Summary of Working Group C: Injection, Extraction, Accelerator Systems

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Outline of Summary

1. Essence of the Work Group
   - New ring/lattice concepts
   - Commissioning efforts
   - Designs for new facilities or upgrade plans (and challenges)
   - Operational facilities
     - Problems encountered
2. Foil technology status
3. Future technology for H- injection
4. Working group perspectives

Essence of the Work Group

- Composition: 2 oral sessions (9 talks) + Poster session (9 posters)
  - 1st session concentrating on injection
  - 2nd session on new accelerator designs and extraction
  - Work group discussion after 1st session focused on injection issues.
- New ring/lattice concepts
  - Non-Scaling FixedFieldAlternatingGradient rings/lattices
- Commissioning efforts
  - EMMA
- Designs for new facilities or upgrade plans
  - CERN (PSB and PS2)
  - PAMELA
  - PEFP
  - Project X
  - Mu2e (resonant extraction from FNAL Debuncher)
- Operational facilities
  - SNS
  - JPARC

New Accelerator/lattice Concepts

- NS-FFAG
  - Benefit with large momentum aperture
    - With one or a few passes
      - Gantries
      - RlA's for muons and electrons
      - p+- or proton rings for longitudinal manipulations
    - For non-relativistic particles ->a few hundred turns
      - Particle therapy machines
      - Proton Drivers
      - Heavy ion drivers
- New "solid state direct drive" linear induction accelerator

Commissioning efforts

- Electron Model for Many Applications (EMMA)
  - Although not High Energy or High Intensity- first demonstration of a Non-Scaling FFAG(10-20 MeV)
    - Goals: EMMA Experiment (verify this new concept works)
      - Rapid acceleration with large tune variation
      - Serpentine acceleration
      - Map the transverse and longitudinal acceptances
    - Completed injection commissioning (1000's turns)
      - Limited diagnostics (BPM's)
      - Injection kicker ringing
    - Demonstration of acceleration (current focus)
    - Detailed bench marking with codes

Challenges for machines under design

- Project X:
  - Foil issues associated with long duration (~25 ms) injection of CW beam for proton driver or multiple short pulse injections. Constrains beam current to ~1mA which increases circulating beam hits on foil.
- CERN:
  - Both Linac2 upgrade from50 MeV protons to 160 MeV H- requires PSB injection upgrade to H- multiturn injection. will try to use existing injection hardware.
  - PSB extraction upgrade from 1.4 GeV to 2 GeV and the modification of PS for 2 GeV injection (including upgrade of injection line hardware)
  - Challenge is to make the new system work with the old hardware.
- PAMELA:
  - 30 to 70-250 MeV NS-FFAG (orbit moves with energy)
  - Design a fast and slow vertical extraction system which matches into extraction channel without
- Mu2e:
  - Design a resonant extraction system with good spill quality and low losses in the presence of large space charge and momentum spread.
- PEFP:
  - Currently operating 20 MeV linac, cavities to extend to 100 MeV finished this year. Plans for upgrade to 1 GeV RCS

Operational facilities

- Injection Experience in Recent High Power Machines
  - Despite detailed design work, both machines have suffered problems in injection areas.
  - Injection radiation levels are the hottest areas in both machines. This was anticipated.
  - Not anticipated was the amount of manpower + monetary resources that would be dedicated to addressing injection region issues after start of operations.

JPARC + SNS Injection/Extraction Recent Issues

JPARC:

- High loss due to circulating beam foil hits. Full aperture model not available during design stages, so loss locations not accurately predicted.
- IDmp aperture restriction causing beam loss.
- Extraction septum stray field issue

SNS

- IDmp aperture restriction also a problem for SNS.
- Foil damage and failure due to vacuum breakdown.
- Foil assembly damage due to reflected convoy (H- stripped) electrons.

Foil Technology Status

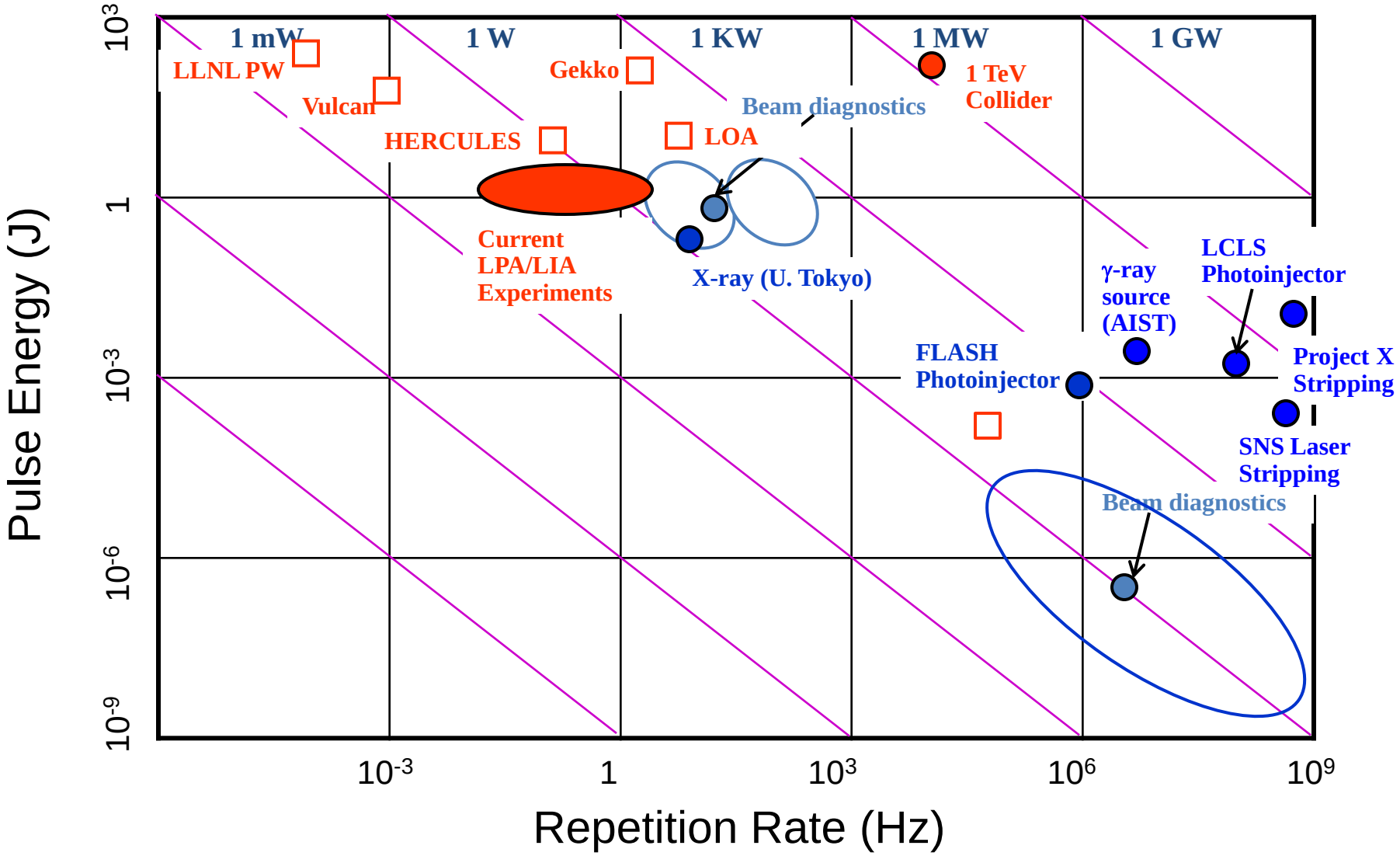
- Some foils currently in use are those which were under discussion as "promising new foil candidates" at HB2002, HB2004.

Machine	Beam Power	Foil	Lifetime / Use
JPARC	120 kW	HBC	1 Yr
SNS	1 MW	Diamond foil	18 weeks
LANL	80 kW	HBC	2 per year
ISIS	200 kW	Aluminum Oxide	1 per year

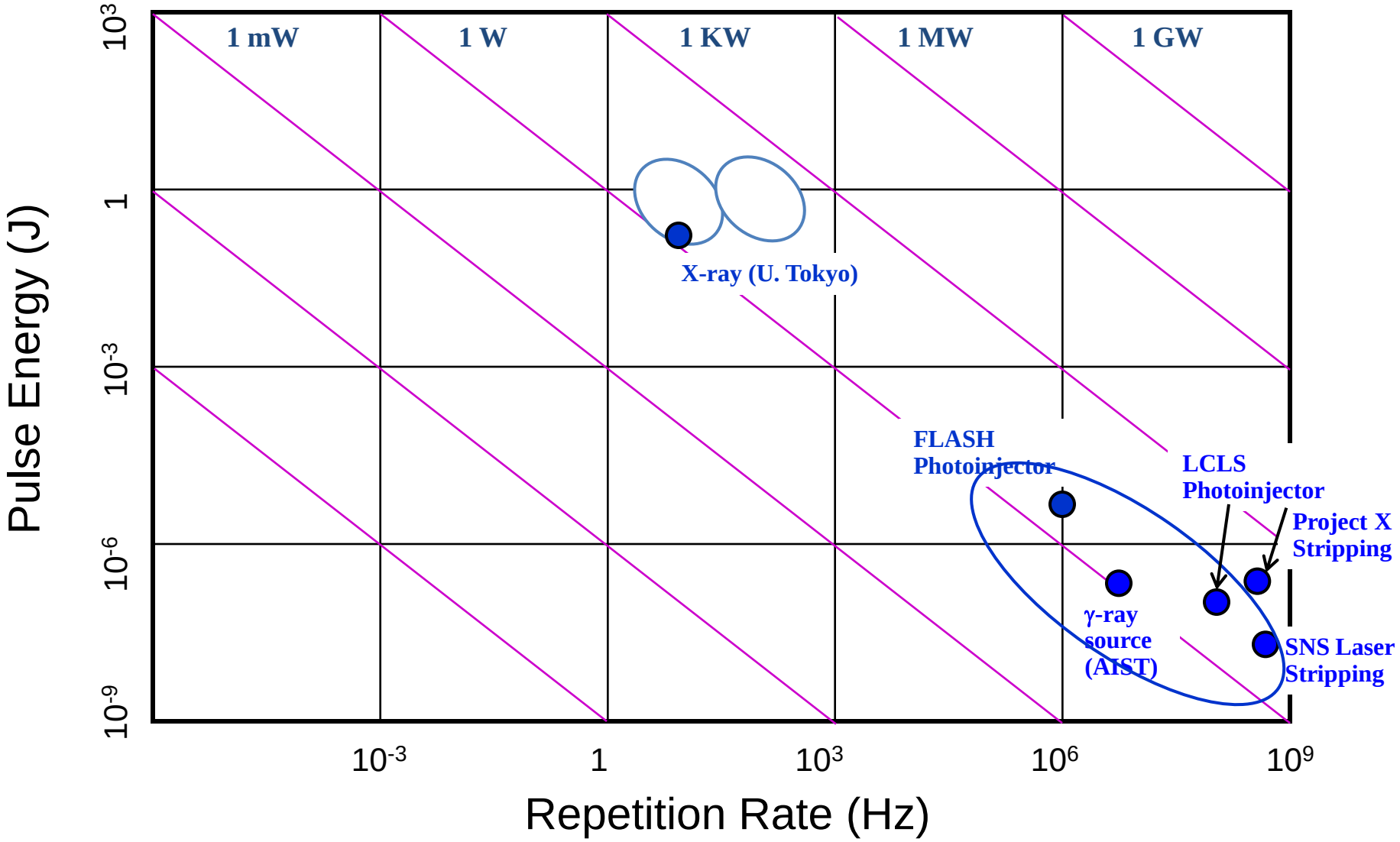
Future Technology for H- Injection

- Unique foil injection concepts
  - "Rotating foils"
- Laser technology
  - Lasers have come a long way in the last decade, but still fall short of laser-assisted stripping injection needs for high power beams.
  - Injection stripping requires: high peak power (MW) , large pulse energy (mJ-mJ), high average power (kW), high pulse frequency (100's Mhz)
  - Burst mode laser system
  - Recycling helps but has it's own challenges.
  - Coherent beam combining
  - Cryogenic laser amplifiers

Gap between application requirements and available specs



Average power dropped more than 1000 times!



Working Group Perspective

- **Question:** What do we need to get to 5 MW and beyond?
- **Response**:

  1) "A model versus measurement benchmark of foil temperature."

  We need to validate the foil models before we can rely on them to give us limits.

  This is a complicated diagnostics measurement because of the high radiation in the environment of the injection foil.

Working Group Conclusions

Working Group Comment:

Dump lines are not getting enough attention during the design stages.

For high power beams, the waste beams contain a significant amount of beam power and beam loss can be an issue.

Dump lines need more aperture, more knobs, e.g, more flexibility overall.

In the End

- There were many enlightening presentations
- There were many fruitful discussions
- There was much food and coffee
- A wonderful banquet
- Superb presentation and support personnel
- Friendly smiles everywhere
- And a big round of applause for PSI.