Front-End Decay Channel Beams

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From work in collaboration with

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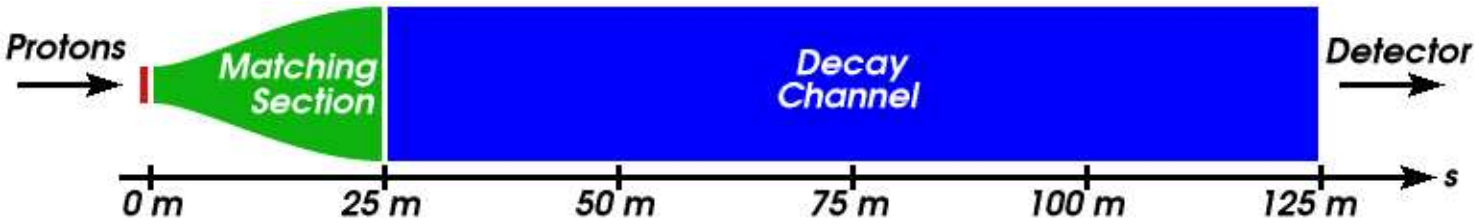
Overview:

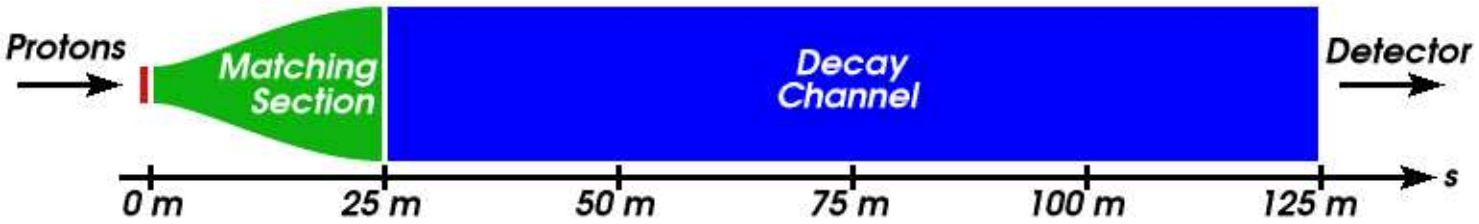
- Front-End Neutrino Beam...
  - ...Alternative use for front-end technology
  - ...Simple carbon target (*FS1*)
  - ...Upgraded FNAL proton driver (2 MW @ 8 GeV)
  - ...High-flux without the cost
  - ...Low-energy & broad spectrum
- Stopped-Muon Neutrino Beam...
  - ...Large carbon-block target
  - ...Upgraded FNAL proton driver
  - ...Simple and effective baseline
  - ...Comparable with SNS neutrino studies

Front-End Schematic:



- Incident proton beam...
  - ...2 MW and 8 GeV at 100 mrad
- Carbon target...
  - ...1.5 cm diameter at 100 mrad (80 cm long)
- Tapered solenoid matching section...
  - ...Roughly uniform 20 T at target
  - ...Uniform 1.25 T in decay channel
- Uniform solenoid decay channel...
  - ...1.25 T over 100 m

Front-End Charged Particle Beam:

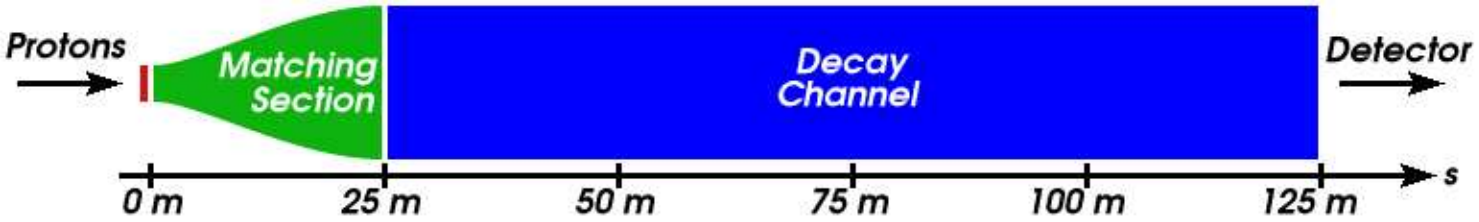


- Evolution of the beam...

  ...Charged particles per proton-on-target

	$s = 25$ m	$s = 50$ m	$s = 75$ m	$s = 100$ m	$s = 125$ m
μ^+/P	0.16	0.20	0.21	0.21	0.22
μ^-/P	0.16	0.20	0.21	0.21	0.21
π^+/P	0.095	0.051	0.030	0.020	0.014
π^-/P	0.087	0.044	0.025	0.016	0.011

Front-End Neutrino Production:



- Production of the neautrino beam...

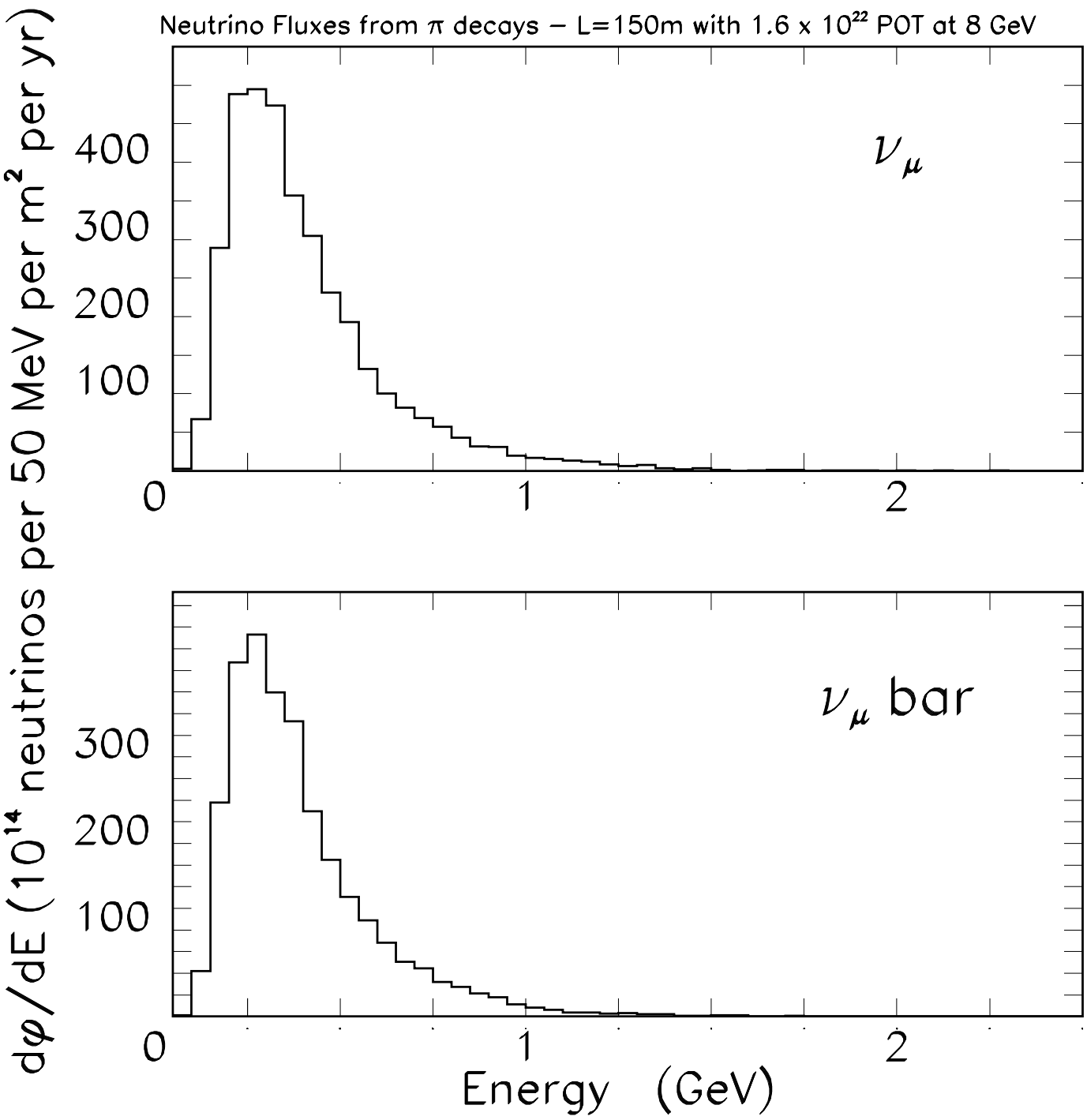
  ...Neutrinos produced per proton-on-target

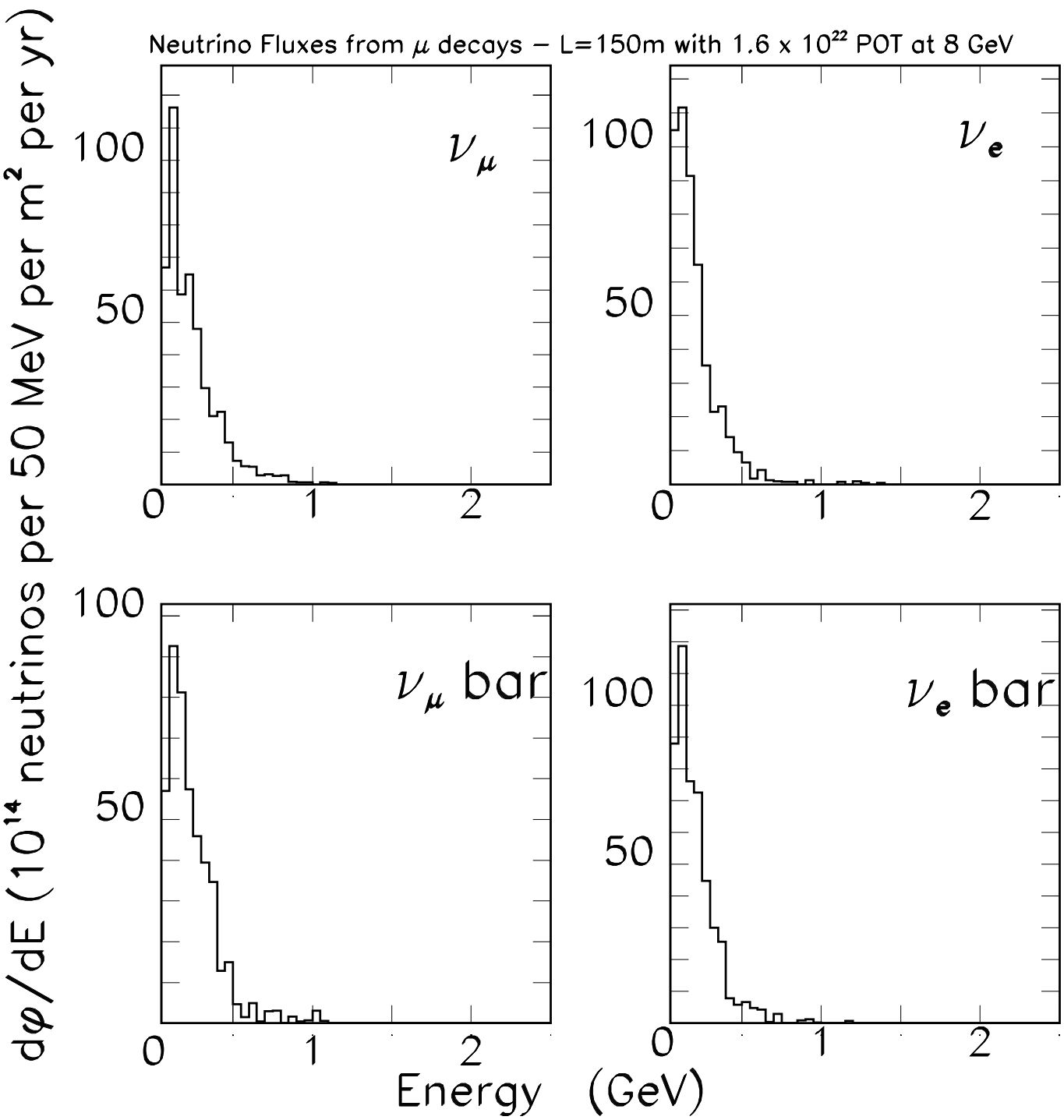
	25 – 50 m	50 – 75 m	75 – 100 m	100 – 125 m
ν_μ/P	0.047	0.023	0.014	0.0095
$\bar{\nu}_\mu/P$	0.046	0.021	0.012	0.0086
ν_e/P	0.0031	0.0034	0.0033	0.0034
$\bar{\nu}_e/P$	0.0032	0.0035	0.0034	0.0034

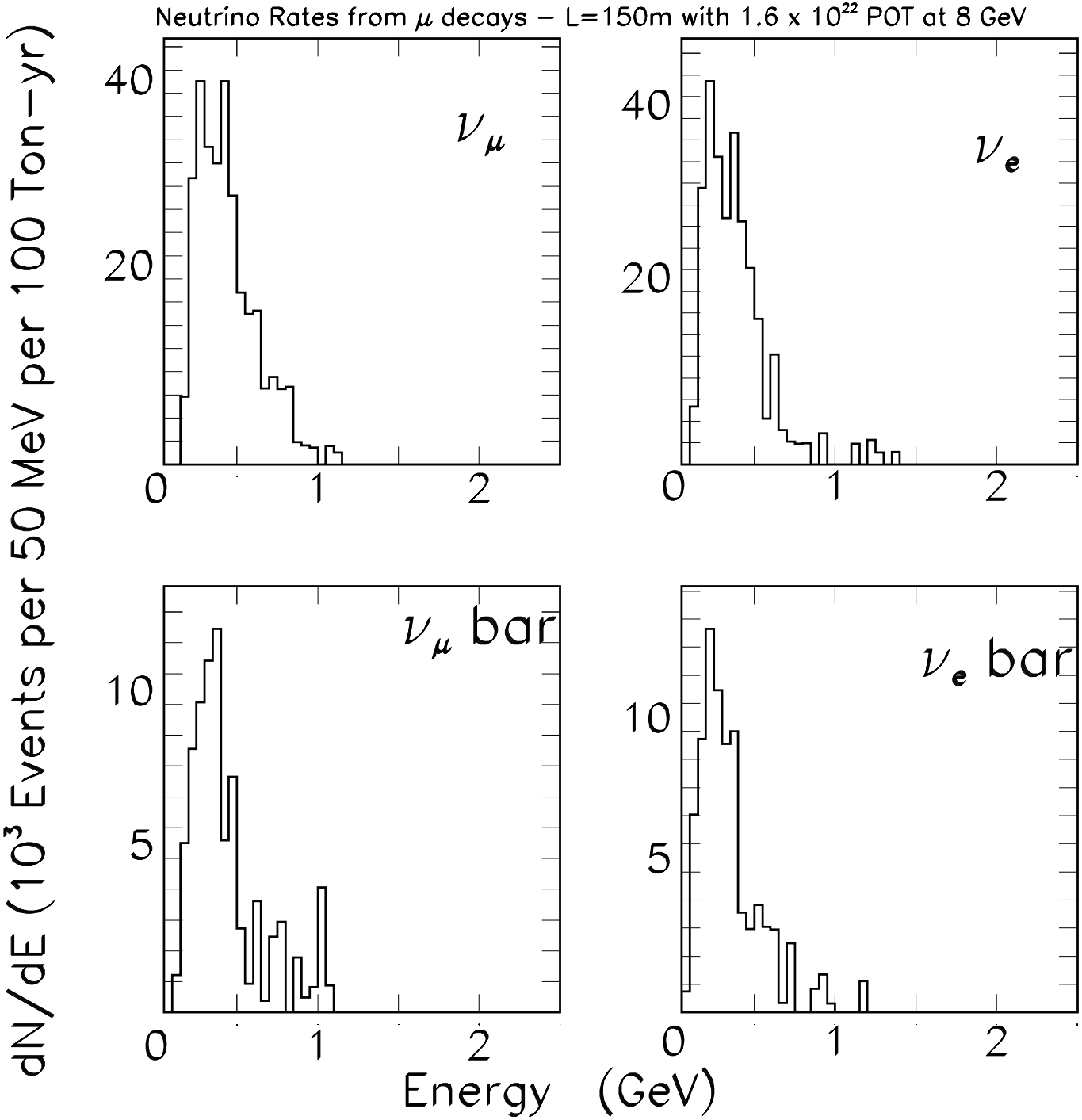
Front-End Neutrino Detection:

- Neutrino detector...
  - ...FINESSE-like detector
  - ...Located on-axis at $s = 225$
    (i.e., 100 m from the end of the decay channel)
  - ...Fiducial Mass: 100 tons

- Neutrino fluxes...
  - ...Averaged over an $R = 10$ m radius
  - ...Assuming 1.6×10^{22} POT/year
    (i.e., 10^7 seconds/year)
  - ...Considering *only* neutrinos produced from
    $s = 75$ m to $s = 125$ m (i.e., last 50 m)


Neutrino Fluxes from π decays – L=150m with 1.6 x 10^22 POT at 8 GeV
dφ/dE (10^14 neutrinos per 50 MeV per m^2 per yr)
400
300
200
100
0
1
2
ν_μ
300
200
100
0
1
2
ν_μ bar
Energy (GeV)


Neutrino Fluxes from μ decays – L=150m with 1.6 x 10^22 POT at 8 GeV
dφ/dE (10^14 neutrinos per 50 MeV per m^2 per yr)
Energy (GeV)
ν_μ
ν_e
ν_μ bar
ν_e bar
100
50
0
1
2


Neutrino Rates from μ decays – L=150m with 1.6 x 10^22 POT at 8 GeV
dN/dE (10^3 Events per 50 MeV per 100 Ton–yr)
Energy (GeV)
νμ
νe
νμ bar
νe bar
40
20
10
5
0
1
2

Front-End Neutrino Event Rates:

- Integrated rates...

  ...From μ-decays *only*

  ...In the last 50 m of the decay chanel

	Events/year
ν_μ	310000
ν_e	290000
$\bar{\nu}_\mu$	84000
$\bar{\nu}_e$	85000

- Significant rates...

  ...Shows promise, but requires more sophistication!
  (Maybe a bend & a longer decay channel)

  ...Physics program unexplored!

FNAL Stopped-Muon Overview:

- Upgraded FNAL proton driver...
  - ...OPTIMAL: 2 MW and 8 GeV
  - ...ALTERNATE: 1.25 MW and 5 GeV
- Carbon target/beam dump...
  - ...5 m radius and 10 m long (*Overkill!*)
  - ...Stops π^+ and μ^+ before decay-at-rest (DAR)
  - ...Captures π^- and μ^- before decay
- Neutrinos produced...
  - ...Prompt DAR neutrinos from π^+ decay
  - ...Delayed DAR neutrinos from μ^+ decay
  - ...Comparable to SNS neutrino production!

SNS Stopped-Muons:

- SNS proton driver...

  ...1.4 MW and 1.3 GeV (at full power)

  ...1.14×10^{14} P/pulse at 60 Hz

  ...695 ns pulse length

- Neutrinos produced...

	$0 \rightarrow 695$ ns	$695 \rightarrow 5000$ ns	> 5000 ns
π^+ DAR	96%	4%	0%
μ^+ DAR	14%	74%	12%

  ...CUT: $695 < t < 5000$ ns

- REFERENCE: G. VanDalen, nucl-ex/0309014

SNS/FNAL Stopped-Muon Comparison:

- Detector...

  ...MiniBooNE-like detector: $M_F = 250$ tons (mineral oil)

  ...Off axis and 60 m away from target

  ...$R \approx 5$ m radius

- Comparison...

	FNAL (8 GeV)	FNAL (5 GeV)	SNS
DAR ν (ν/P)	1.5	0.9	0.13
(ν/yr)	7.4×10^{22}	4.5×10^{22}	2.9×10^{22}
ν_e Events/yr	28000 ϵ_{rec}	17000 ϵ_{rec}	11000 ϵ_{rec}
ν_μ Events/yr	4800 ϵ_{rec}	3000 ϵ_{rec}	1900 ϵ_{rec}
$\bar{\nu}_\mu$ Events/yr	10000 ϵ_{rec}	6000 ϵ_{rec}	3900 ϵ_{rec}

...Includes combined $\nu\, e$ and $\nu_e\, C$ (CC & NC) events