Cost Saving

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Study 2 costs

Table A.1: **Construction Cost Rollup per Components for Study-II Neutrino Factory.** All costs are in FY01 dollars.

System	Magnets ($M)	RF power ($M)	RF cav. ($M)	Vac. ($M)	PS ($M)	Diagn. ($M)	Cryo ($M)	Util. ($M)	Conv. Facil. ($M)	Sum ($M)
Proton Driver	5.5	7.0	66.1	9.8	26.6	2.2	28.5		21.9	167.6
Target Systems	30.3			0.8	3.5	8.0	18.8		30.2	91.6
Decay Channel	3.1			0.2	0.1	1.0	0.2			4.6
Induction Linacs	35.0		90.3	4.4	163.3	3.0	3.6		19.5	319.1
Bunching	48.8	6.5	3.2	2.7	2.1	5.0	0.3			68.6
Cooling Channel	127.6	105.6	17.7	4.3	4.8	28.0	9.5		19.5	317.0
Pre-accel. linac	46.3	68.4	44.1	7.5	3.0	6.0	13.6			188.9
RLA	129.0	89.2	63.4	16.4	5.6	4.0	28.9		19.0	355.5
Storage Ring	38.5			4.8	2.2	29.0	4.8		28.1	107.4
Site Utilities								126.9		126.9
Totals	**464.1**	**276.7**	**284.8**	**50.9**	**211.2**	**86.2**	**108.2**	**126.9**	**138.2**	**1,747.2**

Extracted Totals

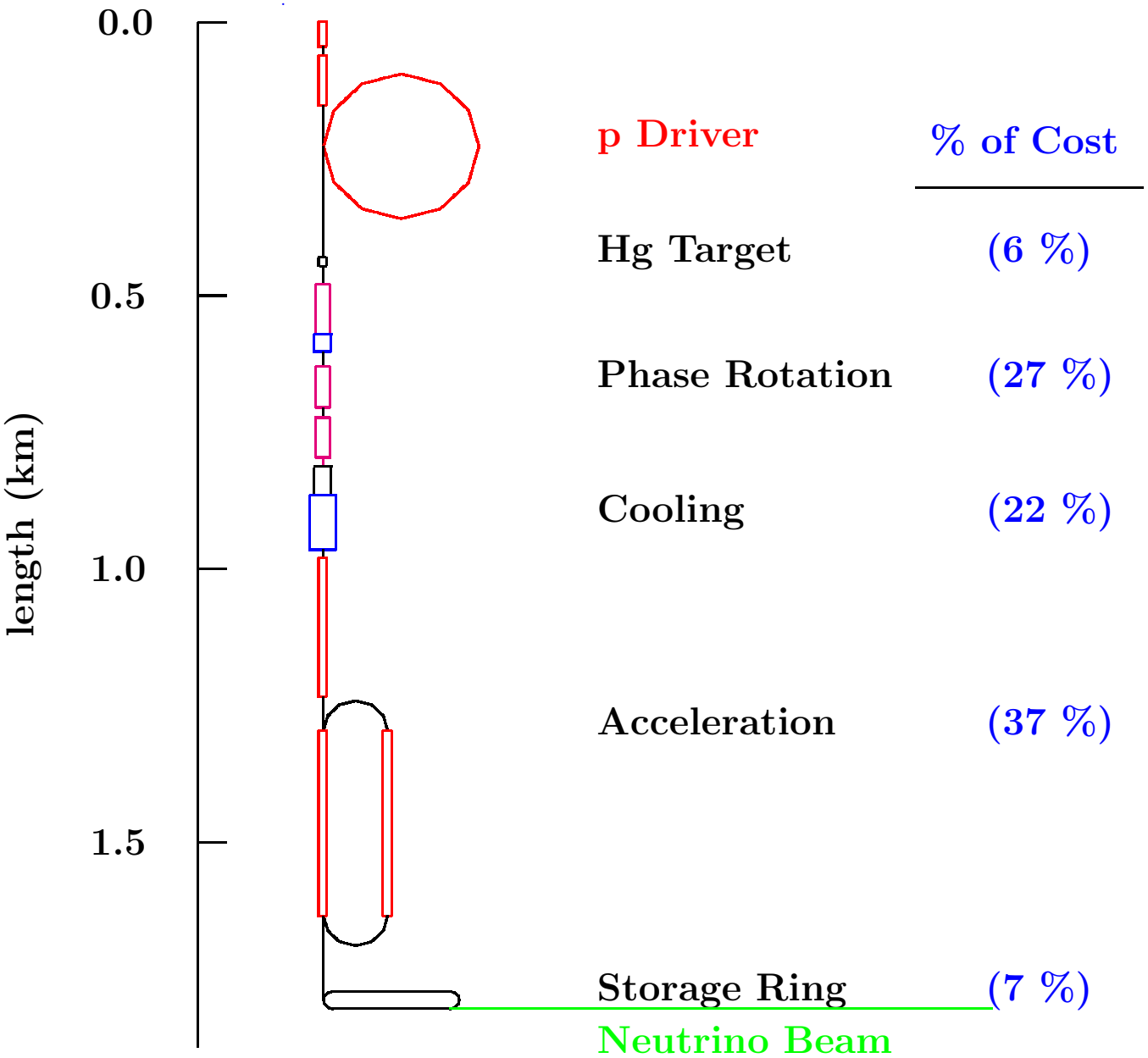
	Cost M$	Base M$	% of total	% of Base
Driver	168		9.6	
Target	92	92	5.2	6
Phase Rot & Bunching	393	393	22.5	27
Cooling	317	317	18.1	22
Linac + RLA	544	544	31.1	37
Storage Ring	107	107	6.1	7
Site	127		7.2	
Total	1747	1452	100	100

These costs do not include 10% missing items, contingency, inflation etc. But I use it as basis for % savings.

The total, excluding Driver (which has other uses), and "Site Utilities" (assumed $\propto$ item costs), is 1453 M$.

** I will give savings as % of this cost.

Study 2 Schematic



Plug Compatible Mods

- Increase Driver Power
  - Gain Intensity $\times 4$
  - Moderate Cost $\approx$6 % **
  - Very Cost Effective
  - feasibility moderate
- Bunched Phase Rotation
  - Intensity gain/loss unknown
  - Cost Saving $\approx\approx$21% **
  - feasibility high
- No Cooling
  - Loss of Intensity to $\times 1/3$
  - Cost Saving $\approx$22 % **
    depending on upgradeability
- Spiral Emittance Exchange Cooling
  - Improved performance $\times$1-2
  - Increased cost, because longer,
  - feasibility moderate
    Cost increase unknown

- **200 MHz Non-Scaling FFAG**
  - **Performace a little down**
    more turns & more decay
  - **Less Cost from less RF**
  - **More cost from apertures**
  - **Less cost from fewer arcs**
  - **More cost from larger Circ.**
  - **Balance unknown**

Semi-Compatible Mods

Modifications that do not require changes elsewhere, but would logically suggest such changes.

- **Scaling FFAG Acceleration**
  Suggests long bunch front end
  - **Studied in Japan**
  - **$\perp$ acceptance $\approx$Study 2**
  - **Loss of Intensity by more decay $\approx$30%**
  - **Relative Cost unknown**
    Single arcs & Less RF
    But larger circ & Larger aperture

- **Lower Acceptance RLA**
  Suggests cooling to lower emittance
  - FNAL Study and Berg Scaling
  - Consider 1/100 6D acceptance
    1/6 $\times$1/6 ($\perp$), 1/3 ($\parallel$)
  - Loss of intensity better than 1/100
  - Cost savings 7-14 % **
  - See following discussion

- **Lower Acceptance Fast Synchrotron**
  Suggests cooling to lower emittance
  - Requires small $\perp$ emittance
  - allows more turns (e.g. 50)
  - Less RF
  - But more loss unknown
  - Could be much cheaper ???
  - Needs much work

Non Plug Compatible

- **Small Cooling Rings**
  - **Much Recent Progress**
  - **Better performance than Study 2 ??**
  - **Cheeper than Study 2 ??**
  - **Might allow low acceptance Acceleration without loss of performance**
  - **Kicker is least understood**

Discuss Low Acceptance RLA

- Fermi RLA Study
- For acceptance 1/36 ($\perp$s) $\times$1/3 ($\parallel$)
- Saves $\approx$100 M$ from rf $\rightarrow$ 800 MHz
  additional savings from arcs unknown
- So saving $>$ 100 M$ $> 7\%$ **

- Berg RLA Parametric Study
- For factor 1/9 ($\parallel$)
  saves 114 M$ 8 % **
- For 1/9 ($\perp$s)
  saves 57 M$ 4% **

- I guess for Pre-Accelerator
  same fraction of cost for $\perp$:
- e.g. for 1/9 ($\perp$s)
- 34 M$ in linac 2%

Discuss Low Cost Example

- No Driver upgrade
- Bunched phase rotation
- No cooling
- 1/100 acceptance acceleration

- Save 50-57 % **
  for Intensity loss of order 1/30-1/300

We are told that this could be interesting if LSND confirmed

The final performance is quite uncertain, and will depend on whether other components, such as the bunch phase rotation, are modified to match the lower acceptance.

Discuss Small Cooling Rings

They have the potential to allow the cost savings of low acceptance acceleration, without loss of performance, and without large additional cost.

They might offer the hope that the resulting neutrino factory would be upgradeable to a Muon Collider.

But small (and thus relatively cheap) cooling rings are incompatible with Study 2, or the current bunched beam, phase rotations. (The bunch trains from these front ends are too long to fit in the small ring.)

Large rings, or spiral cooling would give the performance, but would be expensive.

There are several approaches that might give the performance without greater cost:

1. **Use a short induction linac for phase rotation, followed by a buncher, and use only that part of the train that fits. The smaller accepted longitudinal phase space means that it will not have high performance. It will also not be very cheap (it uses an induction linac).**
2. **Develop a version of bunched beam phase rotation that is shorter and makes a shorter train. As above, the efficiency cannot be high.**
3. **Phase rotate with low frequency RF (a la CERN, or US Status Report), cool in a low frequency ring, or low frequency "linear" channel, bunch at the required higher frequency, and inject.**
4. **As above, but longitudinally pre-cool until a single bunch will match the main cooling ring without re bunching (as proposed by Valeri). This may be the most efficient, but requires the most new equipment.**

Conclusion for Non-Compatible Options

- Each involves a MAJOR change in the scheme, and would require a MAJOR (Study 1 or 2 type) effort to establish its practicability and cost.
- Only such radical changes offer the hope of high (study 2 or better) performance, at reduced cost.
- Only option #4 might form the basis of a Muon Collider front end.

But The Compatible Solutions:

- Have similar cost to Study 2, or
- Are cheaper, but
  have much worse performance.
- They are probably not upgradeable to Muon Colliders.