Case Study

Design 5 - group 3

Neutrino Source

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Requirements

Pulse length	3 ns
No. of bunches	5 bunches
Repetition rate	50 – 60 Hz
Average beam power	~ 4 MW
Beam energy	2 – 8 GeV
Particle type	p+ or H-

3 possibilities:

- Neutrino factory (μ decay)
- Super-beam (π decay)
- Beta-beams (β decay of instable nuclei, i.e. ^{18}He ^{8}L ^{8}B)

Physics considerations (I)

- ν production chain:

$$\mathbf{p + TARGET} \rightarrow \pi \rightarrow \boldsymbol{\mu} + \nu_\mu \rightarrow e + \boxed{\boldsymbol{\nu_\mu}} + \underline{\nu}_{\mathbf{e}}$$

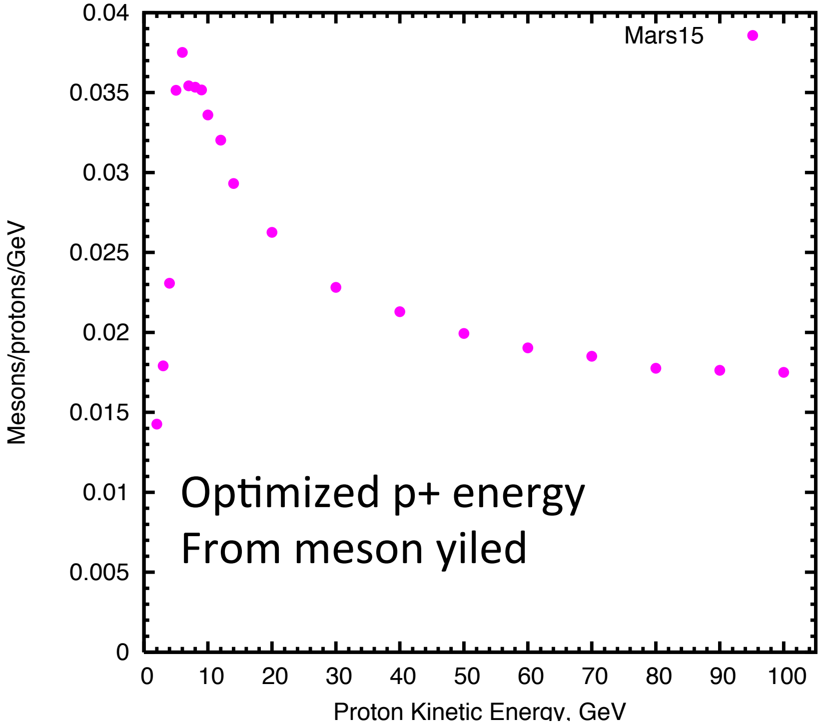
- **Fast pulsed** (to trap the π/μ)
- **High power**: $P = I \times E_p \times f$

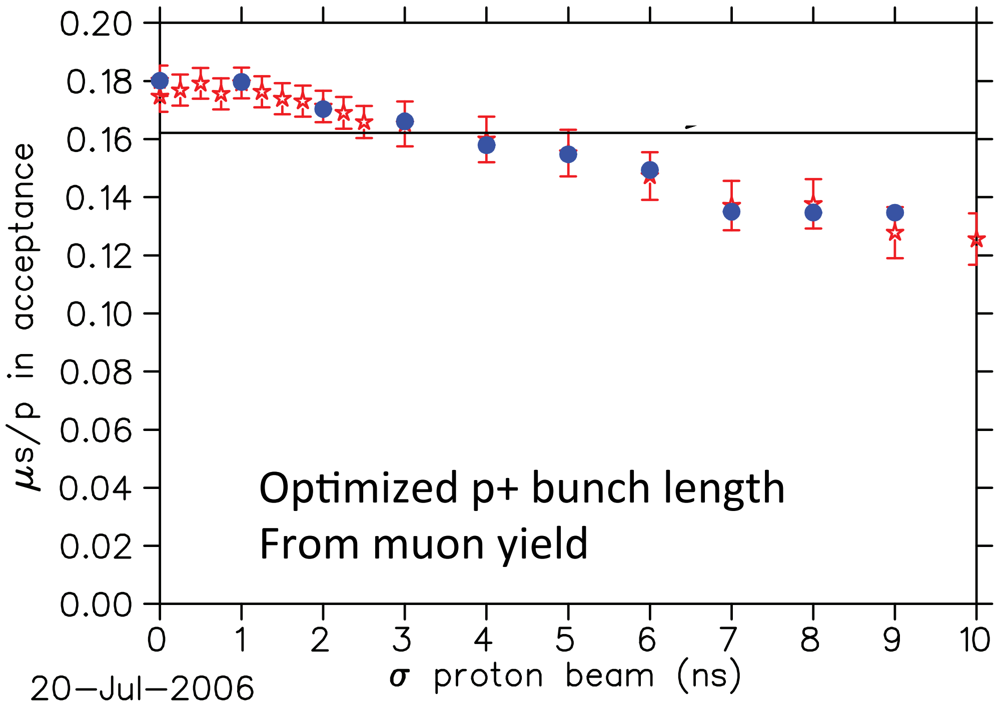
High Energy (E_p)	2 – 8 GeV
High repetition rate (f)	50 – 60 Hz
High power (P)	~ 4 MW
Short bunches	5 x 3 ns

- Large number
- High energy
- Small energy spread

- High intensity
- High energy
- Known spectrum
- Low contamination

Physics considerations (II)





- From the "Interim Design Report" of the IDS-NF collaboration

Beam intensity @ TARGET

- Given the optimal parameters we can compute the **number of p+ per bunch n_p at the target:**

$$\mathbf{P = e \times E_p \times n_b \times n_p \times F}$$

$$4\text{ MW} = e \times (2\text{-- }8)\text{ GeV} \times 5 \times 3\text{ ns} \times \mathbf{n_p} \times 50\text{ Hz}$$

- For $E_p = 2$ GeV → $n_p = 5 \times 10^{13}$ p+ / bunch

- For $\mathbf{E_p}$ = **8 GeV** → $\mathbf{n_p = 1.25 \times 10^{13}}$ **p+ / bunch**

typical values for neutrino factory: $n_p \sim 10^{14}$

Accelerator Choices

- Given the **high beam intensity, power, and pulse f_{rep}** , we should consider a **LINAC**-based setup
  - Provides opportunity to use the facility for other applications simultaneously
- Similar design planned for Project X (8 GeV) and studied for SPL complex (5 GeV, 534 m)

However:

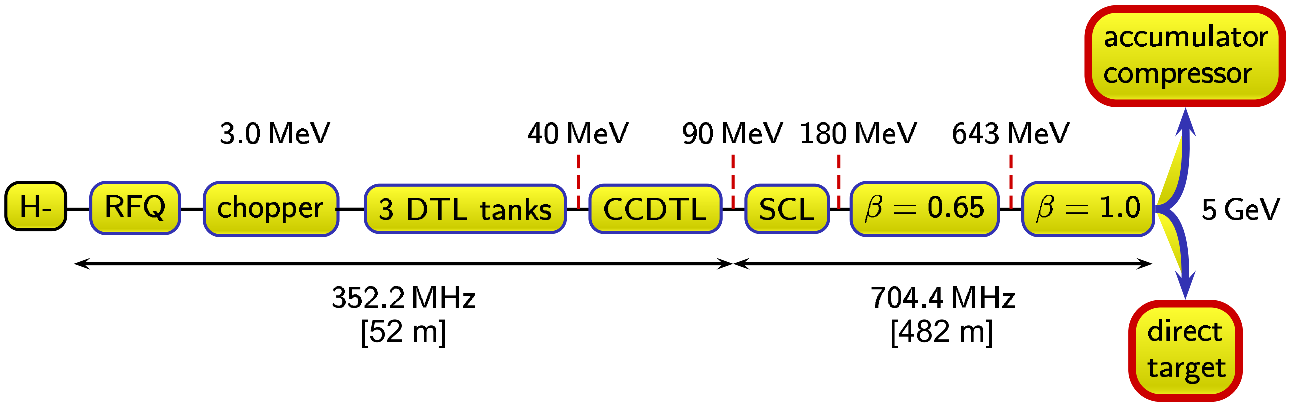
- A linac alone is not adequate for creating the necessary pulse structure at the target

→ We need an **accumulator** + **bunch compressor**

LINAC parameters

- ❖ **t_{pulse} = 0.4 ms** (typical value)
- ❖ **f = 50 Hz** (required pulse repetition rate)
- ❖ **H^- injection**
- We computed:
  - Duty cycle: **η = 2%**
  - Average current: **I = P / (E * η) = 25 mA**

- Comparing with SPL design [see picture], we should go to higher frequency (1.4 GHz) and benefit from ILC technology (cryogenic, RF cavities)



ACCUMULATOR parameters

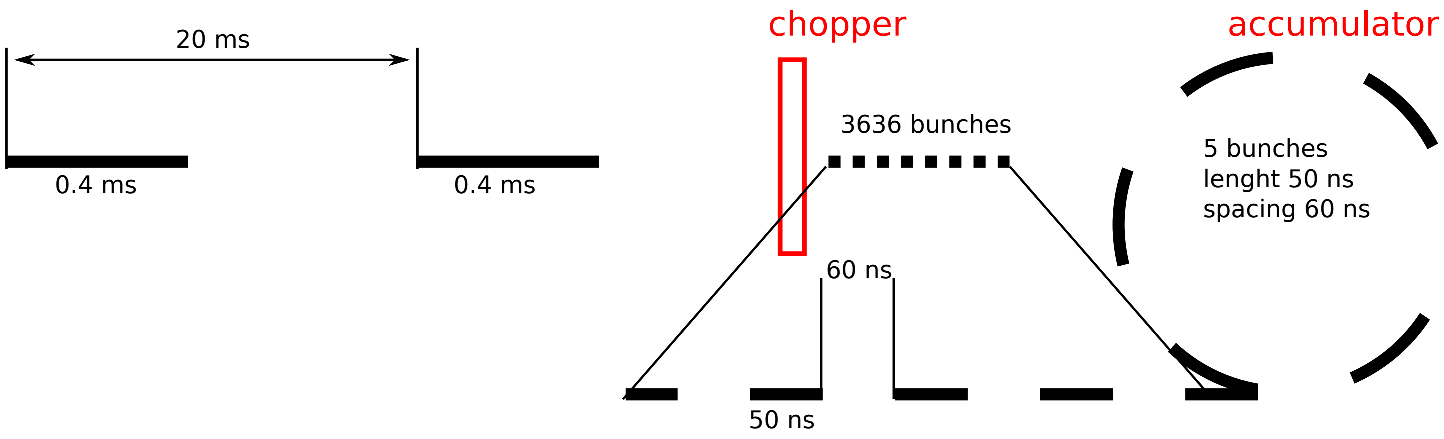
- Conventional magnets: B = 1 T
  particle energy from linac: E = 8 GeV
- We computed:
  - curvature: **ρ = 26.7 m** ($B\rho = 3.3(p/q)$)
  - circumference: **C = 167.76 m** (neglecting straight sections)
  - revolution **τ_{rev} = 0.56 μs**
  - number of turns for injection: **715 turns**

  → Injection can only be made with charge exchange scheme
  - If we use a isochronous machine, no RF system needed

- We shall optimize time structure of injected beam with **5 bunches of 50 ns separated by 60 ns gaps.**

Bunch structure

- **Injection into accumulator ring will be challenging**
- Time structure:



- A compressor will then shorten the bunches from 50 ns to 3 ns, by phase rotation.
  - ρ, τ_{rev} will be the same as the compressor
  - RF harmonic number will be 5

Summary

- Elements in our ν facility:

LINAC (H- , E = 8 GeV, t_{pulse} = 0.2 ms, I = 25 mA, duty cycle = 2%)

ACCUMULATOR (isochronous, n_b = 5, t_{bunch} = 50 ns, t_{sep} = 60 ns, n_p = 1.25 x 10^{13})

COMPRESSOR (5 bunches, t_{bunch} = 50 ns → 3 ns)

- Challenges:
  - Very long linac
  - Cryogenic technology
  - Fast chopping
  - Beam losses in the linac

Thanks for Listening