Front End RF and Gas Cavities

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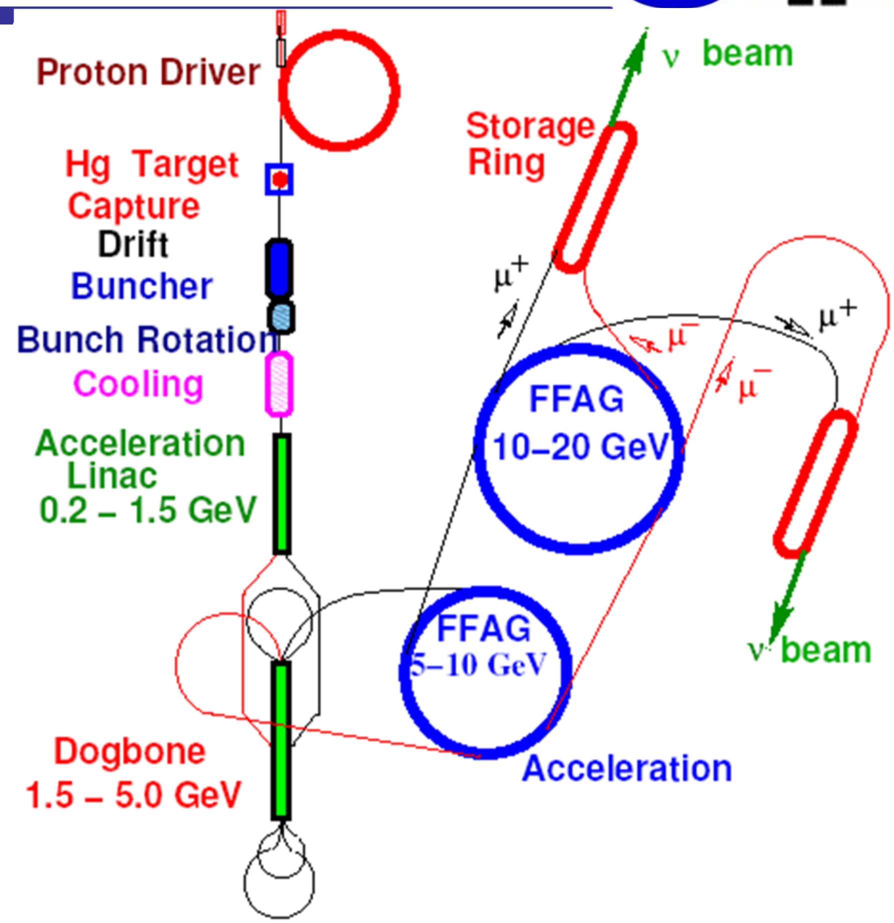
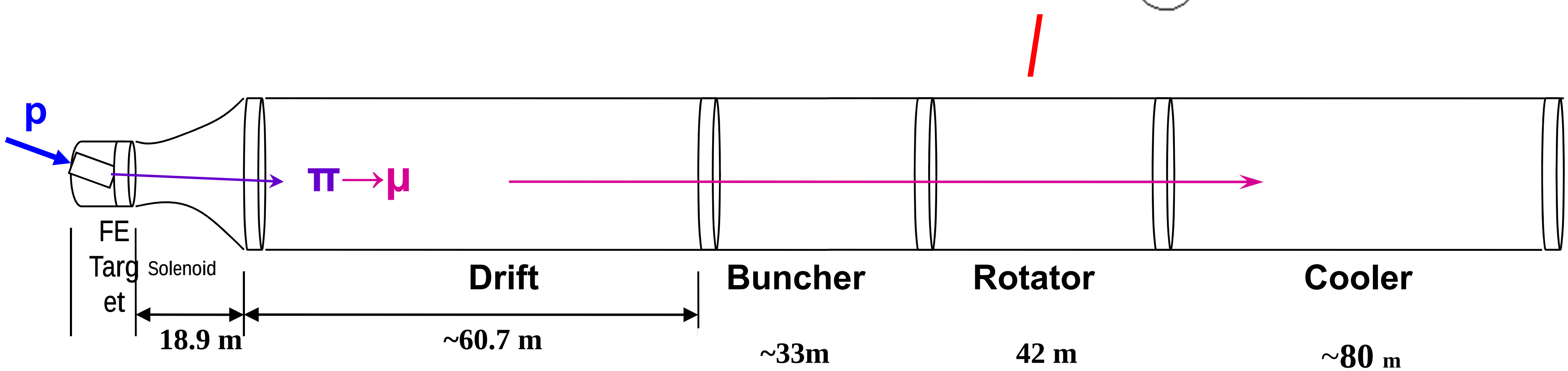
Outline

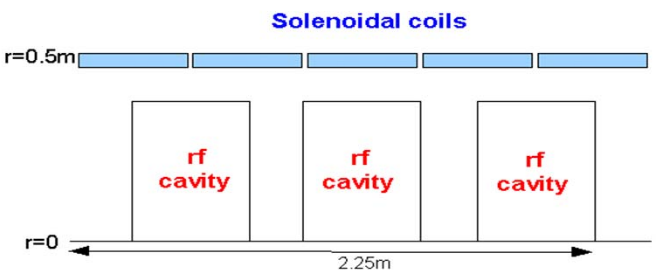
- Introduction
  - ν-Factory Front end
  - rf/B limitation
- gas-filled rf
  - ν-Factory→μ^+-μ^- Collider
- Discussion

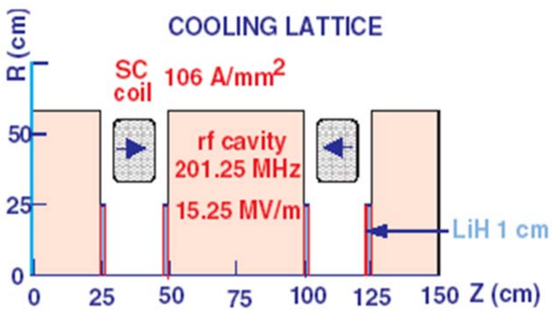




Parameters of IDR baseline

- Initial drift from target to buncher is 79.6m
  - 18.9m (adiabatic ~20T to ~1.5T solenoid)
  - 60.7m (1.5T solenoid)
- Buncher rf – 33m
  - 320 → 232 MHz
  - 0 → 9 MV/m (2/3 occupancy)
  - B=1.5T
- Rotator rf -42m
  - 232 → 202 MHz
  - 12 MV/m (2/3 occupancy)
  - B=1.5T
- Cooler (50 to 90m)
  - ASOL lattice, P_0 = 232MeV/c,
  - Baseline has ~16MV/m, 2 1.1 cm LiH absorbers /cell





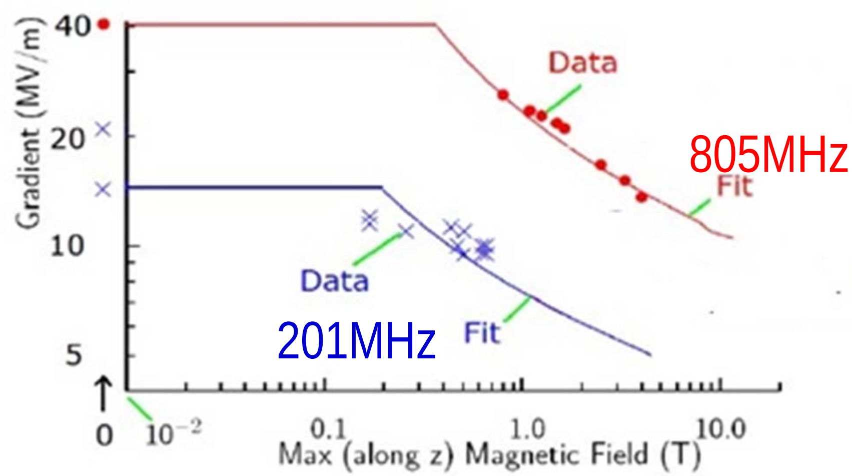
Possible rf cavity limitations

V'_{rf} may be limited in B-fields

- 800 MHz pillbox cavity
- 200 MHz pillbox test (different B)

➢ NF needs up to ~1.5T, 12 MV/m

- More for cooling



Potential strategies:

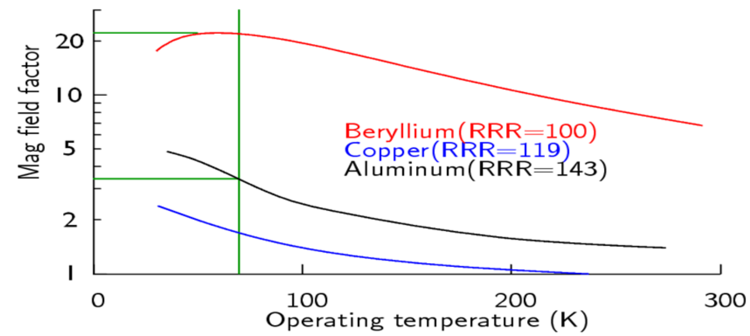
➢ Use Be Cavities (Palmer)

➢ Use lower fields (V', B)

- <10MV/m at 1.5T?
  - Need variant for cooling ?

➢ Cooling channel variants

- Use gas-filled rf cavities
- Insulated rf cavities
- Bucked coils (Alekou)
- Magnetic shielding

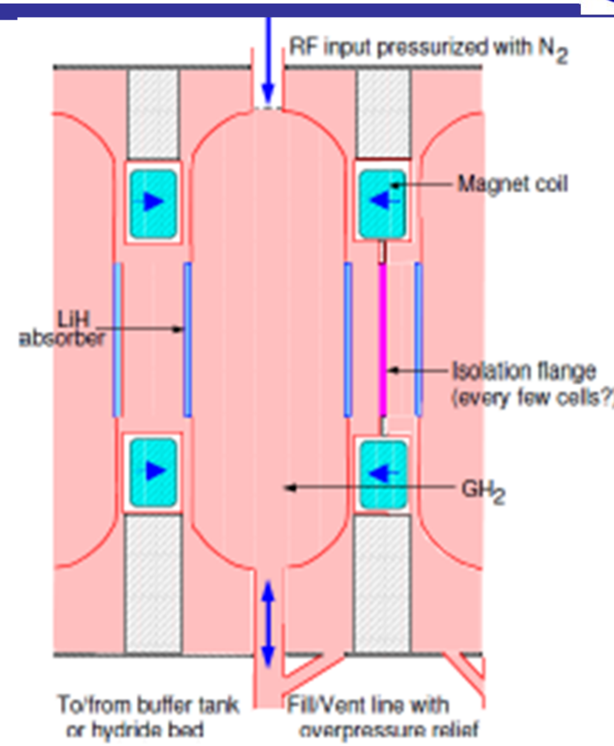


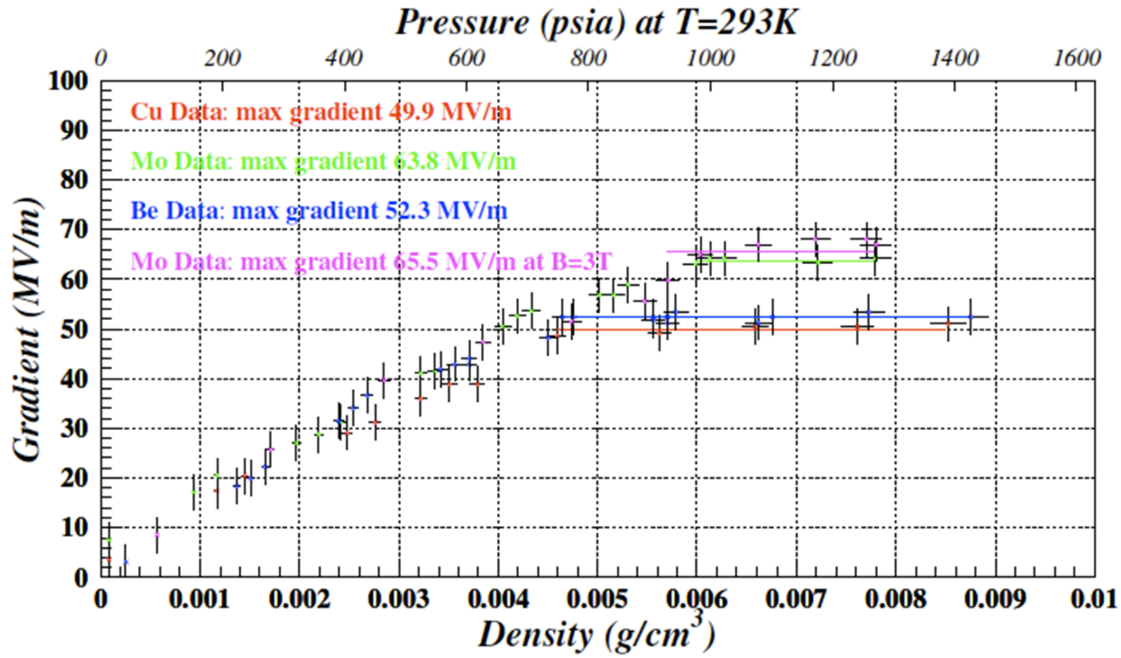
Need More Experiments !

- **at ~200MHz**
- **with B ~$B_{frontend}$**

H_2 gas-filled rf in front end cooling section

- Scenario I
  - include only enough gas to prevent breakdown – ~20 atm
    - E/P = ~9.9 V/cm/Torr
- Scenario II
  - include gas density to provide all cooling
    - ~100atm
      - E/P ~2





beam in rf cavity

- ionization produces electrons along the beam path
  - ~1 e^- / 35eV of energy loss (?)
  - μ in H_2 – 4.1 MeV/gm/cm^2
    - At Liquid density (0.0708) 8290 e^- /cm
    - At 1 atm ~9.82 e^-/cm
    - At 20 atm ~196 e^-/cm
    - At 100atm ~980 e^-/cm
  - Electrons have low energy collisions with H_2 in electric field, equilibrating to a meant velocity proportional

- baseline 200 MHz cavity is 0.5m long
  - 10^4 e/cavity per μ at 20 atm
  - 5×10^4e/cavity at 100 atm

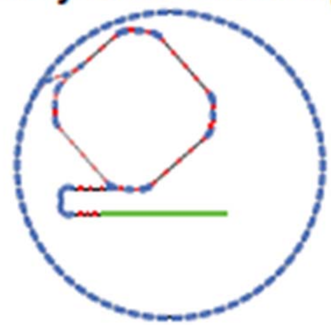
Electrons within cavity

- Electrons have low energy collisions with H_2 in electric field, equilibrating to a mean velocity proportional to x=E/P (Hylen)
  - $$\vec{v}(x) = \mu_H(x)\vec{x} \times 5.9 \times 10^5 \text{ m/s}$$
  - $$\mu_H(x) \cong 0.0172x^{-0.53}(1-0.024x^{0.71})^{-1.75}$$
    - x is in V/cm/Torr
- Electrons extract energy from the cavity from eV·**E**
  - Energy loss per rf cycle:
  - $$\Delta E \cong \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} e\mu_H(x\cos\theta)x\cos\theta\ 5.935 \times 10^5 E_{rf}\cos\theta d\theta$$
    - assumes electron velocity tracks Electric field through rf cycle
  - $\Delta E = 2.6\times10^{-16}$ J (x=10) or $\Delta E = 1.1\times10^{-16}$ J (x=2)
    - 16MV/m, 200 MHz

Beam Scenario ?

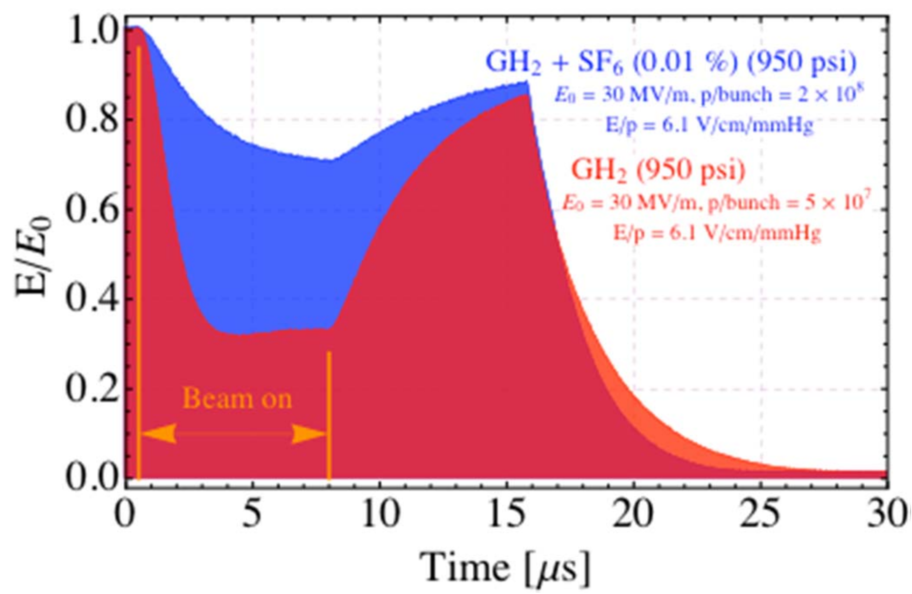
- Muon + intensity depends on proton production intensity
  - Assume 4MW – 8GeV
  - $N_p \approx 3\times10^{15}$/s
- 60 Hz scenario
  - ~5×10^{13}/bunch
  - Each bunch produces train of secondary bunches
    - ~20 bunches, 0.2 μ/p
    - ~5×10^{11} charges/bunch
- 50 Hz, 5 bunches/cycle
  - ~1.2×10^{13}/bunch
    - ~10^{11} charges/bunch

FFAG/synchrotron option



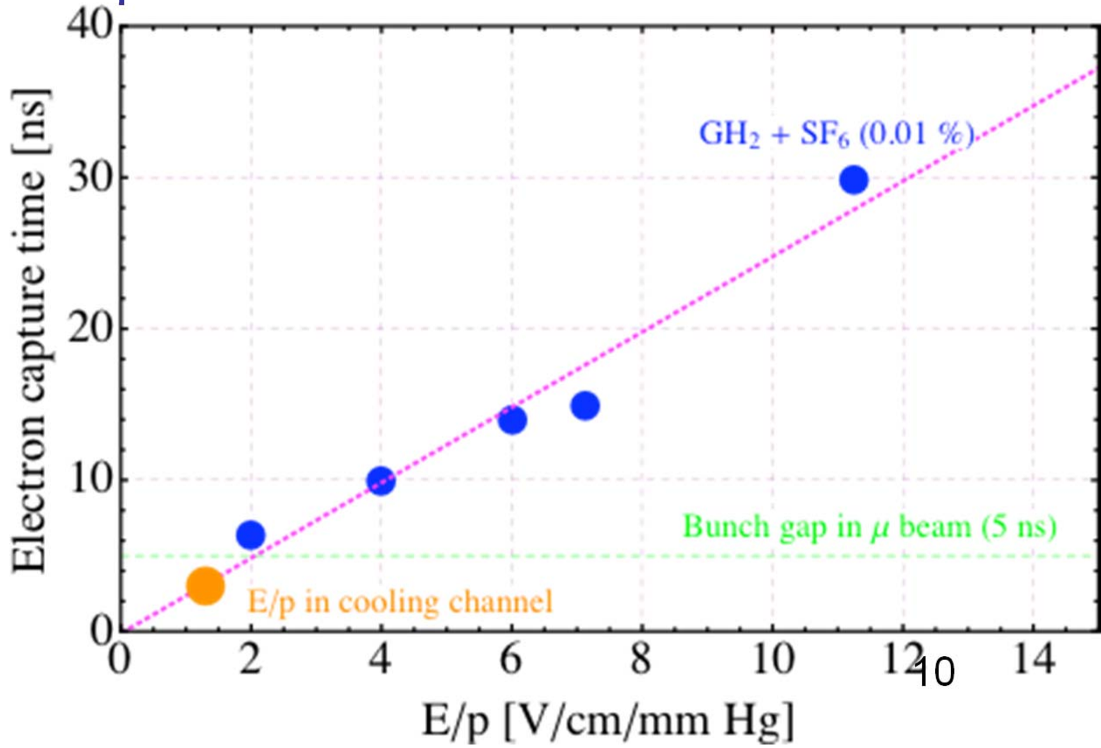
Effect in rf cavity:

- Baseline stored energy in 1 rf cavity is 158J
  - $5\times10^{11}\times10^{4}\times 2.6\times10^{-16}$ J/cavity/bunch/rf cycle
    - ~1.3J/rf cycle
  - but we have ~20 bunches
    - ~26J/rf cycle
  - after 20 rf cycles
    - lose 200J
- Assumes no recombination/loss of electrons over 100ns
  - (20 cycles)
- 100 atm scenario is only a factor of 2 worse.



Mitigation

- Fewer p/bunch
  - 50Hz, 5 bunches, 2MW scenario reduces by factor of ~10
    - manageable
- Must reduce free electron lifetime in gas
  - if < ~10ns problem is manageable
  - < ~200ns (KY)
  - Is smaller with small amount of dopant



Conclusions

- Gas-filled rf in ν-Factory Front end Cooling **could have large beam-loading effect**
  - Require electron recombination within ~20ns
  - Can obtain this with dopant in H_2

- Gas-Filled rf can be used in Front end
  - is not trouble-free however