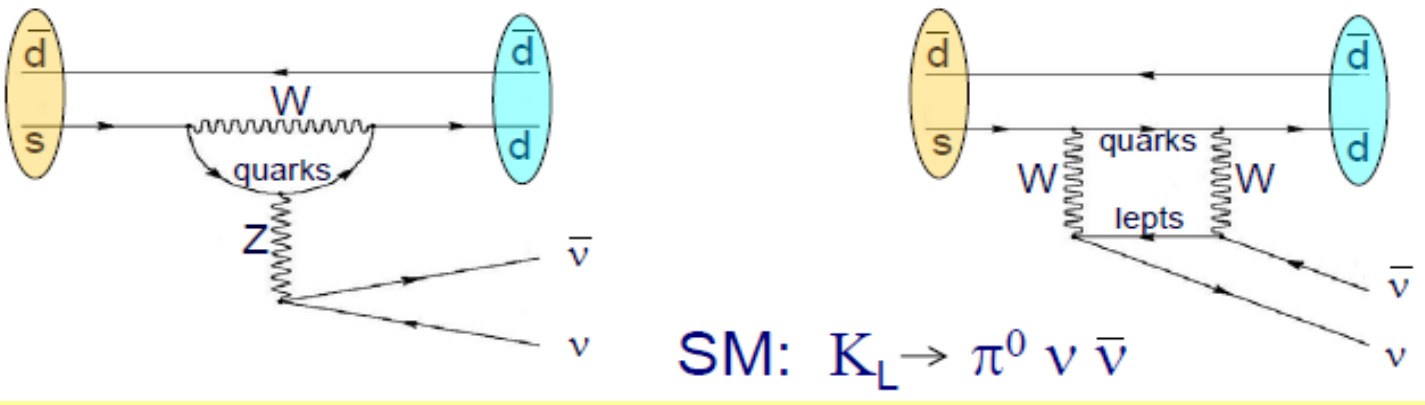
Kaon Physics and Project X

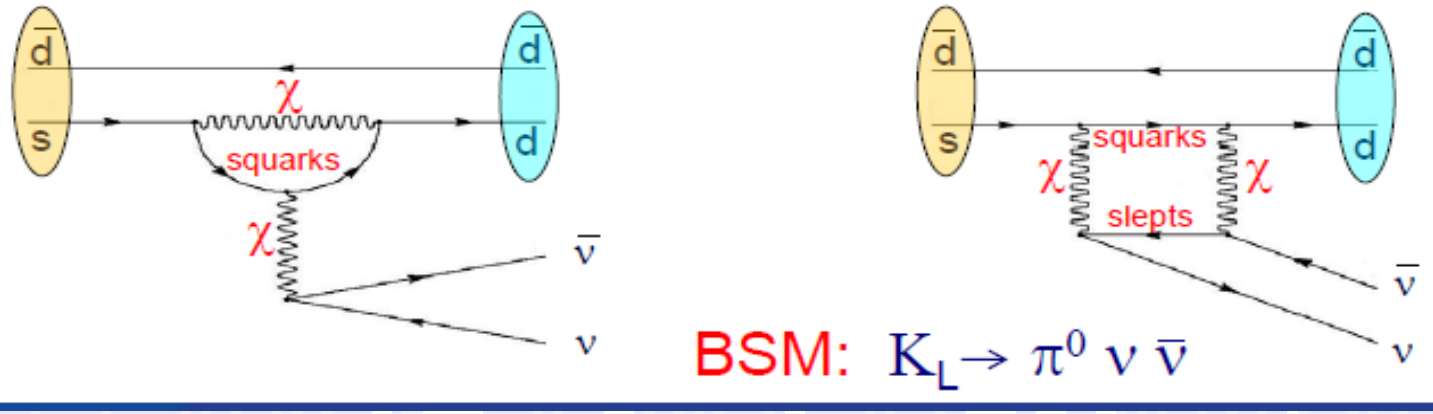
Mike Martens

October 15th, 2010

The Window of Ultra-rare Kaon Decays in Project X



Standard Model rate of 3 parts per 100 billion, known to < 3% precision



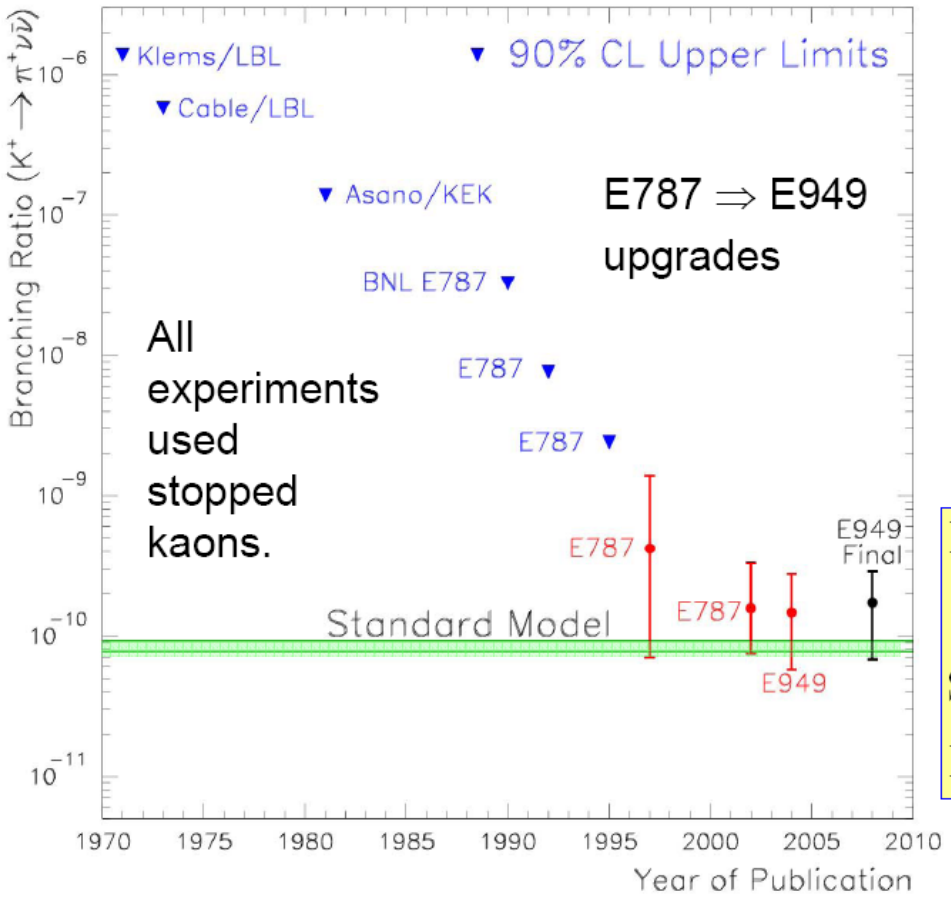
BSM particles within loops can increase the rate by x10 with respect to SM.

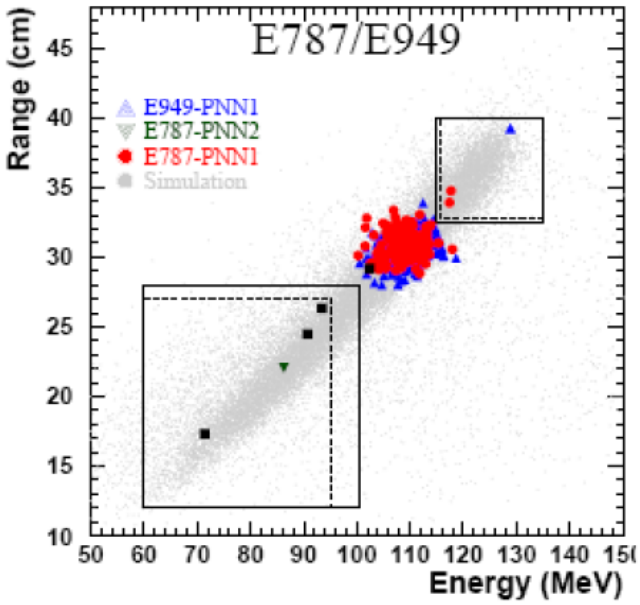
Kaon Physics

- Precision measurements of the rare decays
  - $K^+ \rightarrow \pi^+ \nu \nu$
    - The SM Branching Ratio = $(8.5 \pm 0.07) \times 10^{-11}$
    - Measured $(1.73^{+1.15}_{-1.05}) \times 10^{-10}$ (BNL E949 final result)
  - $K_L \rightarrow \pi^0 \nu \nu$
    - The SM Branching Ratio = $(2.7 \pm 0.40) \times 10^{-11}$,

- Two high impact rare kaon decay experiments have been identified for the initial Project X program:
  - Both experiments can be driven with 3 GeV Project X beam using a common production target.
  - These measurements will reach precision comparable to the small uncertainties of Standard Model predictions and will realize the ultimate potential for these processes to reveal new physics.

$K^+ \to \pi^+ \nu\bar{\nu}$ History





E787/E949 Final: 7 events observed

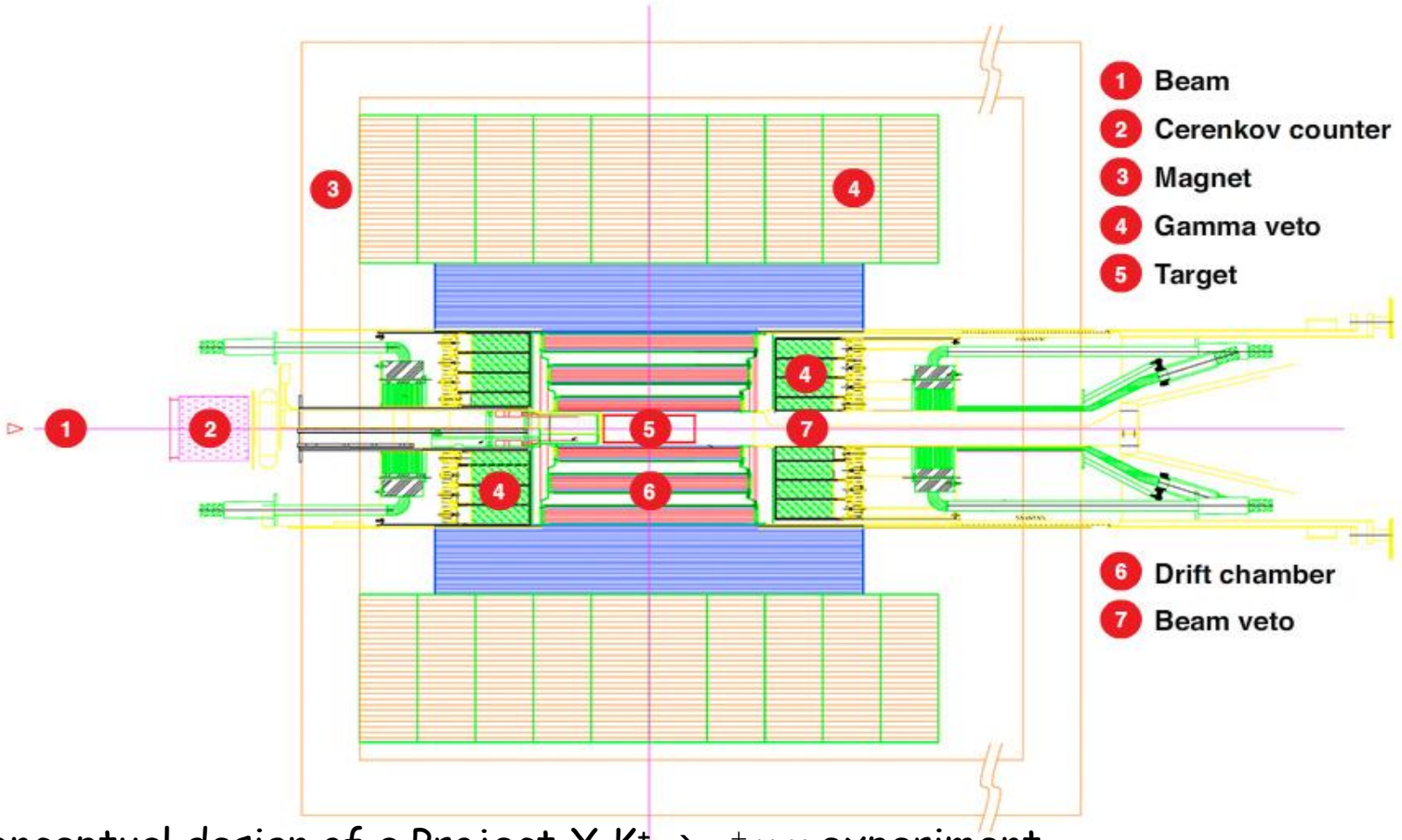
$$B(K^+ \to \pi^+ \nu\bar{\nu}) = 1.73^{+1.15}_{-1.05} x10^{-10}$$

Standard Model:

$$B(K^+ \to \pi^+ \nu\bar{\nu}) = (0.85 \pm 0.07) x10^{-10}$$

BNL AGS

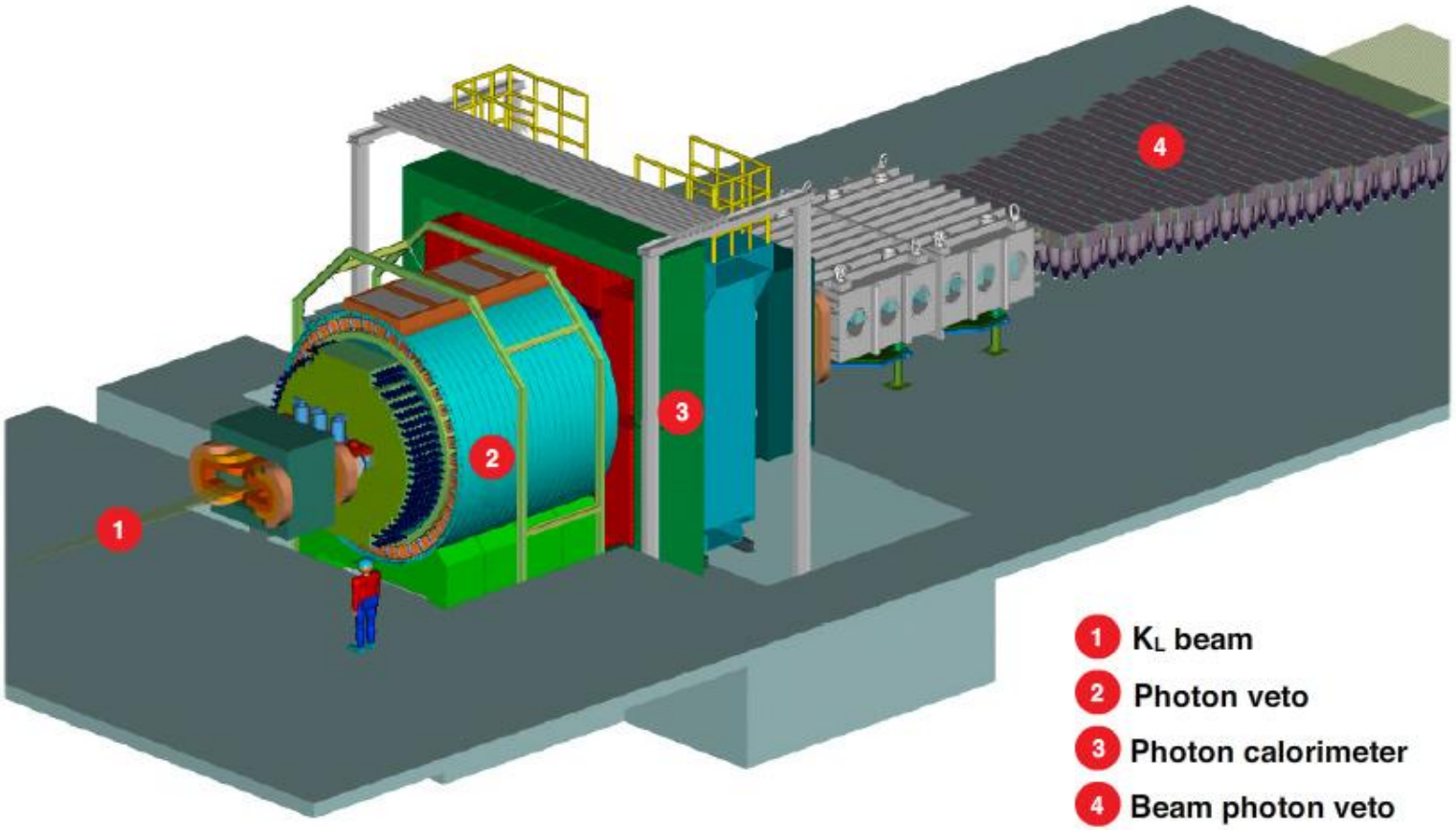
$K^+ \rightarrow \pi^+ \nu\bar{\nu}$ Experiment



Conceptual design of a Project X $K^+ \rightarrow \pi^+ \nu \nu$ experiment.

Based on evolution of BNL E949.

$K_L \rightarrow \pi^0 \nu\bar{\nu}$ Experiment



Conceptual design of the Project X $K_L \rightarrow \pi^0 \nu \nu$ experiment.
Based on KOPIO.

Chopping and splitting for 3-GeV experiments

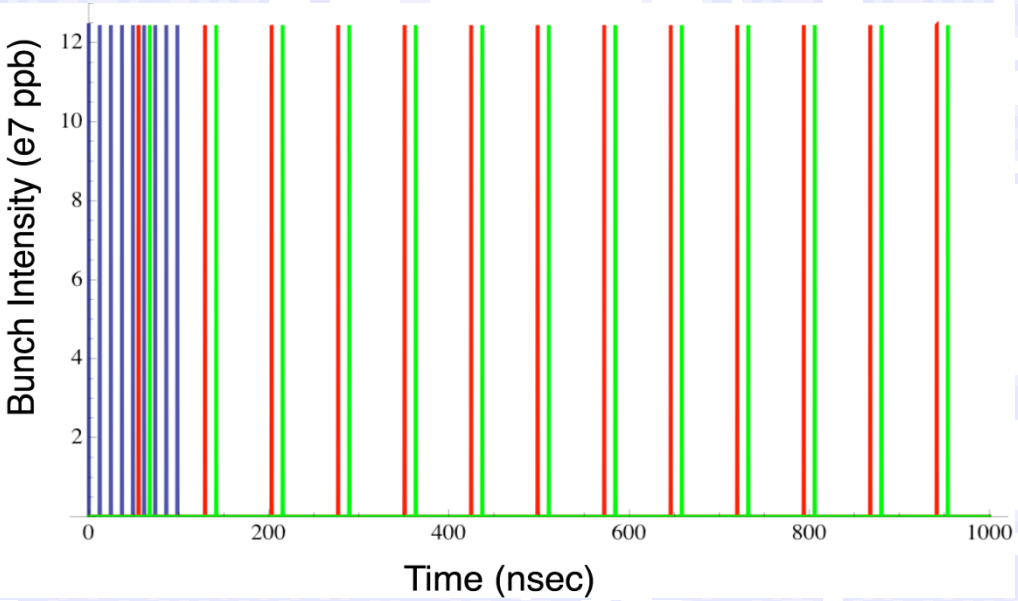
1 μsec period at 3 GeV

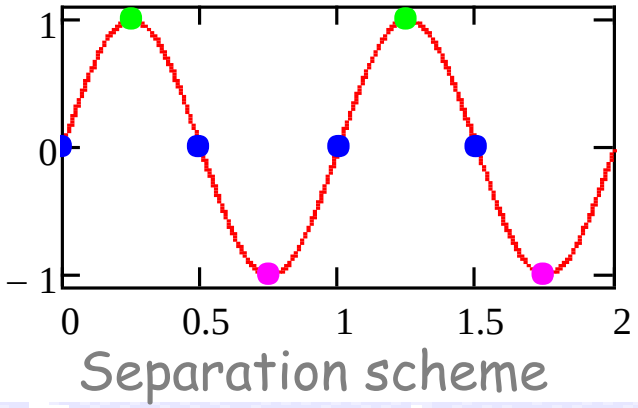
mu2e pulse (9e7) 152.5 MHz 100 nsec 600 kW

Kaon pulse (9e7) 27 MHz 1200 kW

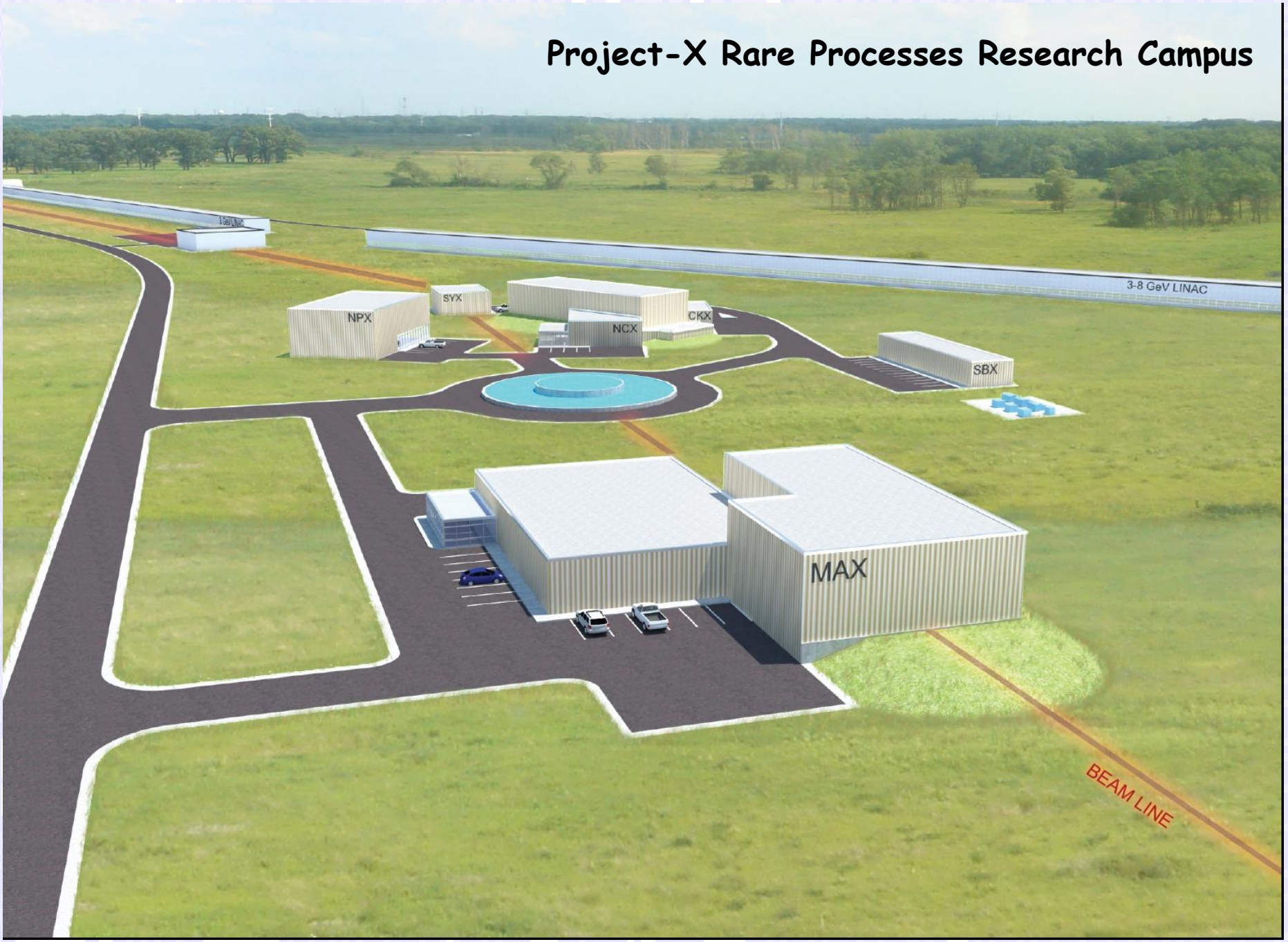
Nuclear pulse (9e7) 27 MHz 1200 kW

Ion source operates at 4 mA
75% of bunches are chopped

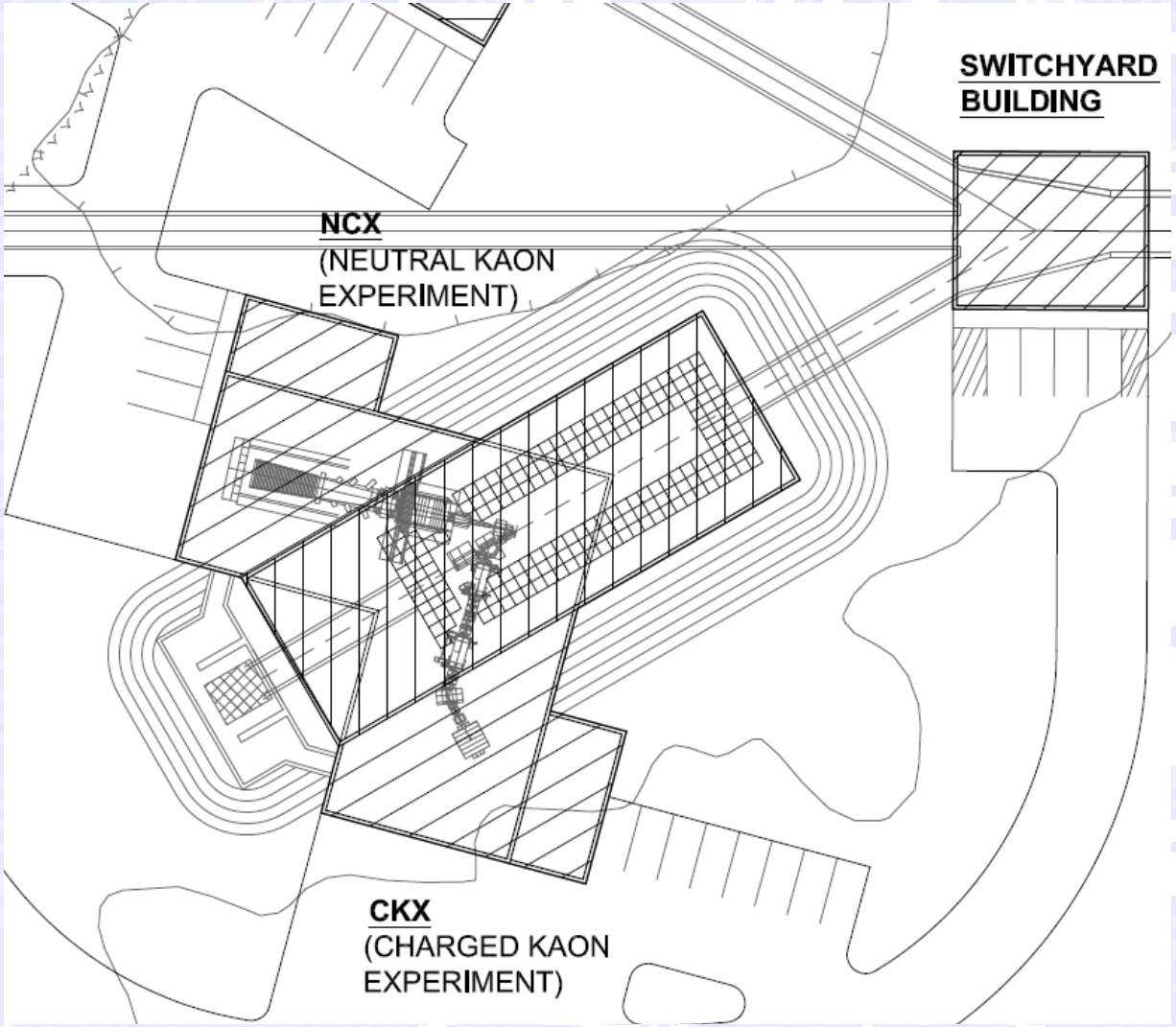




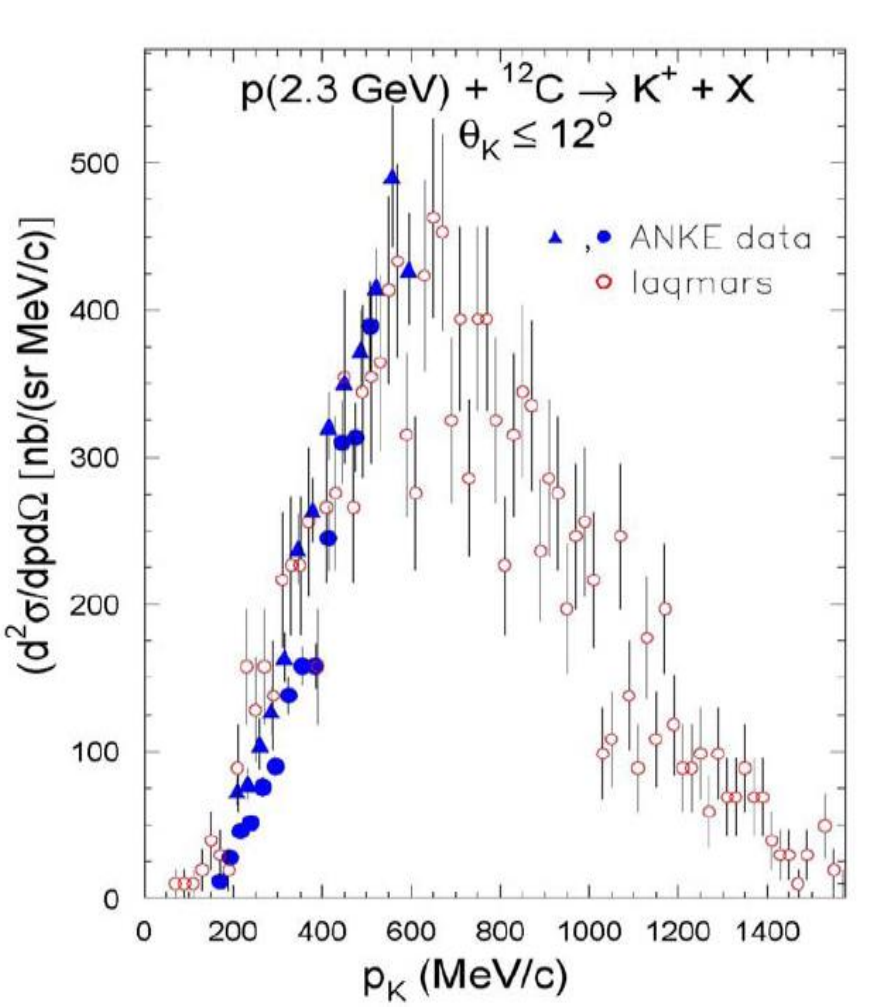
Project-X Rare Processes Research Campus



Common Target for Charged and Neutral Kaon Experiments



Validating Simulation Tools…



- Los Alamos + MARS simulation suite (LAQGSM + MARS15) is now a state of the art tool set to simulate the challenging region between 1-4 GeV/c proton beam momentum.

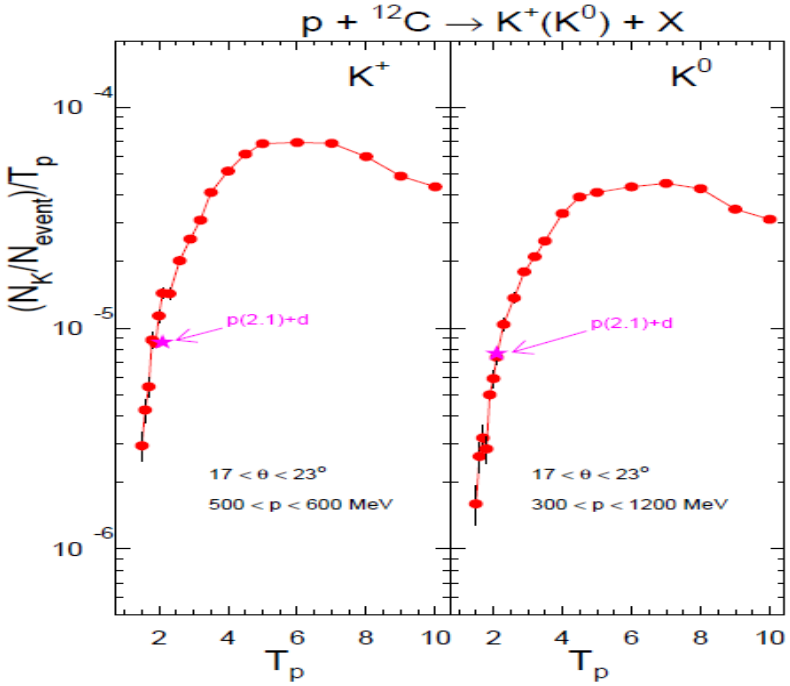
[Gudima, Mokhov, Striganov]

- Validated against the high quality data sets from COSY.

- Data shown: Buscher et al (2004) ANKE experiment at COSY, absolutely normalized.

Kaon Yield

- The estimated (LAQGSM/MARS15) kaon yield at constant beam power (yield/T_p) for experimentally optimal angular and energy regions as a function of T_p (GeV).



- The production yield curve of kaons vs. incident proton energy sets the minimum CW linac energy at ~ 3 GeV

Proton Beam Power

	Beam Energy T_p	Protons/second (avg) on [target (l_I)]	p(K^+) (MeV/c)	Stopping K^+/second	K^+/p^+ Production Ratio
BNL AGS (E949)	21 GeV	$12x10^{12}$ on [0.7 l_I Pt.]	700-730	0.7 x 10^6 K^+/sec	1:24
Project-X/ K^+ expt	3.0 GeV	1/2 x 6000x10^{12} on [1.0 l_I C] This is 1.5 MW.	450-570	98 x 10^6 K^+/sec	1:80

Compares the measured rate of stopping K^+ in the BNL-E949 experiment with full LAQGSM/MARS thick-target simulations for Project-X charged kaon yield with ½ of the 1 ma 3.0 GeV proton beam.

Project X Requirements

- Short, < 50 psec, bunch length at 20-40 MHz
- The sensitivity in the white paper assumes designing for 1/2 of the 3 GeV beam (1mA) beam. This is 1.5 MW. Can a 20-40 MHz train deliver 1.5 MW with the nominal 3-way splitter in the project scope?
- Beam extinction between pulses from the 3 GeV machine. This spec was 10**-3 for the KOPIO experiment, and we should consider 10**-4 for Project-X.

Target Station Issues

- Power management with a carbon target,
  - Nominally 1cm x 1cm x 40cm.
  - NuMI experience and plans is directly relevant.
- Shielding analysis, ground water, etc.
- Design of the dump at the kaon experiment
  - Most of the 1.5 MW enters the dump.
- Feasibility of rad-hard high aperature quads as first components of the charged kaon beam line.
  - Previous experience was with the 50 kW AGS target.

Optimal Energy

- The kaon yield/watt does not saturate until 4 GeV.
- The kaon yield per watt at 4 GeV is about x2 that of 3 GeV, so the same number of kaons could be produced at 4 GeV with a target station running at 1/2 the beam power
- The 3 GeV operating point decision was taken in an era when the 3 to 8 GeV section was a Rapid Cycling Synchrotron, which is more or less the same cost for 3->8 and 4->8 GeV....hence motivating the lowest possible energy for the CW machine.
- The preferred solution now for Project-X is a pulsed linac from 3 to 8 GeV.
- A question thus rears it's head about the cost of 4 GeV CW machine. We can't really conclude we are at an optimal cost point with 3 GeV, particularly considering the cost of high power target stations.
- This should be raised at the meeting. There may be a bit of screaming and yelling about this point....but better now that later.