Case Study:
High intensity neutrino target

JAS – 2014: Beam Loss and Accelerator Protection

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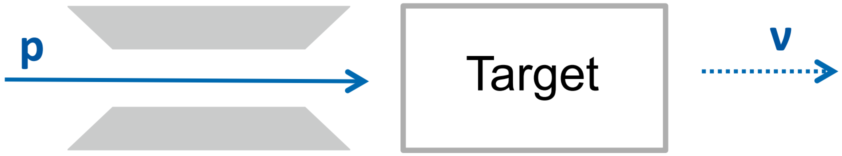


General requirements

- Design a target for a high intensity (**10^{14}** protons/pulse) neutrino beam at **200 GeV**
- Goal: Target must survive!!
- Design a protection (and diagnostic) system for the target
- What about a target for neutron spallation (e.g. protons of 2 GeV, power of 5 MW)?

Safety and machine protection priorities

1. Human safety

   Protect humans from any kind of health and radiation hazards

2. Environmental safety

   Protect environment from radiation/chemical contamination

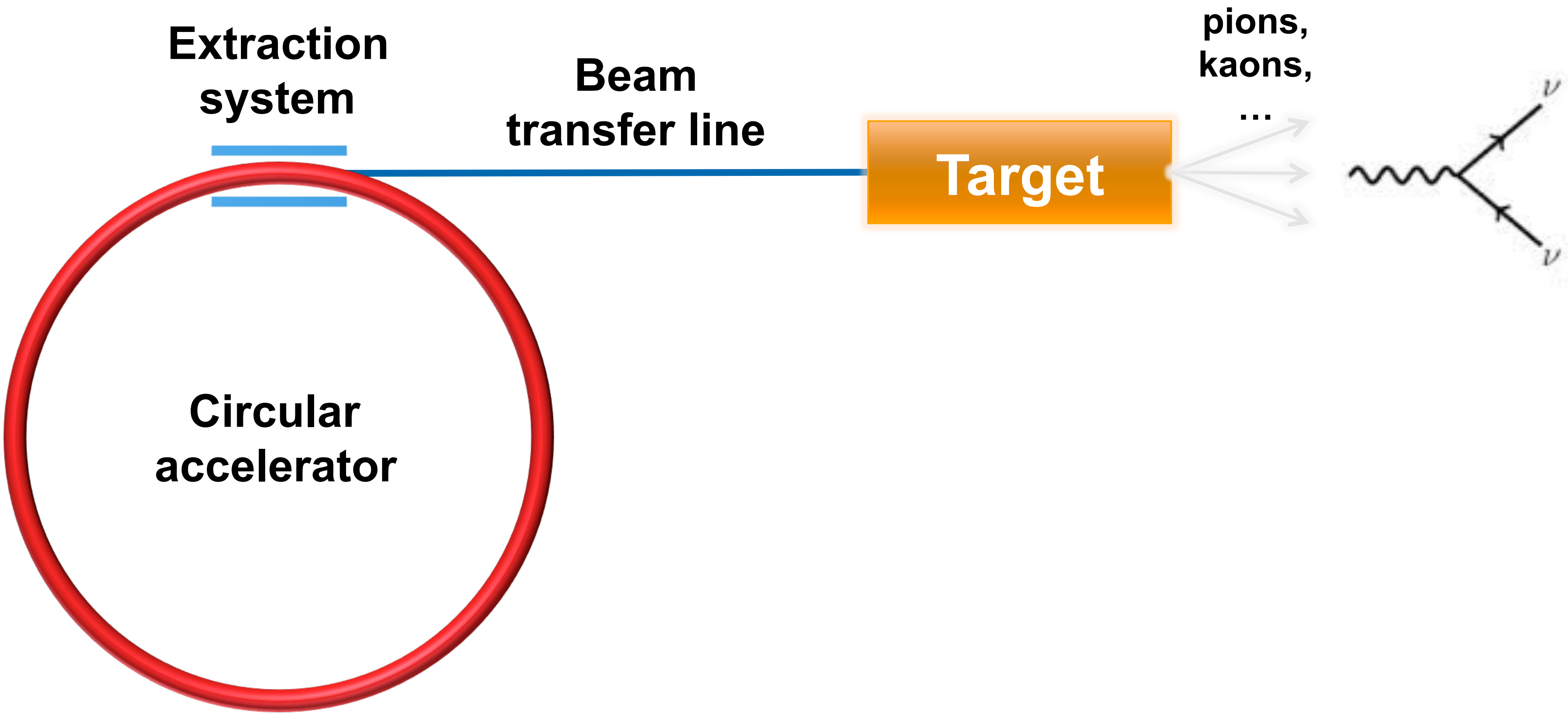
3. Machine protection

   MPS for protecting the machine from any damage during operation

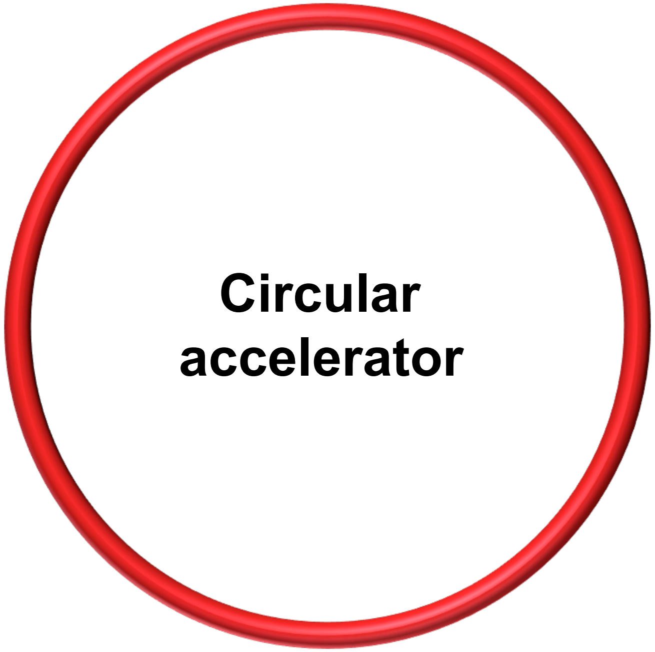
4. Target protection

   System for protecting target during operation

System outline



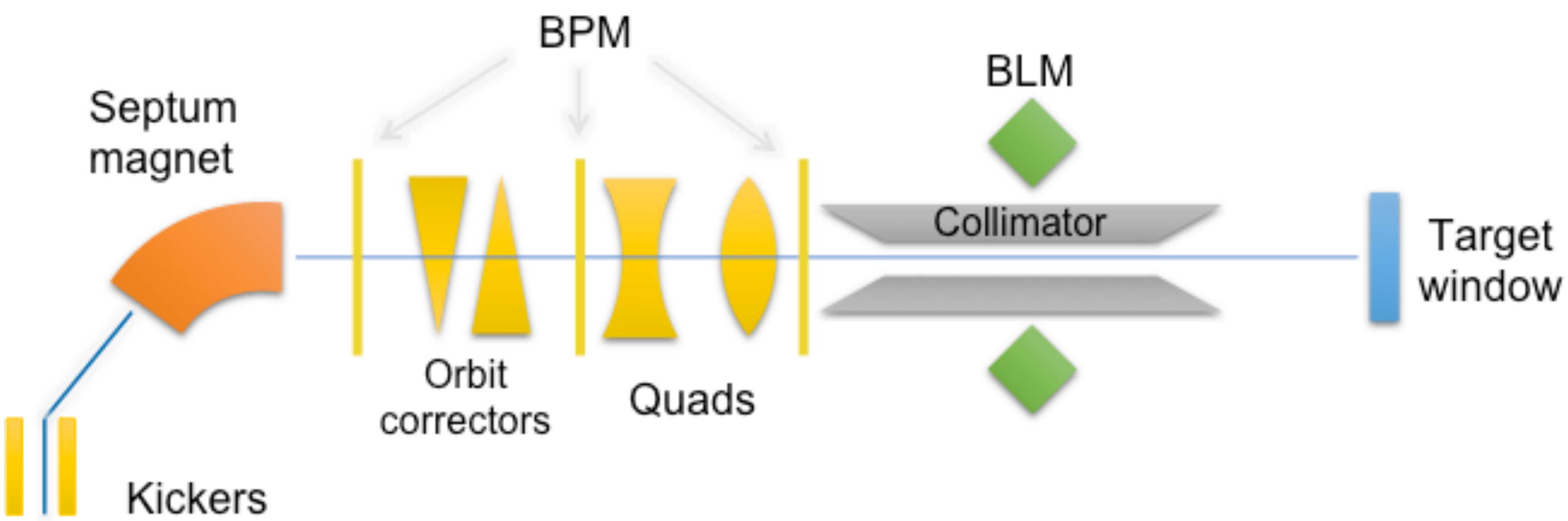
Circular accelerator



- E_p = 200 GeV
- Intensity = 10^{14} p/pulse
- E_{beam} = 3.2 MJ
- Repetition rate = 0.1 Hz
- P = 320 kW
- ε = ??

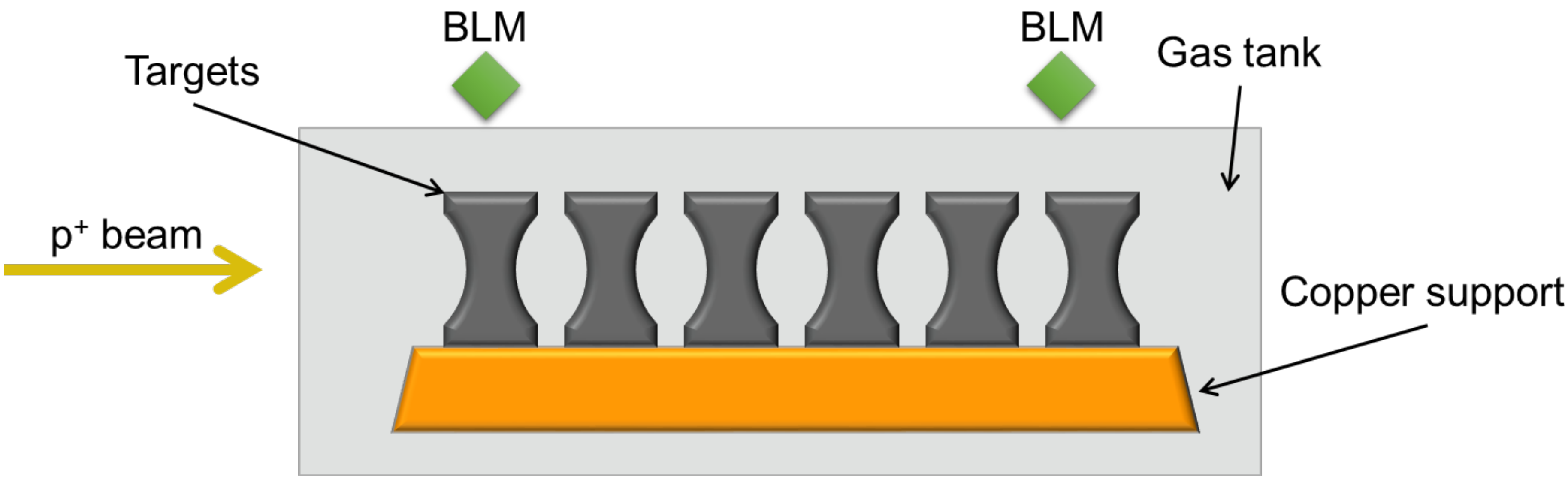
Beam transfer line

- BPM for trajectory check
- Quadrupoles to change the beam focusing
- BLMs will give information about losses



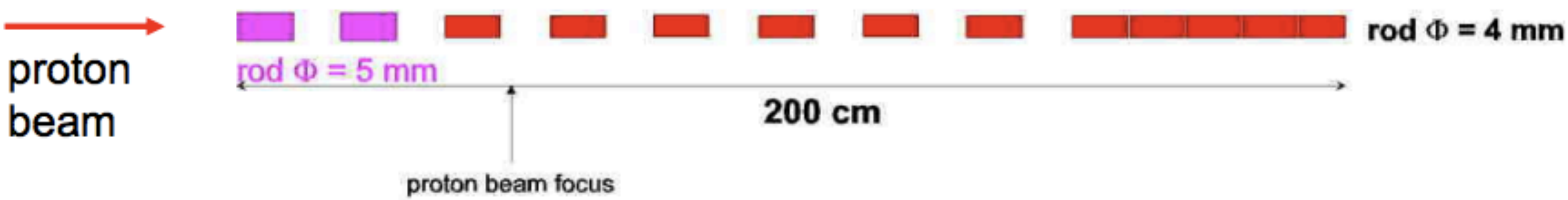
Initial design: Gas cooled segmented carbon target

- Not negligible energy deposition
- Resistant material + easy cooling design and geometry
- Targets fixed on copper (heat cond.) support
- Fragmentation and geometry optimization to increase cooling capacity
- **IDEA:** rotating target to avoid concentrated energy deposition



CNGS example

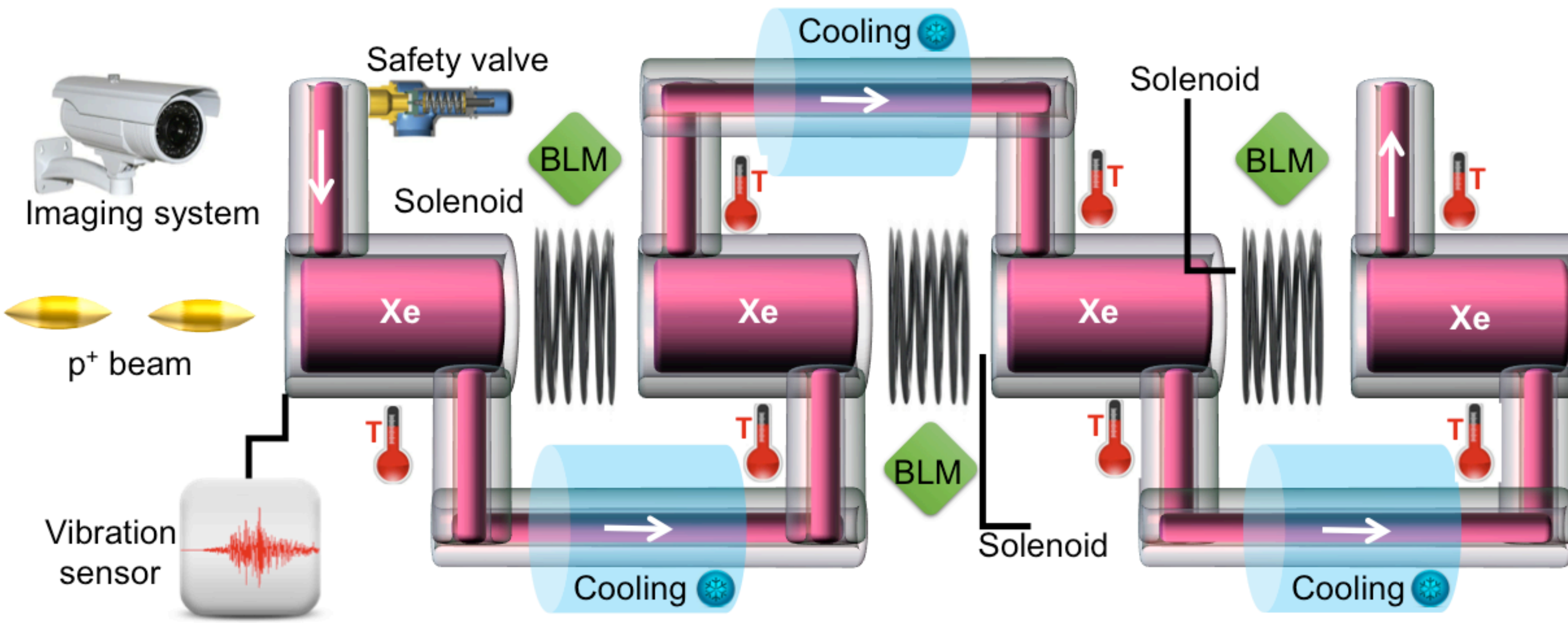
10 cm long carbon rods, Ø = 5mm and/or 4mm



Note: - target rods thin / interspaced to "let the pions out"

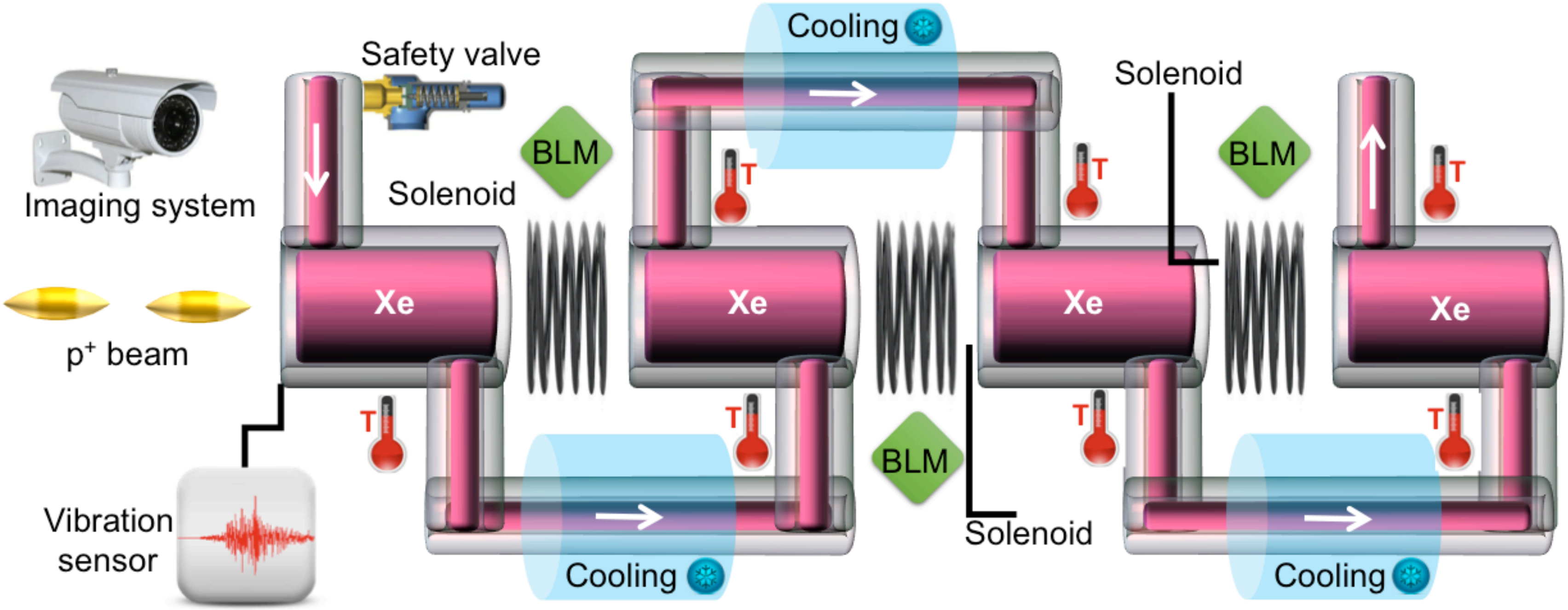
- target shall be robust to resist the beam-induced stresses
- target needs to be cooled (particle energy deposition)

The crazy but fancy segmented high pressure liquid target



The <u>crazy but fancy</u> segmented high pressure liquid target

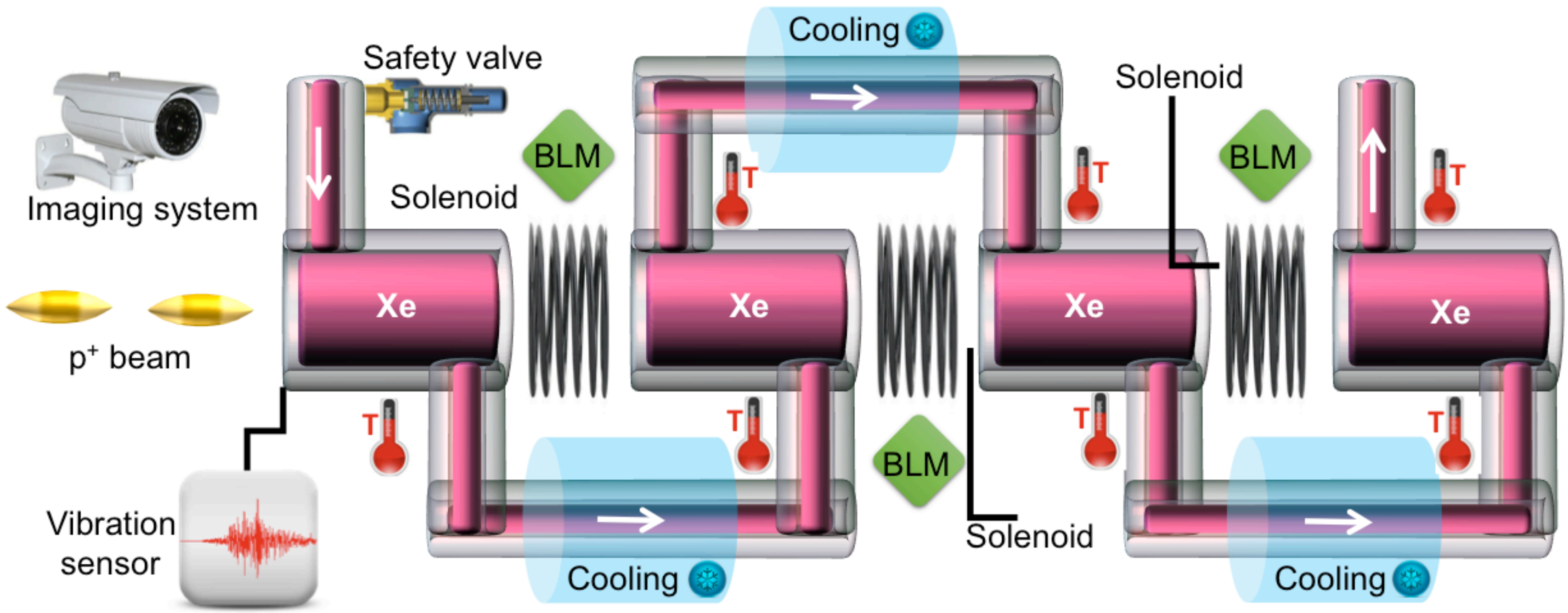
- Xenon as high Z gas
- High pressure → high density (reduced interaction length)
- Gas acts as target and coolant at the same time
- Gas can withstand pressure shocks (no rigid internal structure)
- Solenoids for focusing
- Target is longer



The <u>crazy but fancy</u> segmented high pressure liquid target

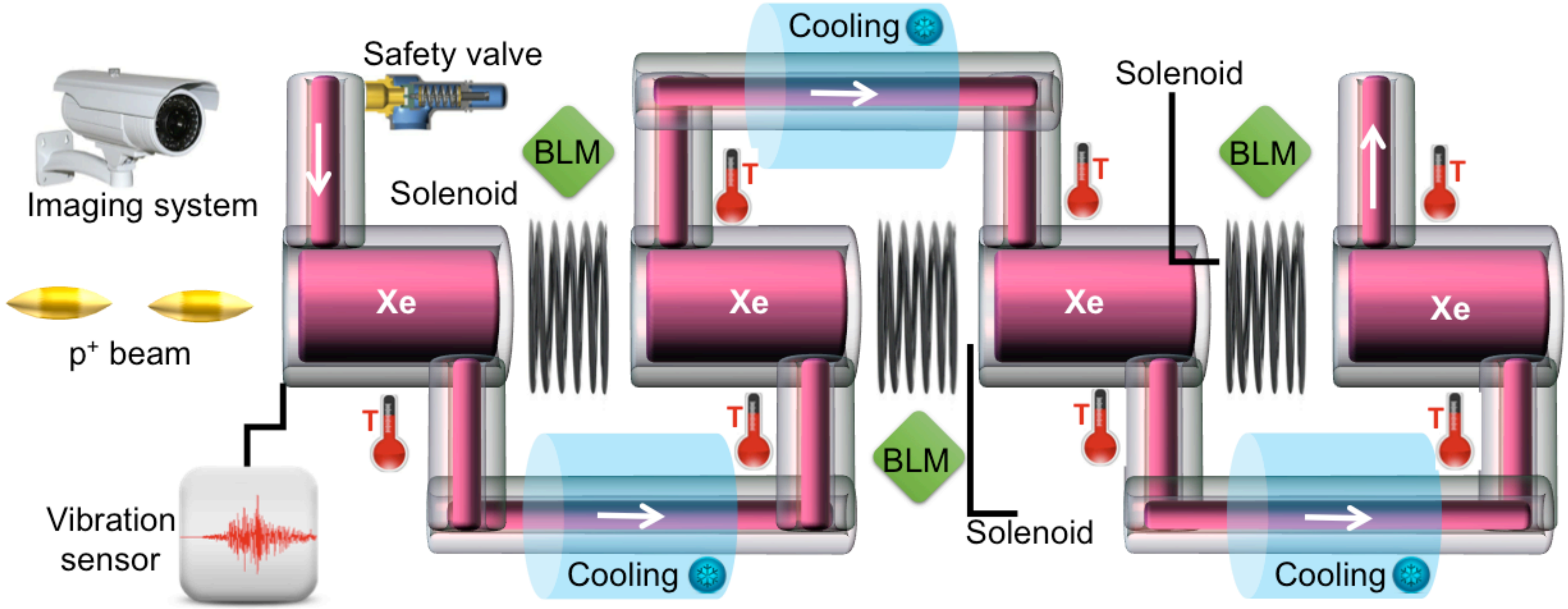
- Xenon nuclear interaction length:
  - λ_I = 1.84 E^4 cm @1 bar
  - λ_I = 1.84 E^2 cm @ 100 bars
- L_{target} = 3 * λ_I ~ **<u>6 m</u>**

- 10 gas tanks of 60 cm each
- 40 cm spacing to let the pions out and provide additional focusing
- Total target length about **<u>10 m</u>**

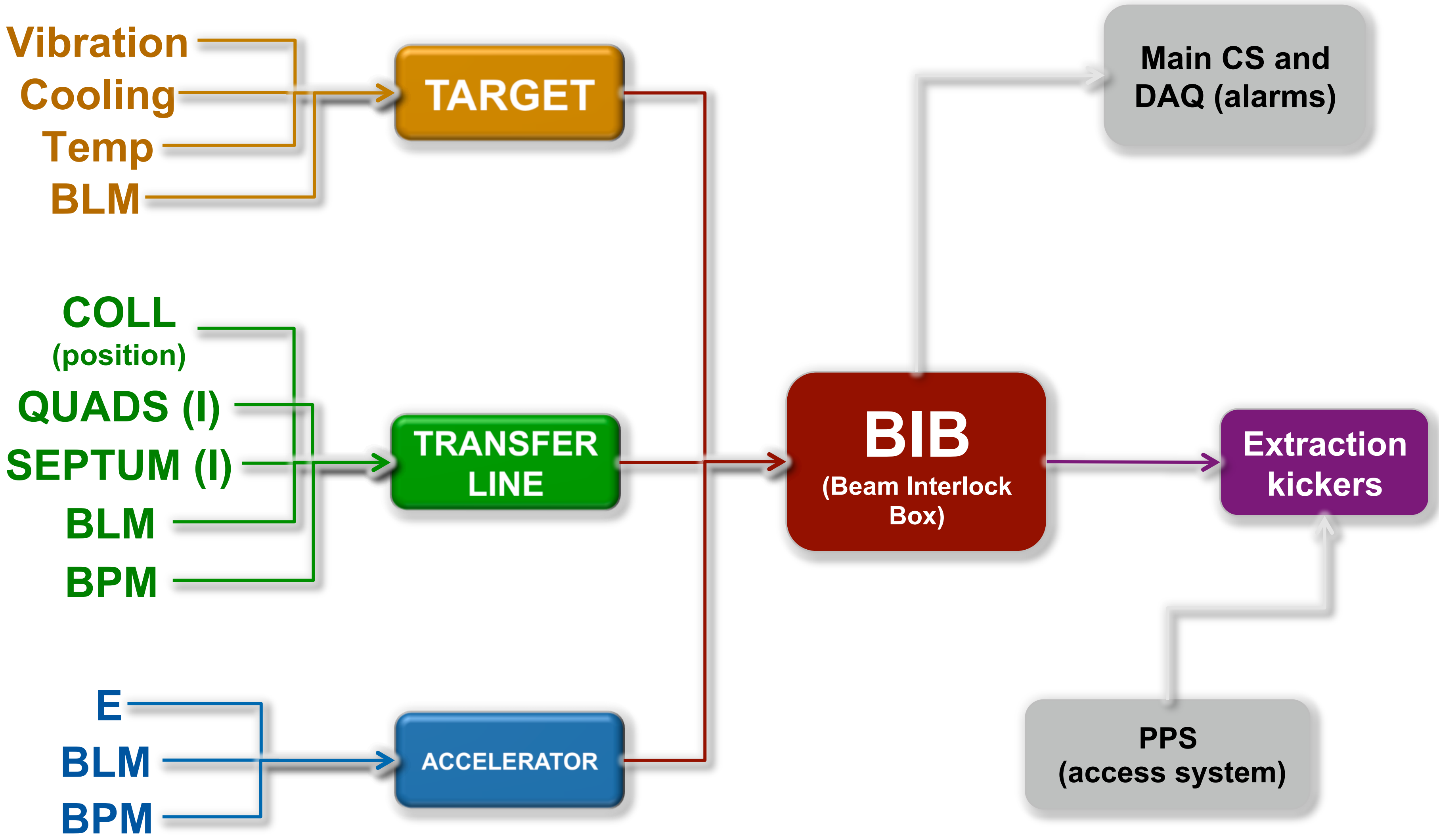


The crazy but fancy segmented high pressure liquid target

- Maximum allowed $\Delta T = 1000$ K
- $C_{heat} = 158.32$ J/(kg*K)
- $\rho = 5.89$ g/l @1 bar, 300 K
  - $\rho = 589$ g/l @100 bar
- V ~ 50 liters
- **Cylindrical target → r = 15 cm**
- **Total cooling power = 320 kW**



Beam interlock System



Conclusions

- We have a really fancy target
- Gas targets seem to be a good alternative to solid ones:
  - They cope better with high temperature and energy deposition
  - Easier and more efficient cooling
  - Longer and have to be operated at high pressure
- In case of spallation source for neutron (protons at 2 GeV and 5 MW) we need to increase the cooling capacity
  - Maybe we can play with gas pressure?

RESERVE SLIDE 1

- Modern accelerators require an availability for providing beam for the users exceeding 90% or even 95%. An accelerator is highly complex and comprises many systems.
  - A target station needs to be highly available, specially due to
    - High radiation levels inside the station
    - Physical access can be very limited
    - Difficult to repair and replace the components
    - MTTR is very high as compared to other accelerator subsystems

- Clarify terms such as reliability, availability, MTBF, MTTR, …
  - **Reliability:** The ability of target station to generate a specified flux of neutrinos under nominal conditions.
  - **Availability:** The ratio of total time a target station generates specified neutrino flux to its total operation lifetime.
  - **MTBF:** The average amount of time that a target station generates operates before a failure occurs
  - **MTTR:** The average time required to repair the system

RESERVE SLIDE 2

- Do all accelerators require a protection system? **NO**
  - The target here requires protection system against:
    - High pressure buildup in the chamber of target
    - High temperature of gas target
    - Beam displacement from its center
    - Deformation and explosion of the chamber due to high pressure and temperature

- Sources of unavailability
  - Off center beam causing stress
  - Inefficient cooling of the target chamber
  - High pressure causing deformation to the target chamber
  - High pressure results in chamber bursting
  - Shock wave generation due to high energy deposition from beam
  - Radiation leakage outside the target station