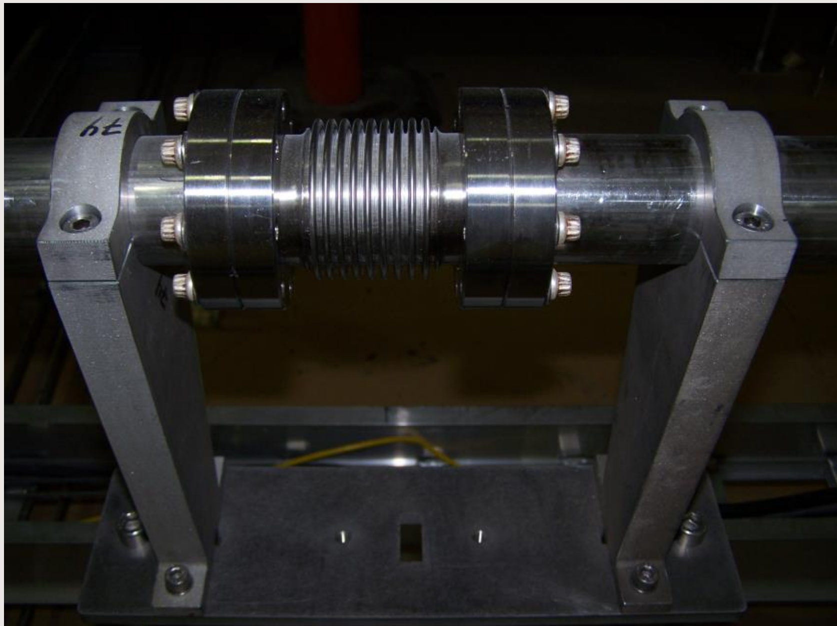


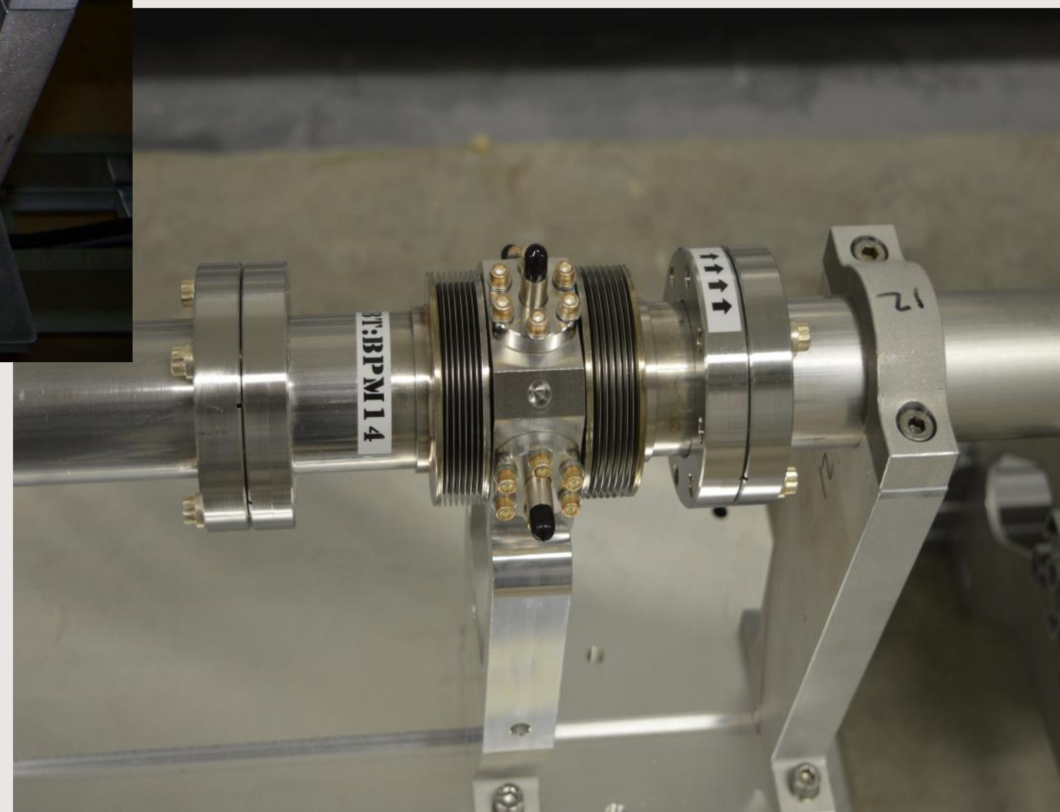
Standardization of parts

- Good
  - Spares on shelf
  - Easier/cheaper to build or buy quantities of components
  - Better understood so easier to install and control

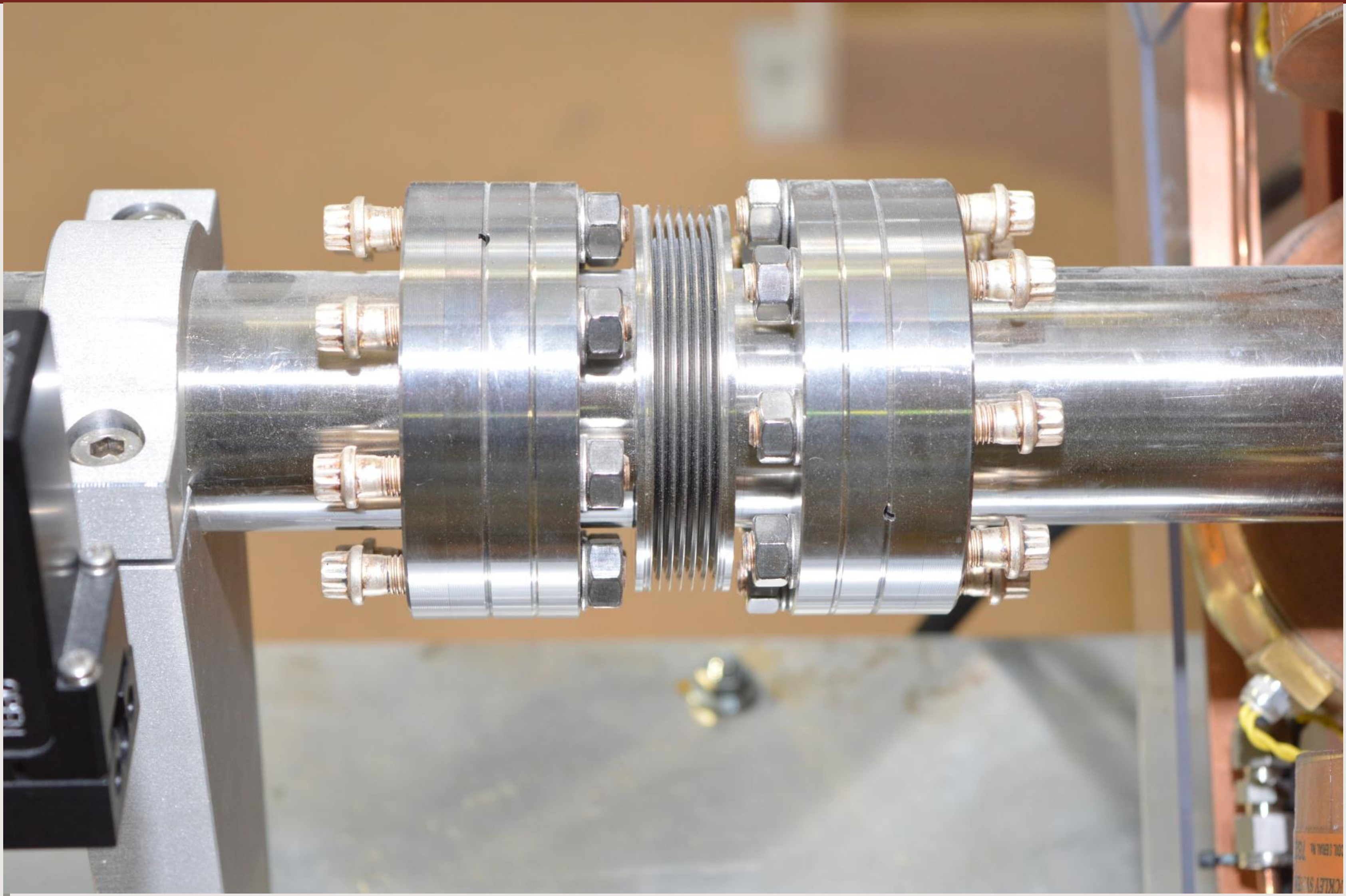
- Bad
  - Limit design/function of parts – must work everywhere
  - Make unsuitable parts work (non-ideal installation)

Good use of standard parts





Bad use of standard parts



Cleaning of beamline equipment

- **Four stage cleaning process**
  - 1. Wash with detergent and water, rinse
  - 2. Clean in ultrasonic tank with clean water, rinse
  - 3. Clean in ultrasonic tank with distilled water
  - 4. Blow dry with clean dry nitrogen

Cleaning of beamline equipment

- The cleaned parts were then bagged and stored in a clean room.
- The cleaned parts were assembled into equipment and aligned in the clean room
- Bagged assemblies were brought into the accelerator hall and mounted on stands
- Vacuum joints were done up as quickly as possible in the hall
- Typically the vacuum system was pumped down to a 10e-7 Torr range in a couple of days with no bake out required

Design for alignment

- Start with design requirements
  - How accurately must equipment be aligned?
- Design with alignment equipment in mind
  - What instruments will be used?
  - What alignment features should be included on equipment?
- Will the equipment require realignment later?
  - How will alignment be done during servicing?
- Define measureable points
  - Don't use hidden or theoretical points to measure to.

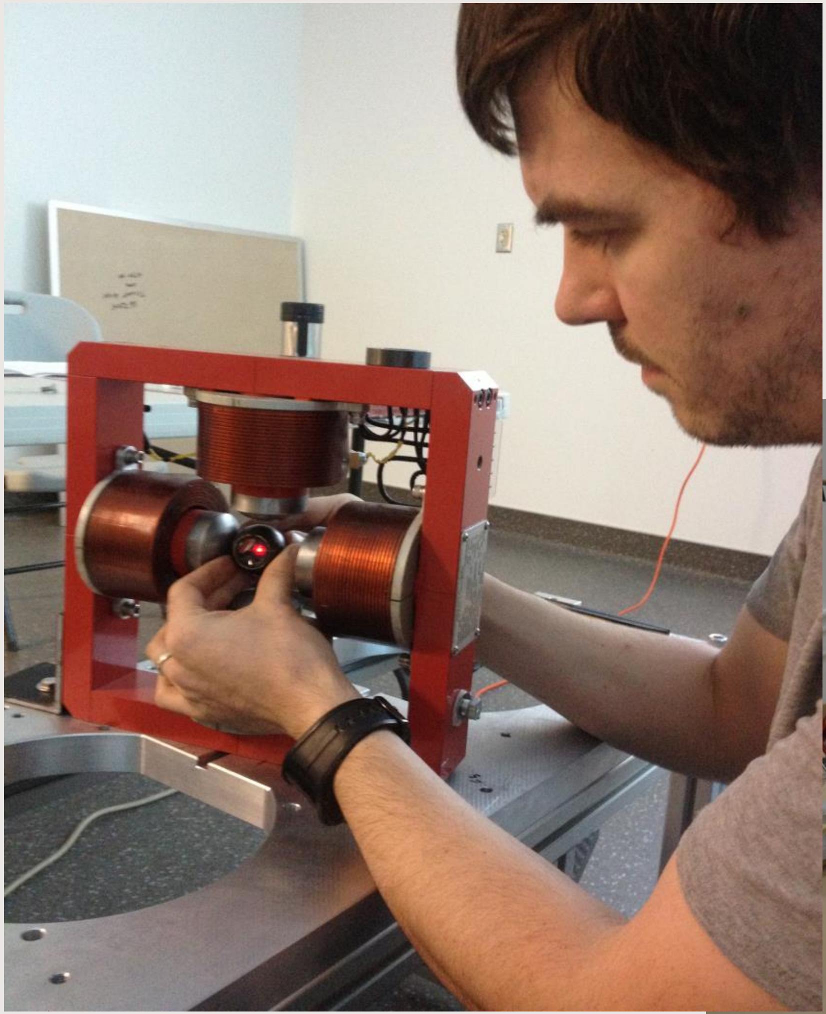
Alignment tolerances

Component	Longitudinal		Transverse		Roll		Pitch		Yaw	
	Physics	Engineering	Physics	Engineering	Physics	Engineering	Physics	Engineering	Physics	Engineering
Dipoles	150 µm rms Note 1	±300 µm	150 µm rms Note 1	±300 µm	±0.4 mrad full width Note 2 Note 5	±0.4 mrad or ±0.023°	±1 mrad full width Note 1 Note 2	±1 mrad or ±0.057°	±1 mrad full width Note 1 Note 2	±1 mrad or ±0.057°
Quads Solenoids	±2 mm full width Note 1	±2 mm	150 µm rms Note 1	±300 µm	±0.6°	±0.6°	±1.2°	±1.2°	±1.2°	±1.2°
Steerers	±2 mm full width Note 1	±2 mm	±1 mm full width	±1 mm	±0.6°	±0.6°	±1.2°	±1.2°	±1.2°	±1.2°
BPMs	1 mm rms	±2 mm	150 µm rms Note 1	±200 µm Note 3	±0.6°	±0.6°	±1.2°	±1.2°	±1.2°	±1.2°
Others Note 4	±2 mm full width	±2 mm	150 µm rms	±300 µm	±0.6°	±0.6°	±1.2°	±1.2°	±1.2°	±1.2°

Offline alignment of equipment

- Using jigs and fixtures allowed equipment to be pre-aligned
- This eliminated in-beamline adjustments resulting in quicker installations
- When equipment does fail, it is possible to quickly replace it with pre-aligned spares
- This system does require an alignment coordinate system to be set up in the hall

Equipment set up



Beamline assembly in tunnel

26 quadrupole magnets
13 double steering magnets
4 monitor boxes with camera stands
8 BPMs
Vacuum isolation valves and pump out connections
All mounted and aligned on 13 stands with all vacuum connections made up in 6 days

Conclusions

To ensure that a high level of reliability is achieved for an accelerator installation both good design practices and quality build practices must be followed.

Thank you!
Merci

Questions?

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