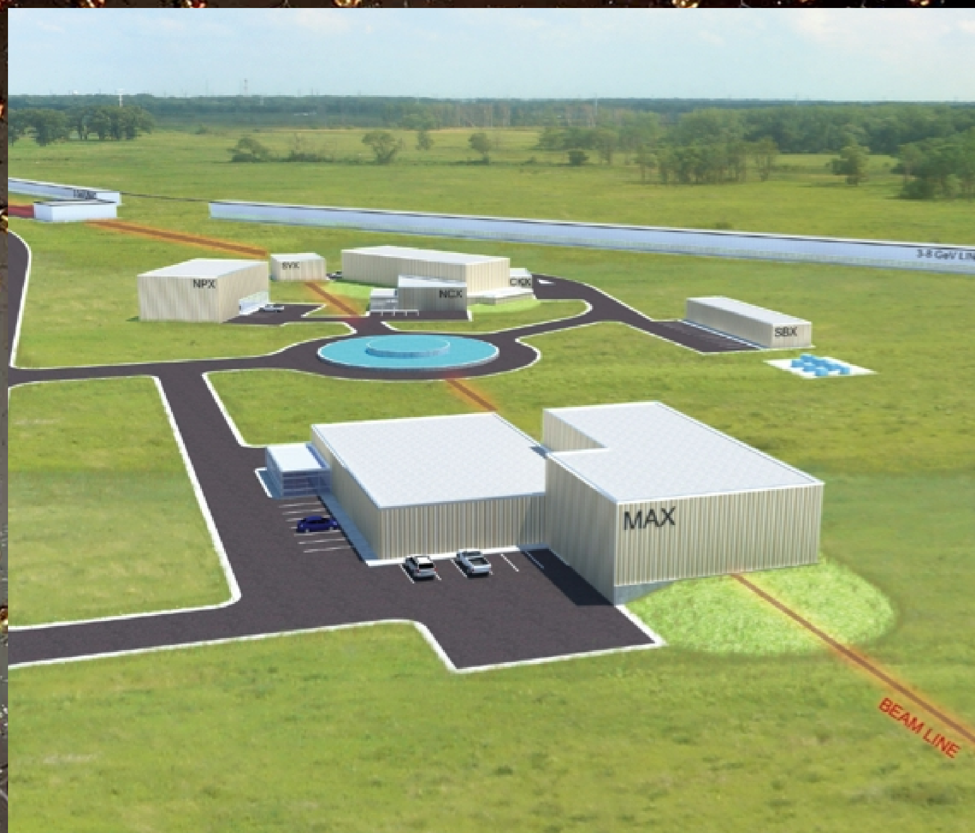
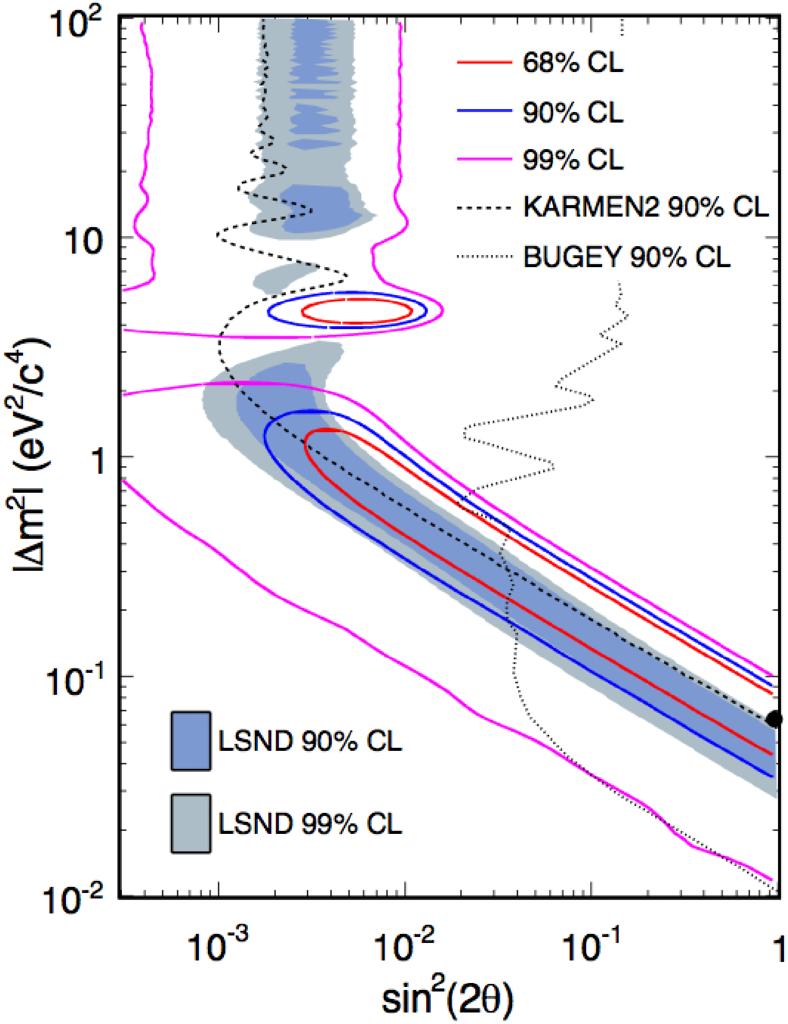
Possibilities for DAR/DIF at Project X

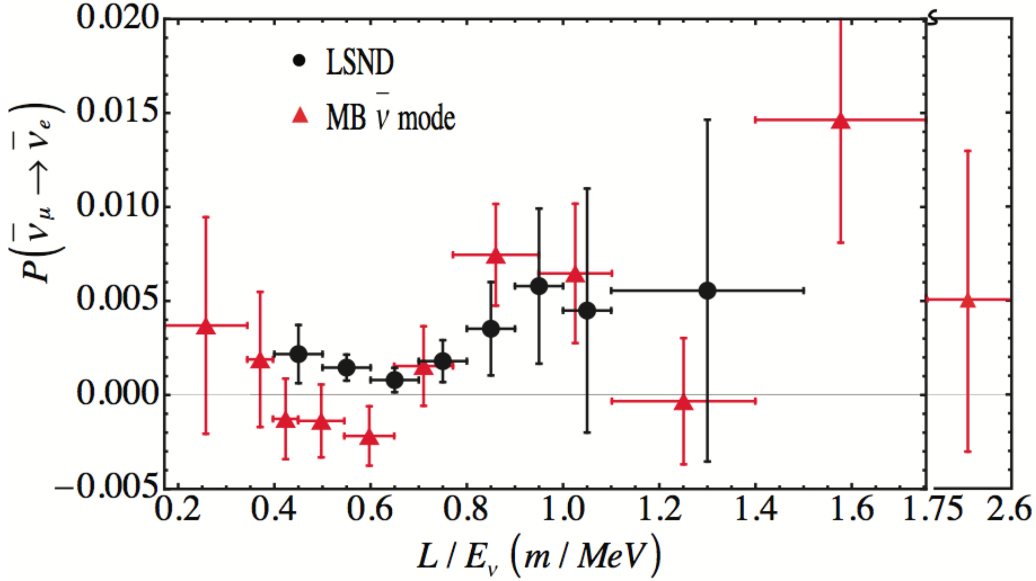
Chris Polly, Fermilab



Lots of hints of new physics at $\Delta m^2 \sim 1\ eV^2$

LSND (3.8σ) & MB anti-ν (2.7σ)

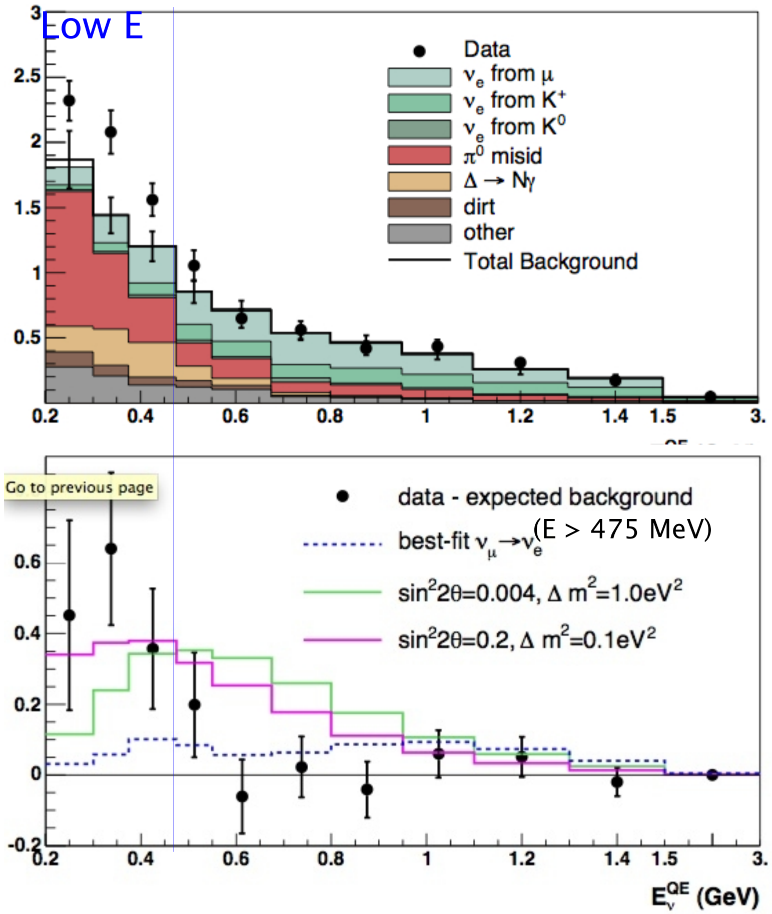


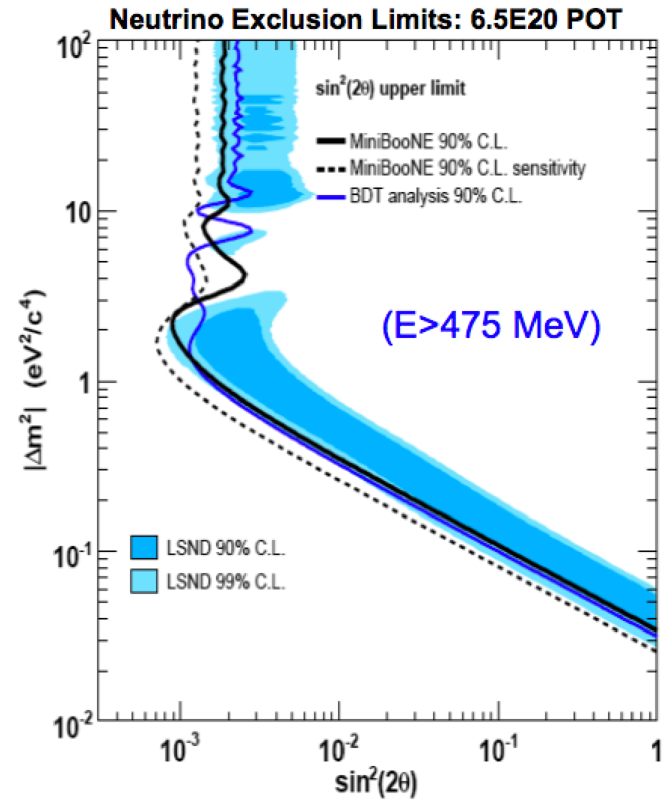


Both experiments prefer similar parameter range in 2ν fit

Lots of hints of new physics at $\Delta m^2 \sim 1$ eV^2

MB ν (3.0σ)

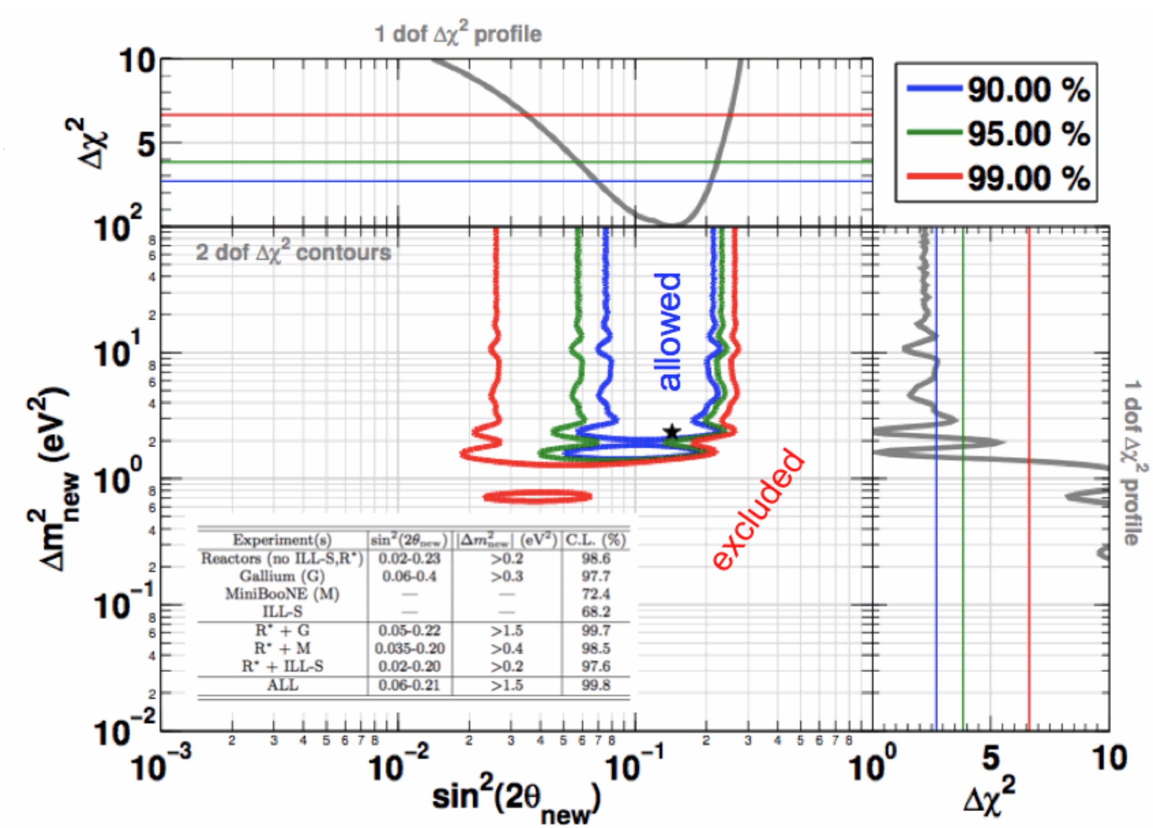




Similar size excess as in anti-ν, but at lower energies...disfavors $\Delta m^2 \sim 1$ eV^2 under 2ν hypothesis

Lots of hints of new physics at $\Delta m^2 \sim 1$ eV^2

Reactor + Gallium anomaly



Experiment(s)	$\sin^2(2\theta_{new})$	$\lvert\Delta m^2_{new}\rvert$ (eV^2)	C.L. (%)
Reactors (no ILL-S,R*)	0.02-0.23	>0.2	98.6
Gallium (G)	0.06-0.4	>0.3	97.7
MiniBooNE (M)	—	—	72.4
ILL-S	—	—	68.2
R* + G	0.05-0.22	>1.5	99.7
R* + M	0.035-0.20	>0.4	98.5
R* + ILL-S	0.02-0.20	>0.2	97.6
ALL	0.06-0.21	>1.5	99.8

The no-oscillation hypothesis is disfavored at 99.8% CL

See talk by G. Mention this conference

Clear we need a new experiment that greatly surpasses any prior experiment's sensitivity

- Has to be a 2 detector experiment
- Better if detectors are identical
- Gamma/electron discrimination helps
- Lots of beam

See talks by G. Mills, R. Patterson, F. Pietropaolo, & R. Guenette talks this workshop for >5σ ideas

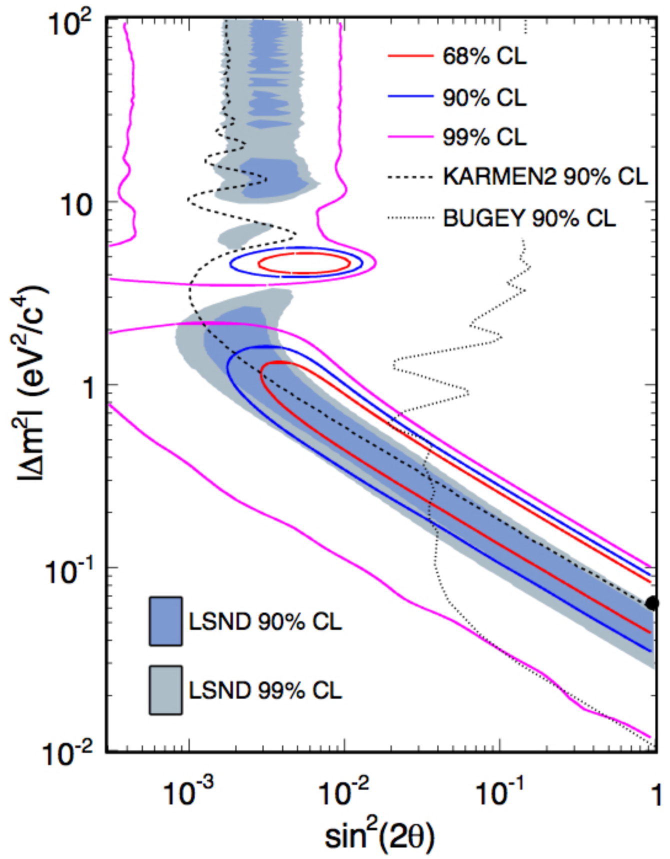
Clear we need a new experiment that greatly surpasses any prior experiment's sensitivity

- Has to be a 2 detector experiment
- Better if detectors are identical
- Gamma/electron discrimination helps
- Lots of beam

Focus of this talk...

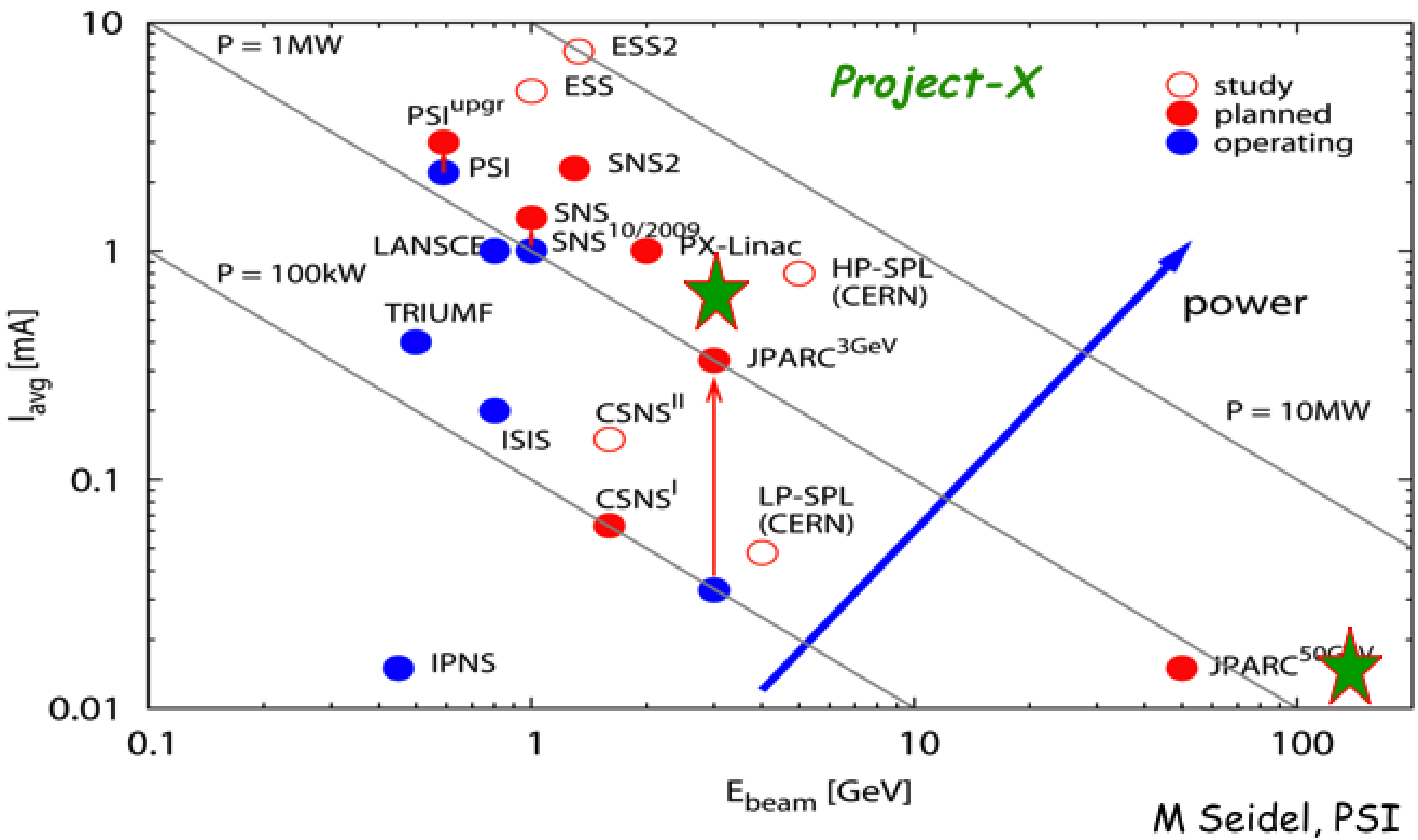
Can we get the beam from Project X?

	Power	Energy	POT
LSND	800 kW	800 MeV	5.9×10^{22}
KARMEN	160 kW	800 MeV	9.2×10^{22}
MB ν	10 kW	8 GeV	6.5×10^{20}
MB anti-ν	10 kW	8 GeV	11×10^{22}
Project X	3000 kW	3 GeV	



Projecting to March 2012 shutdown ...2x published

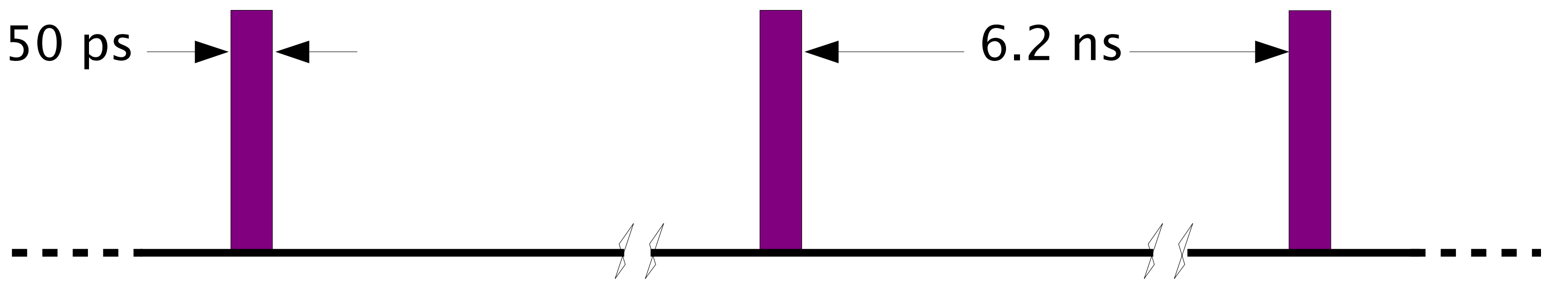
Project X compared to other intense sources



Currently only two other sources >= 1 MW, at energies of 1 GeV (SNS) and 590 MeV (SNS)

Implications of CW on duty cycle

Project X linac operates with 162.5 MHz RF
- 50 ps wide pulse (FWHM) separated by 6.2 ns

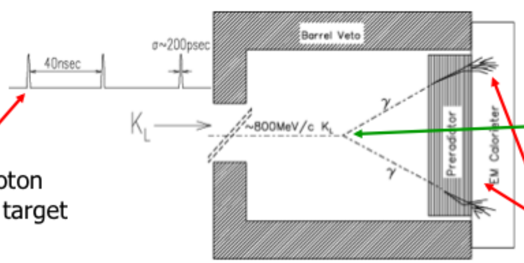


Duty cycle δ_{beam} = 0.008
- Matched well to experiments like $K^0 \rightarrow \pi^0 \nu\nu$

For decay-at-rest (DAR) SBL
- 2.2 μs muon lifetime $\Rightarrow \delta_{DAR}$ = 1.00

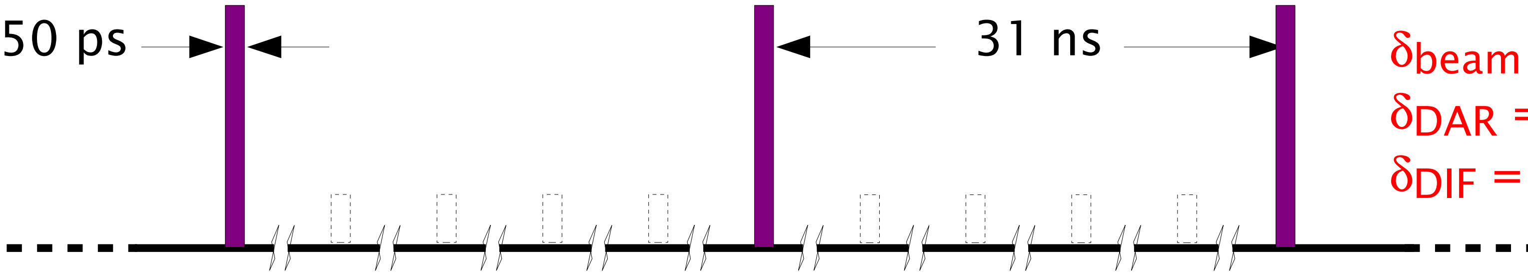
For decay-in-flight (DIF) SBL
- 2 ns smearing due to pion TOF (50 m) and det response $\Rightarrow \delta_{DIF}$ = 0.33

Fully reconstruct the neutral Kaon in $K_L \rightarrow \pi^0 \nu \bar{\nu}$ measuring the Kaon momentum by time-of-flight.



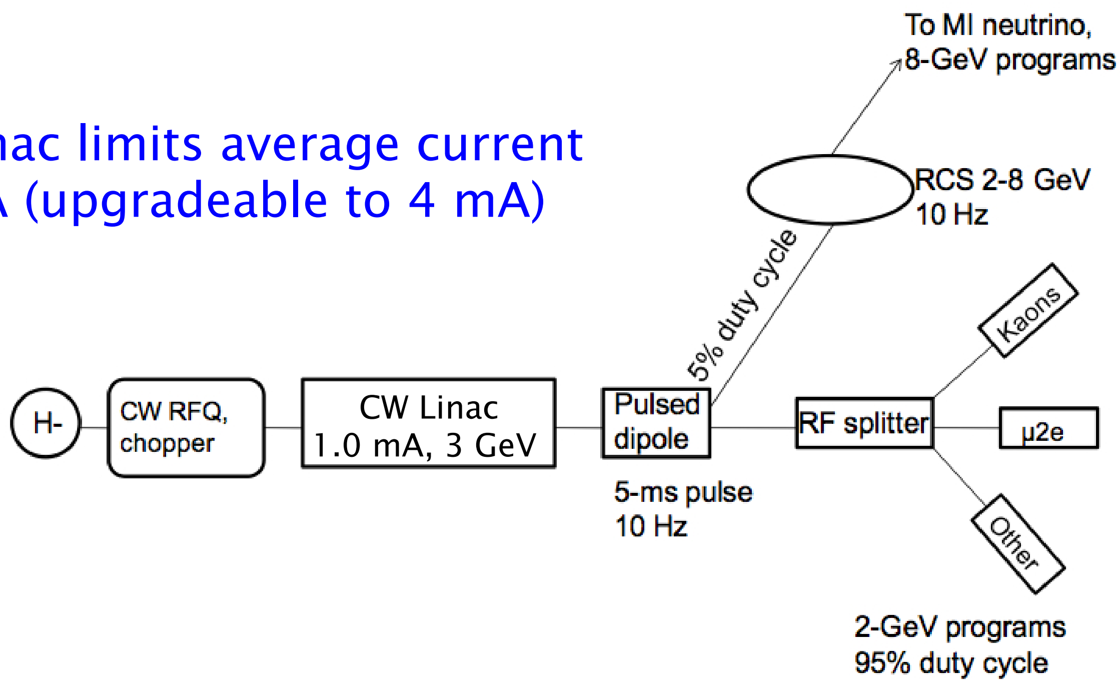
Timing uncertainty due to microbunch width should not dominate the measurement of the kaon momentum; requires RMS width < 200ps. CW linac pulse timing of less than 50ps is intrinsic.

Can reduce δ by turning H- up to 5 mA and chopping out 80% of beam

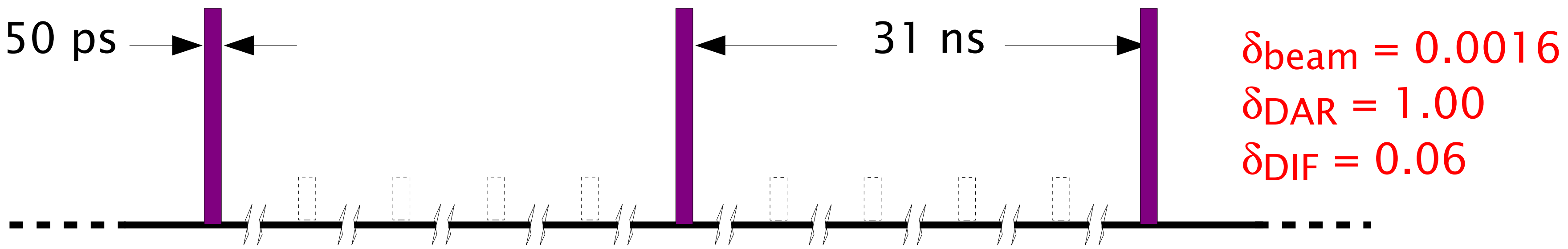


$\delta_{beam} = 0.0016$
$\delta_{DAR} = 1.00$
$\delta_{DIF} = 0.06$

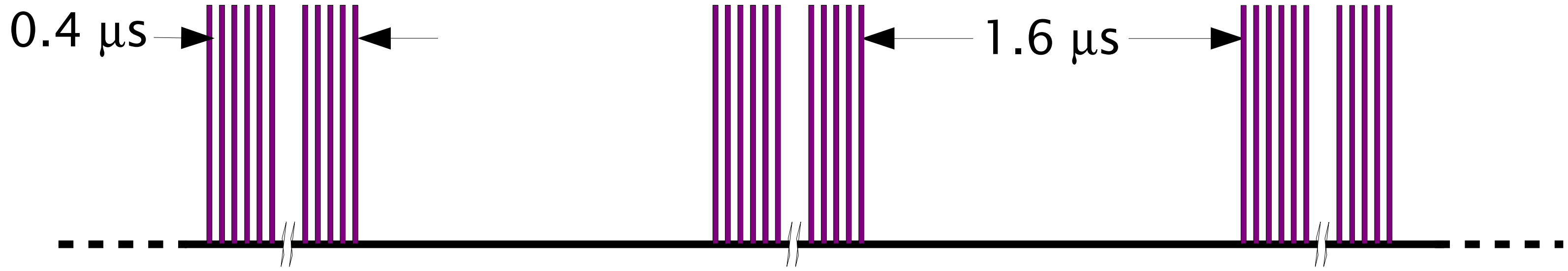
RF power in Linac limits average current overall to 1 mA (upgradeable to 4 mA)



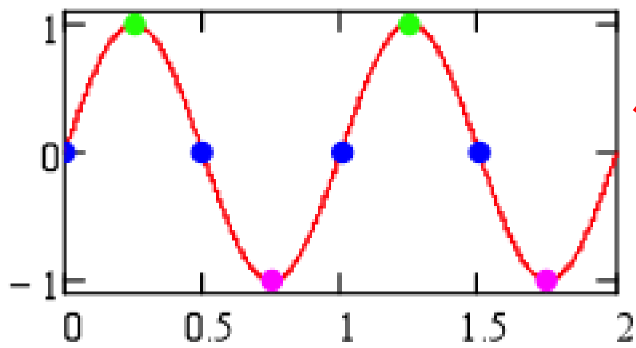
Can reduce δ by turning H- up to 5 mA and chopping out 80% of beam

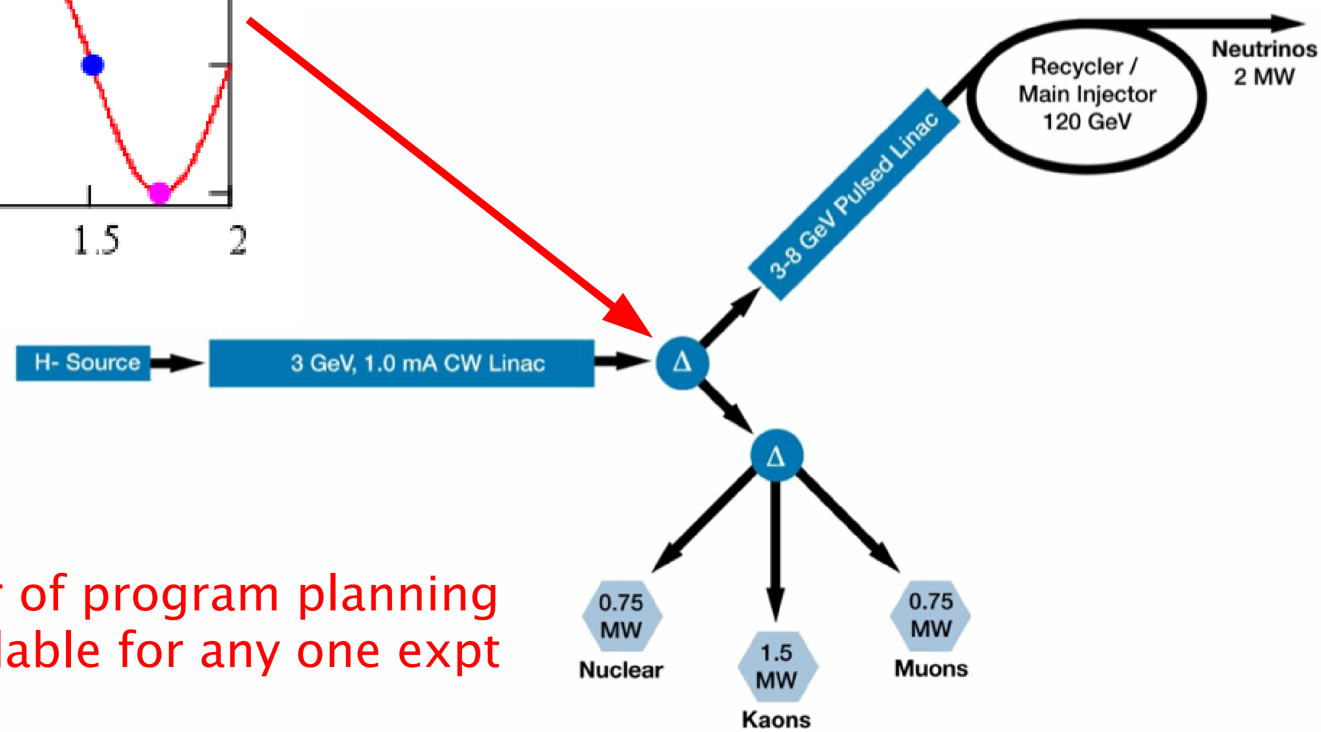


Can also deliver a train of 64 pulses at 5 mA for 400 ns, as long as average current over 2μs is 1 mA

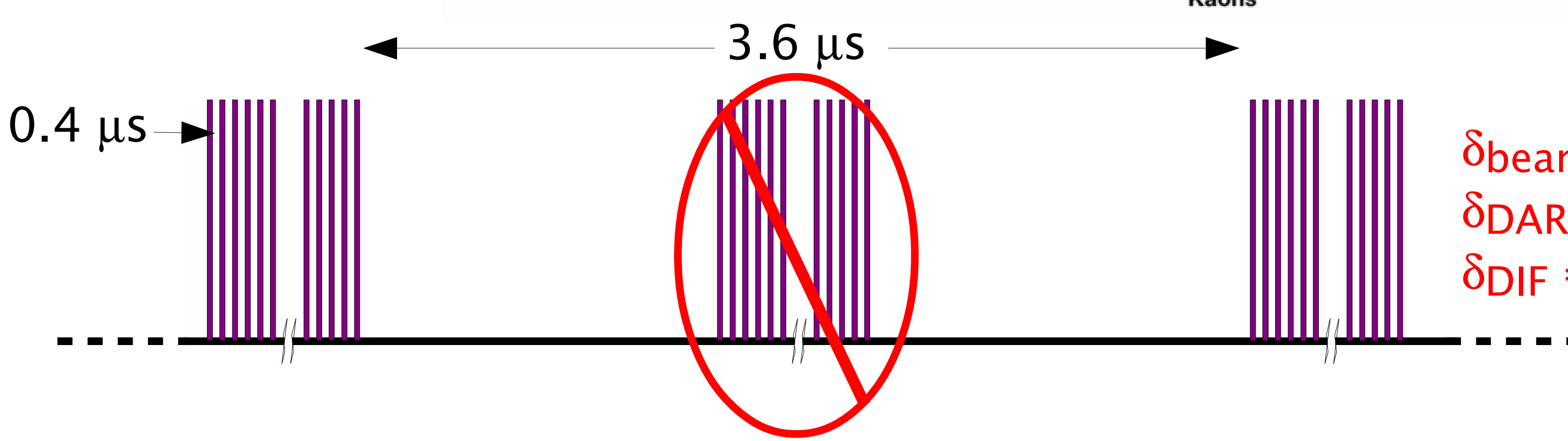


Of course, intention is to run multiple expts





Assume as a matter of program planning only 1.5 MW is available for any one expt



$\delta_{beam} = 0.0008$

$\delta_{DAR} = 1.00$

$\delta_{DIF} = 0.03$

Implication of δ_{DAR} = 1.0 for LSND-like experiment

Cosmic rays were important for LSND

- Dominated trigger (beam ν were < 10^{-5})
- 15.5 μs hold-off resulted in 15% deadtime
- Stringent cuts required to reduce bkgs
  - Michel electrons can fake electron in CCQE
  - Cosmic-induced neutrons can fake delayed n capture
- Easy to subtract with beam off data
- LSND beam on 600 μs/off 7700 μs

δ_{LSND} = 0.07

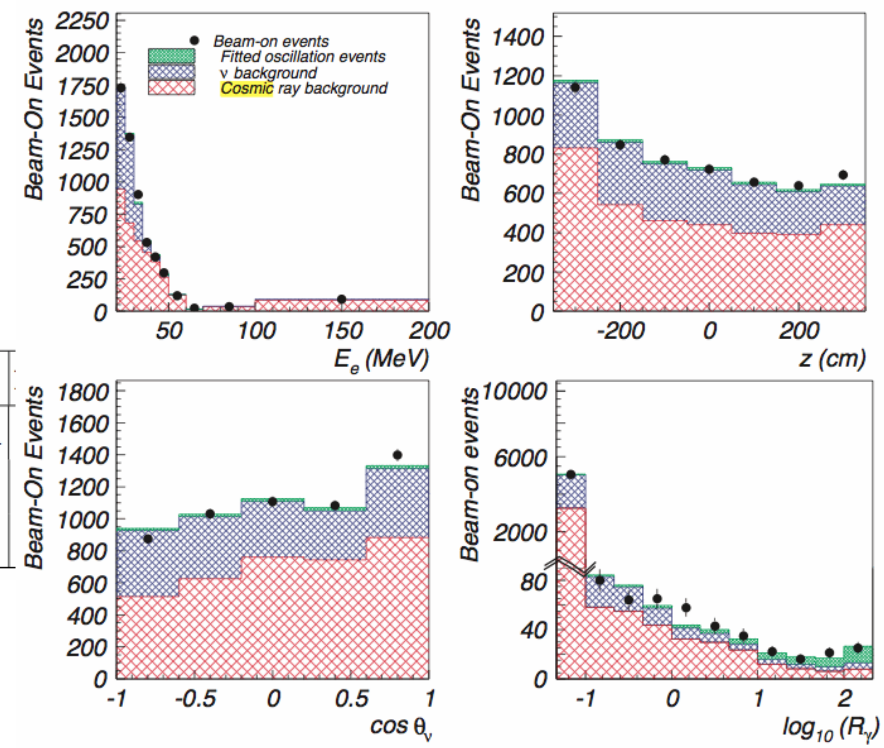
δ_{beam} = 0.0016

δ_{DAR} = 1.00

δ_{DIF} = 0.06

Making the duty cycle 15 times worse would be very bad...

Selection	Beam-On Events	Beam-Off Background	ν Background	Event Excess
$R_\gamma > 1$	205	106.8 ± 2.5	39.2 ± 3.1	$59.0 \pm 14.5 \pm 3.1$
$R_\gamma > 10$	86	36.9 ± 1.5	16.9 ± 2.3	$32.2 \pm 9.4 \pm 2.3$
$R_\gamma > 100$	27	8.3 ± 0.7	5.4 ± 1.0	$13.3 \pm 5.2 \pm 1.0$



http://lanl.arxiv.org/pdf/hep-ex/0104049

Implication of δ_{DIF} = 0.06 for MB-like experiment

MiniBooNE has a very tight beam window

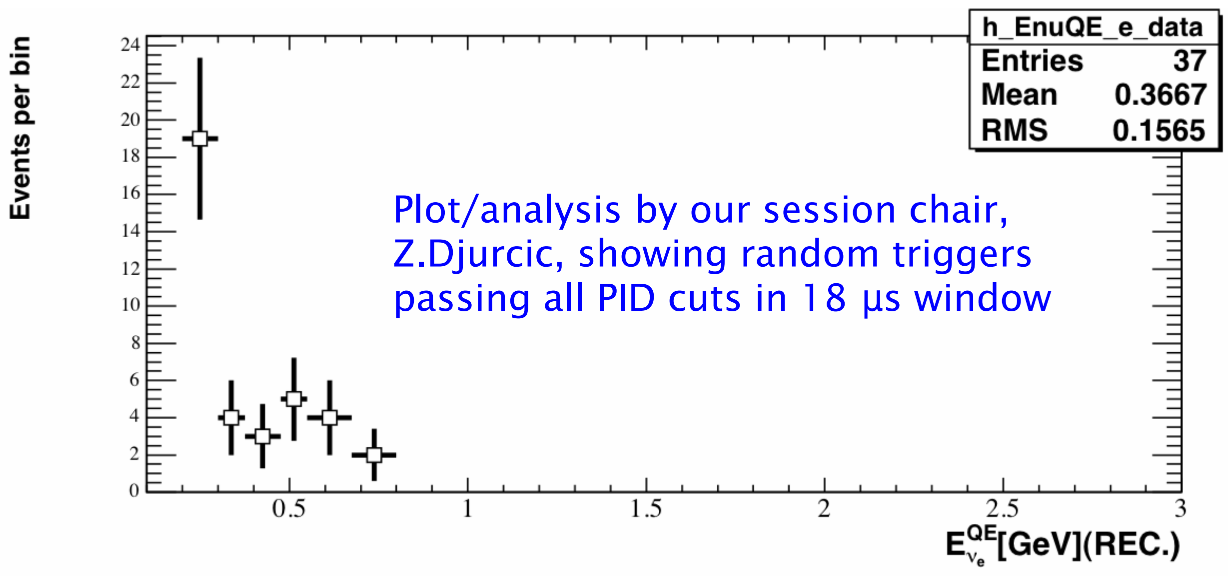
- 1.6 μs beam window at < 2 Hz

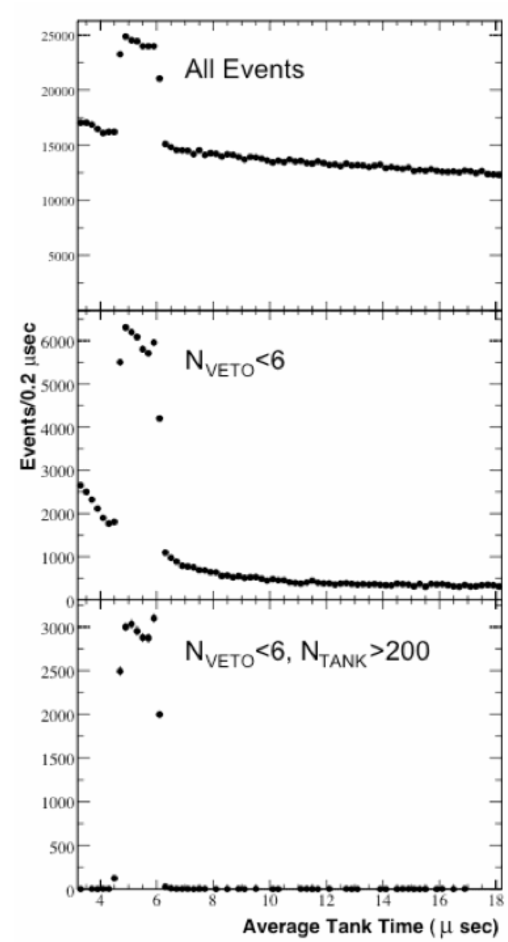
$\delta_{MB} = 3.2 \times 10^{-6}$

$\delta_{beam} = 0.0016$

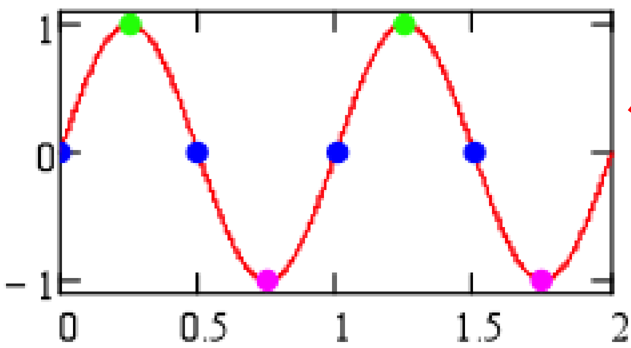
$\delta_{DAR} = 1.00$

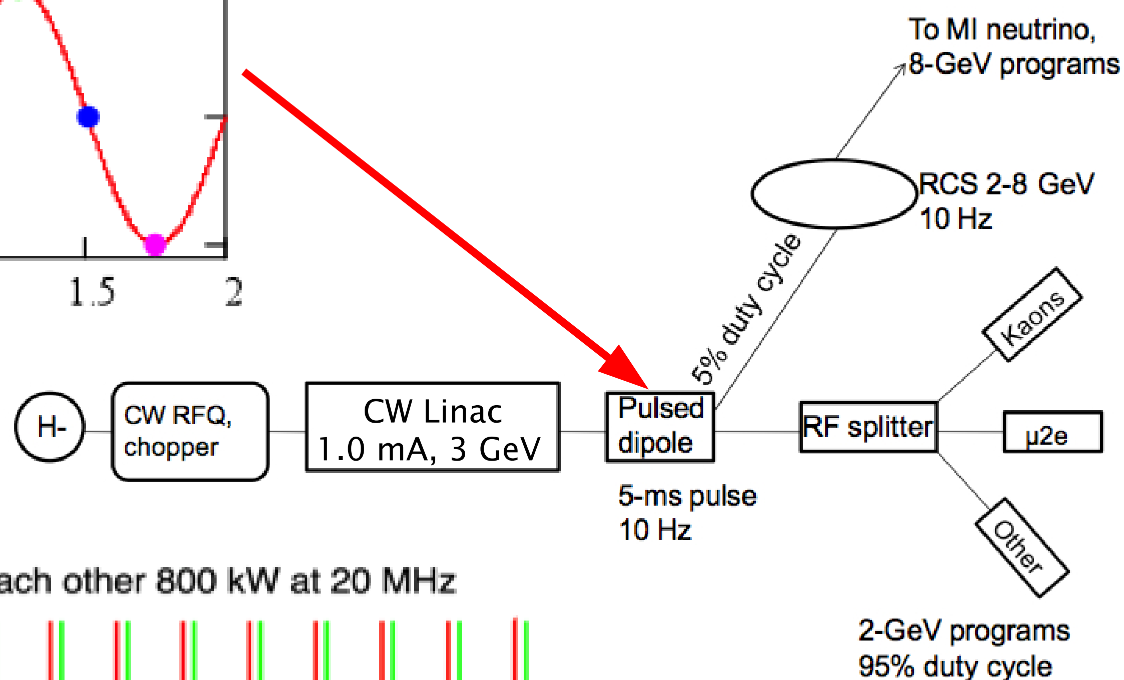
$\delta_{DIF} = 0.06$

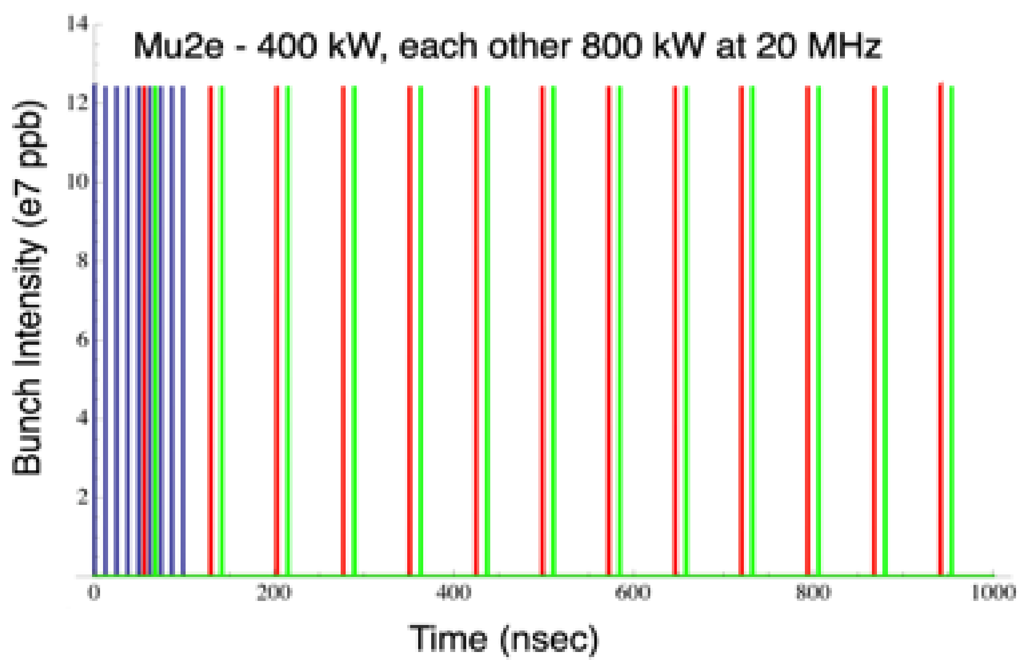




For ν running with 6.5e20 POT, expect 1.1 cosmic induced event with E_ν>475 MeV... scale up by 4 orders of magnitude and that would be a problem

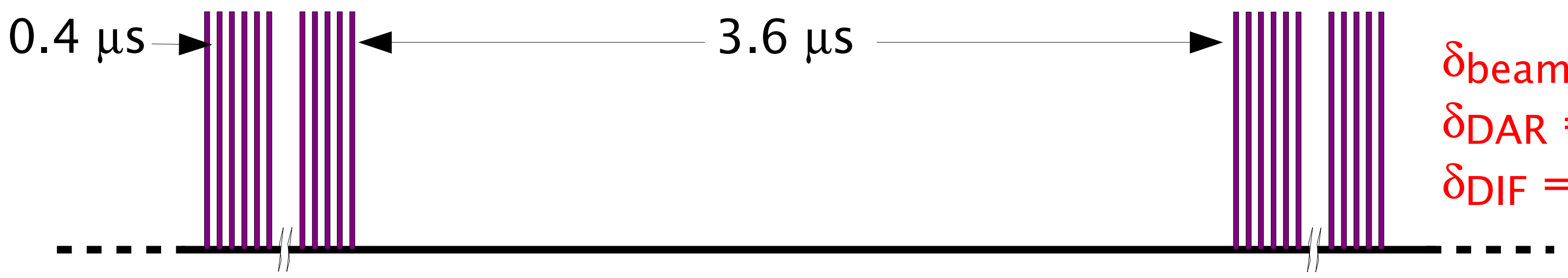






In general the flexibility to create beam structures in Project X is unprecedented, but in the case of DAR/DIF it becomes somewhat complicated

How much can this improve with an accumulator?

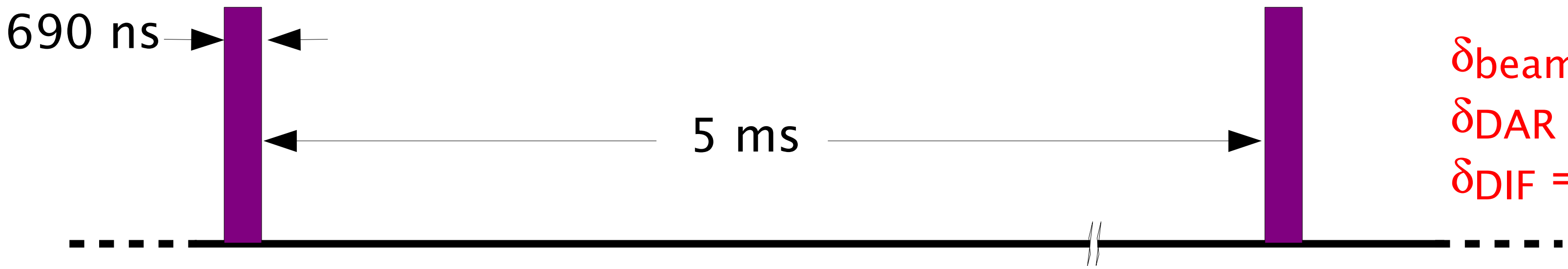


$\delta_{beam} = 0.0008$
$\delta_{DAR} = 1.00$
$\delta_{DIF} = 0.03$

Note: even if the duty cycle were not a problem for DIF, the rate of bunch trains is 250kHz

- Can't imagine using a horn to focus or sign select
- More conventional quadrupole focus could be considered but 1.5 MW environment is harsh

How much can this improve with an accumulator?



δ_{beam} = 0.0008
δ_{DAR} = 1.00
δ_{DIF} = 0.03

Accumulator idea (see S. Holmes talk this conference):
- Wrap CW beam around dedicated acc. ring and then extract in one turn

Limitations
- Can only wrap so long before stripping foil is destroyed (1 ms)
- Need extraction kicker with limited rep rate (200 Hz ⇒ 5 ms)
- Reduces beam power by factor of 5 to 600 kW (60 times MB)
- With 200 m circumference, extraction takes 670 ns
- δ_{ACC} = 1.34 x 10-4 (40 times worse than MB)

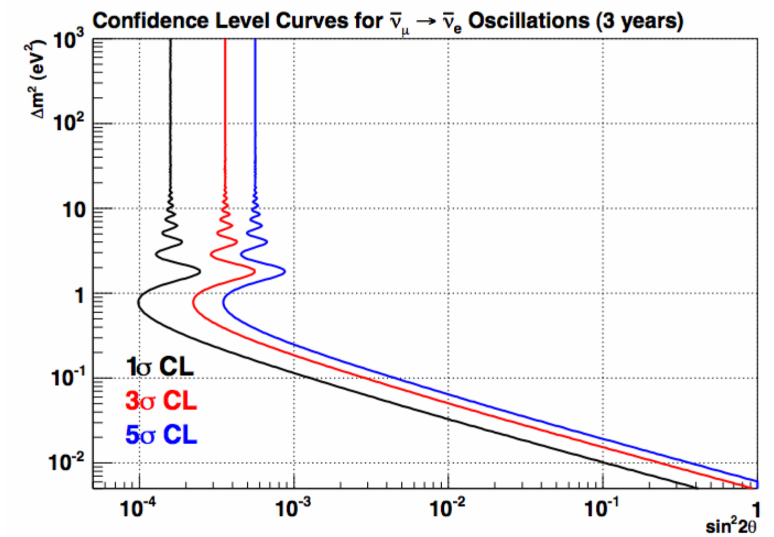
Back to DAR for a moment

Osc SNS at Oak Ridge

- A 600 kW DAR is not terribly compelling

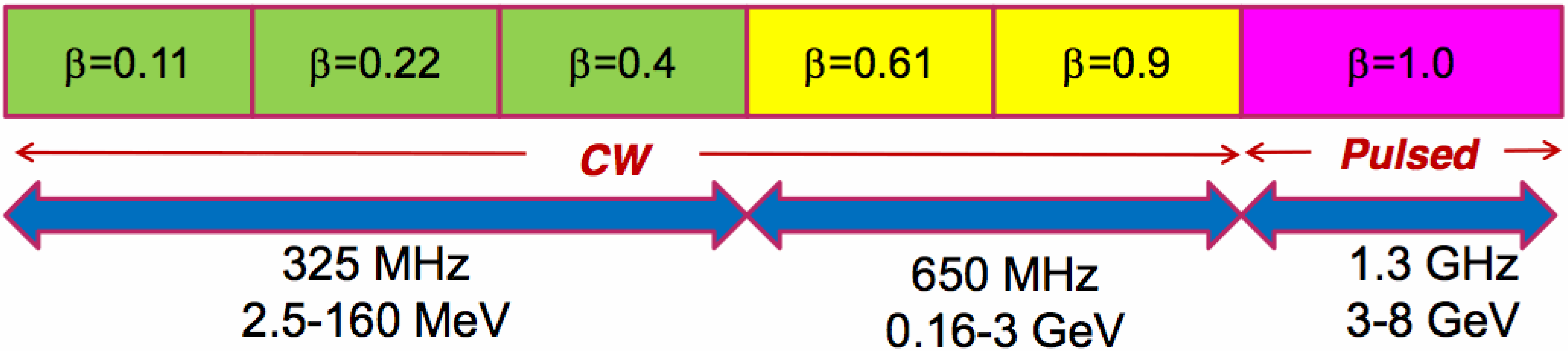
	Power	Energy
LSND	800 kW	800 MeV
Project X Acc	600 kW	3 GeV
Project X	3000 kW	3 GeV

- Could consider putting detector deep underground and running CW $$$
- OscSNS clearly superior
  - MB-like near/far detectors at Oak Ridge
  - Relative to LSND
    - x5 detector mass
    - x1000 lower duty cycle
    - x2 ν flux
    - x10 lower DIF background

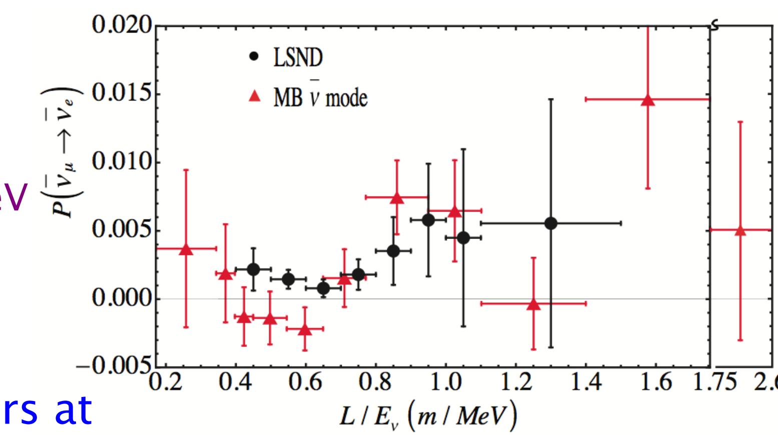


http://physics.calumet.purdue.edu/~oscsns/

One other interesting possibility at Project X



- Possible to change E scale at Project X
  - Possible to retune 650 MHz portion for delivery of 1-3 GeV beams
    - Not something that would be done weekly
    - Conflict of interest with other demands
  - Already planning for a 2nd, early extraction at 1 GeV
    - No interference with rest of program
    - Beam power cut by 3
- Control L/E without having to build new detectors at

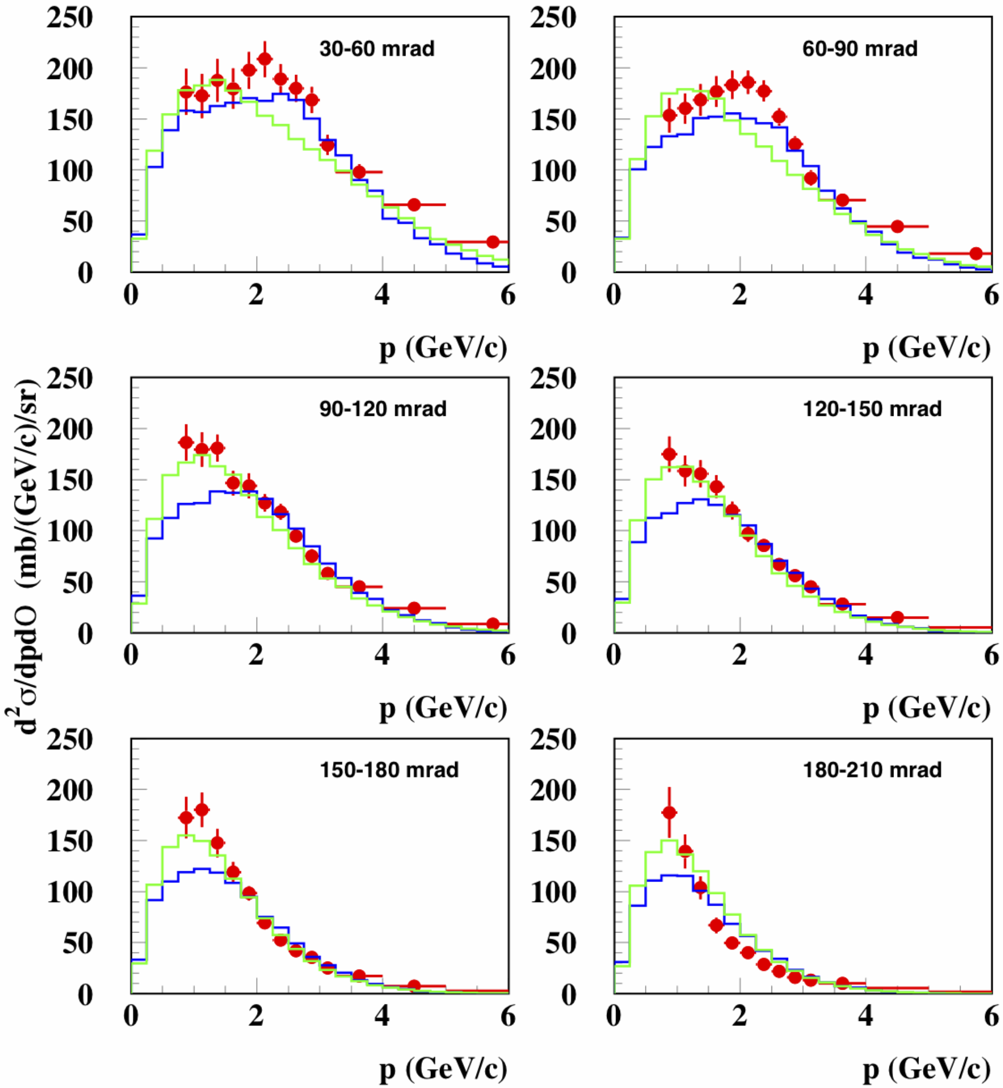


Cross-sections for π+ production

Just starting to take a look at what can be done with 300-600 kW of 1-3 GeV beam

Thanks to Sergei Striganov for running p-Be π/K fluxes with latest MARS-LAQGSM (needed at 1-3 GeV range)

Comparison at 8 GeV:
- HARP data in red
- MARS default in green
- MARS-LAQGSM in blue



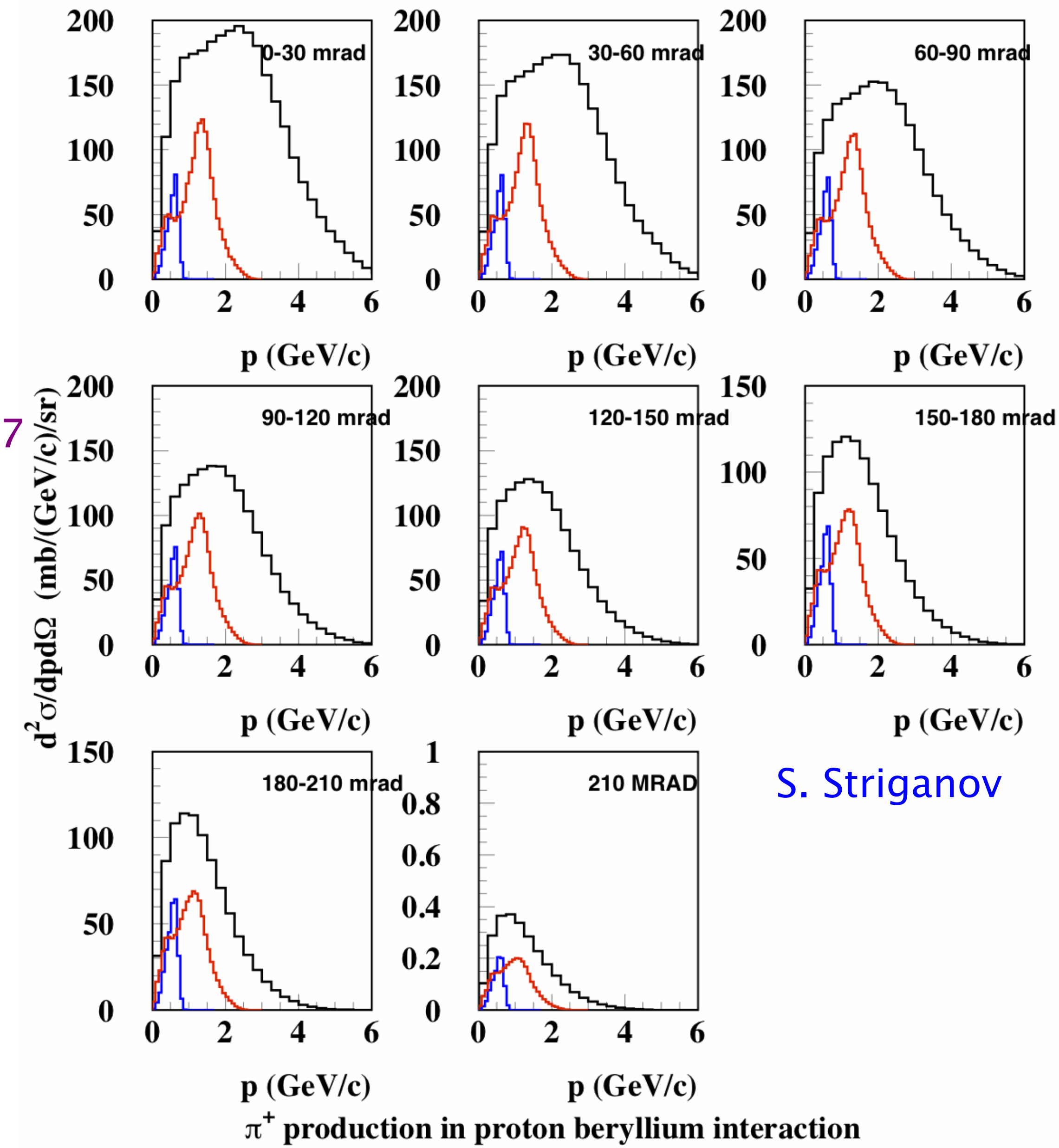
π^+ production in proton beryllium interaction at 8.9 GeV/c

S. Striganov

Cross-sections for π+ production at 1, 3, & 8 GeV

π+ p-Be cross-sections:
- 8 GeV p in black
- 3 GeV p in red
- 1 GeV p in blue

Integrated xsec 3GeV/8GeV = 0.24
Integrated xsec 1GeV/8GeV = 0.057

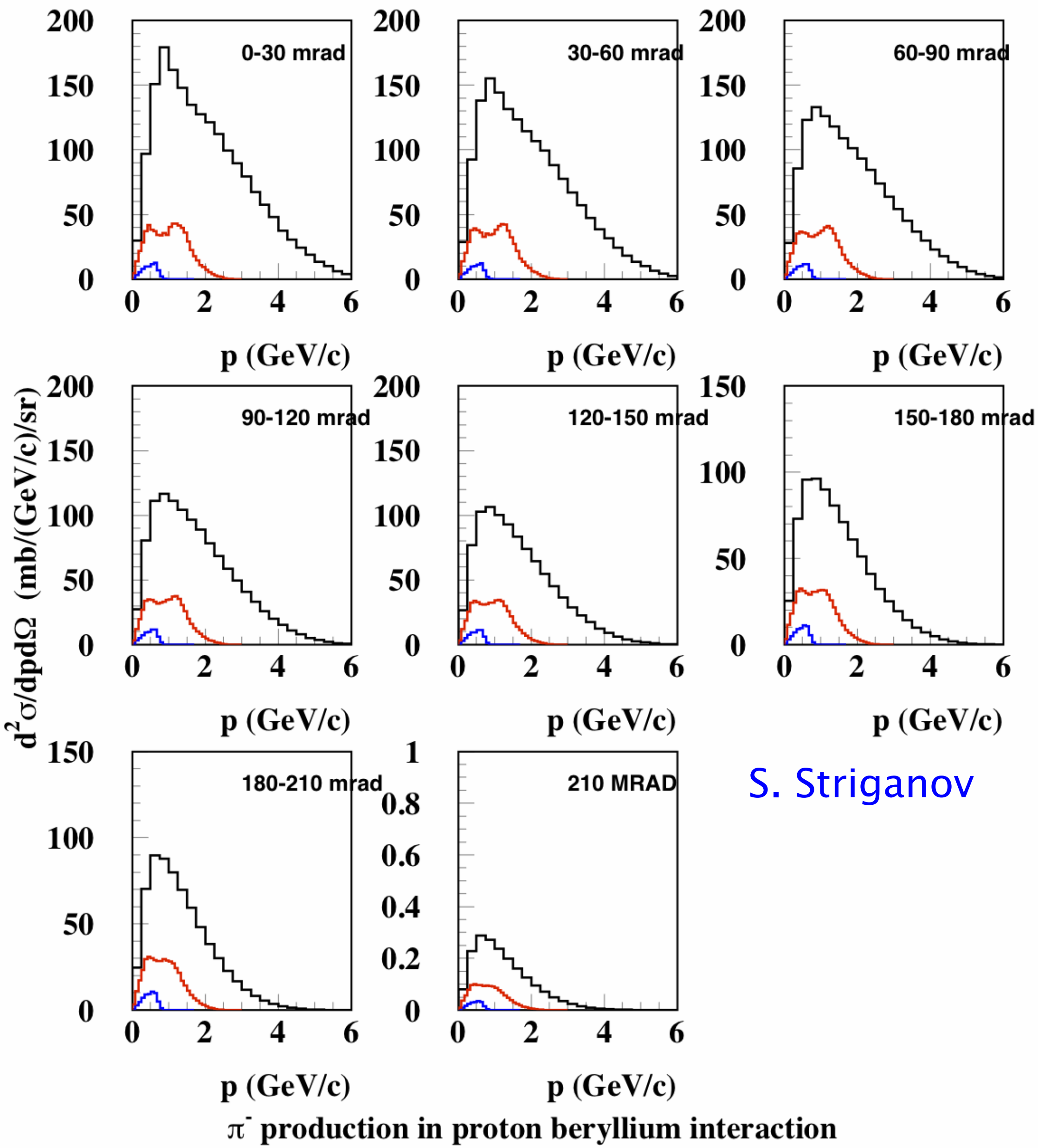


S. Striganov

Cross-sections for π- production at 1, 3, & 8 GeV

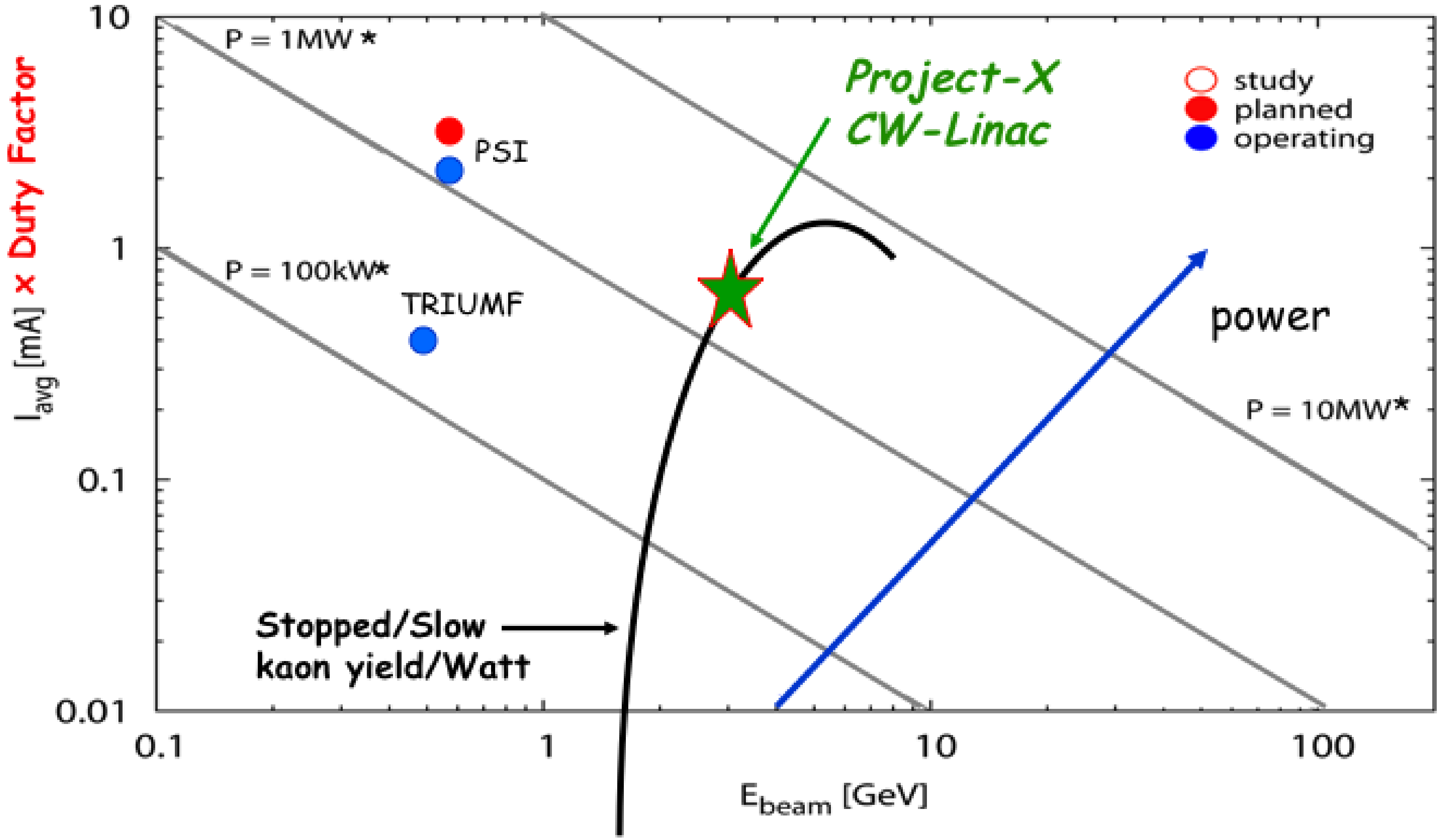
π- p-Be cross-sections:
- 8 GeV p in black
- 3 GeV p in red
- 1 GeV p in blue

Integrated xsec 3GeV/8GeV = 0.17
Integrated xsec 1GeV/8GeV = 0.018



S. Striganov

Cross-sections for K+ production at 3 & 8 GeV



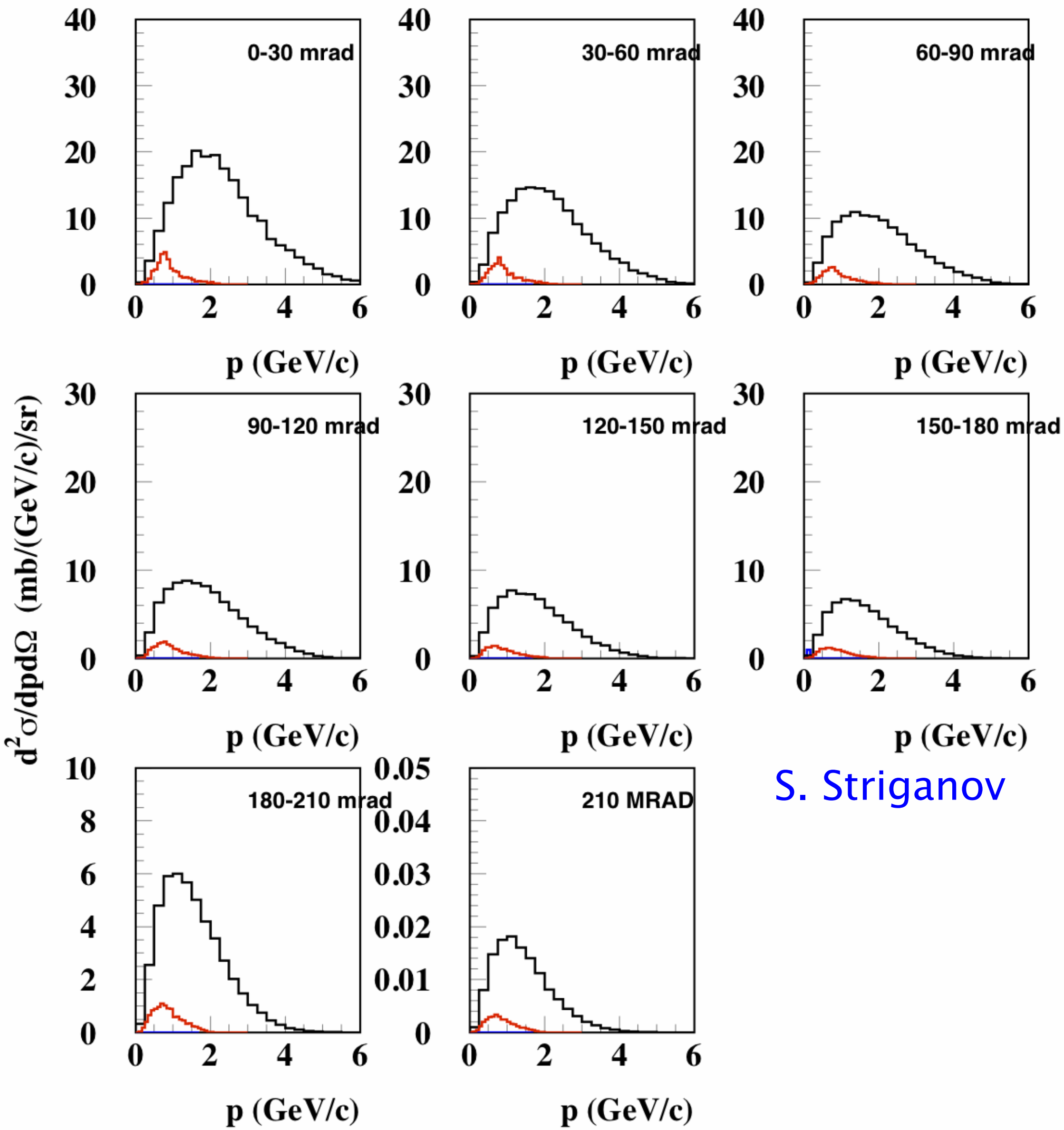
- At 3 GeV, Project X is nearing the maximal efficiency for producing K

Cross-sections for K+ production at 3 & 8 GeV

K+ p-Be cross-sections:
8 GeV p in black
3 GeV p in red

Integrated xsec 3GeV/8GeV = 0.065

Relative K+ content reduced by factor of 3 in 8 GeV -> 3 GeV



K^+ production in proton beryllium interaction

S. Striganov

Conclusion

This was a very educational experience for me in understanding where the disadvantages of a CW machine come into play

- 3MW sounds great, but only if it can be used

With respect to a DAR follow-up to LSND

- Very hard at Project X without going underground
- Probably much cheaper to pursue at SNS

With respect to DIF follow-up to MiniBooNE

- Need an accumulator to get to 300-600 kW (~$50M)
- Can get a factor of 15-30 more π^+ produced relative to BNB
- K+ contamination reduced by factor of 3

Next steps...

- Pass mesons through realistic focussing model
- Find event rates and sensitivities for various detector configurations