ORKA Progress Report

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Fermilab Users' Meeting

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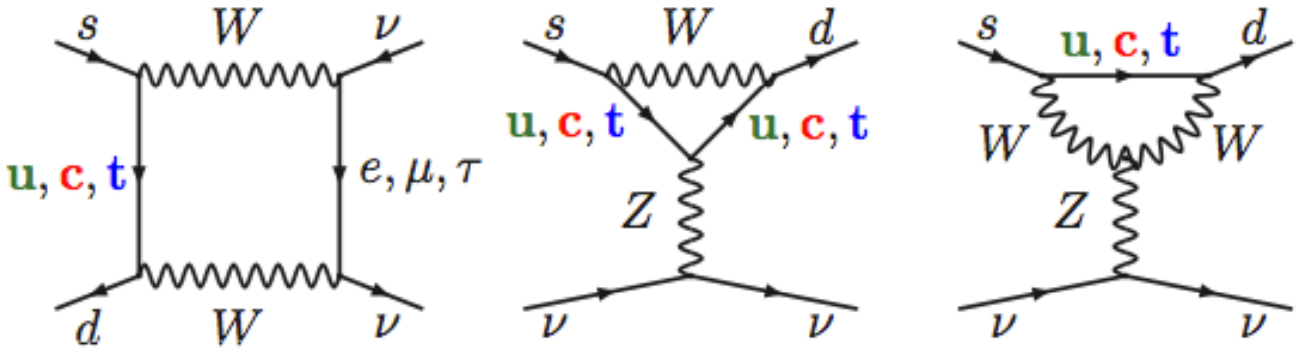
ORKA: The Golden Kaon Experiment

- Precision measurement of $K^+ \to \pi^+ \nu\bar{\nu}$ BR with ~1000 events at FNAL MI
- Expected BR uncertainty matches Standard Model uncertainty
- Sensitivity to new physics at and beyond LHC mass scale
  - New Physics at LHC $\rightarrow$ Explore its flavor structure
  - No New Physics at LHC $\rightarrow$ Explore higher mass scales
- Builds on successful previous experiments
  - BNL E787/E949
  - 7 candidate events already observed

Standard Model Physics

- $K \to \pi \nu \bar{\nu}$ is the most precisely predicted FCNC decay involving quarks

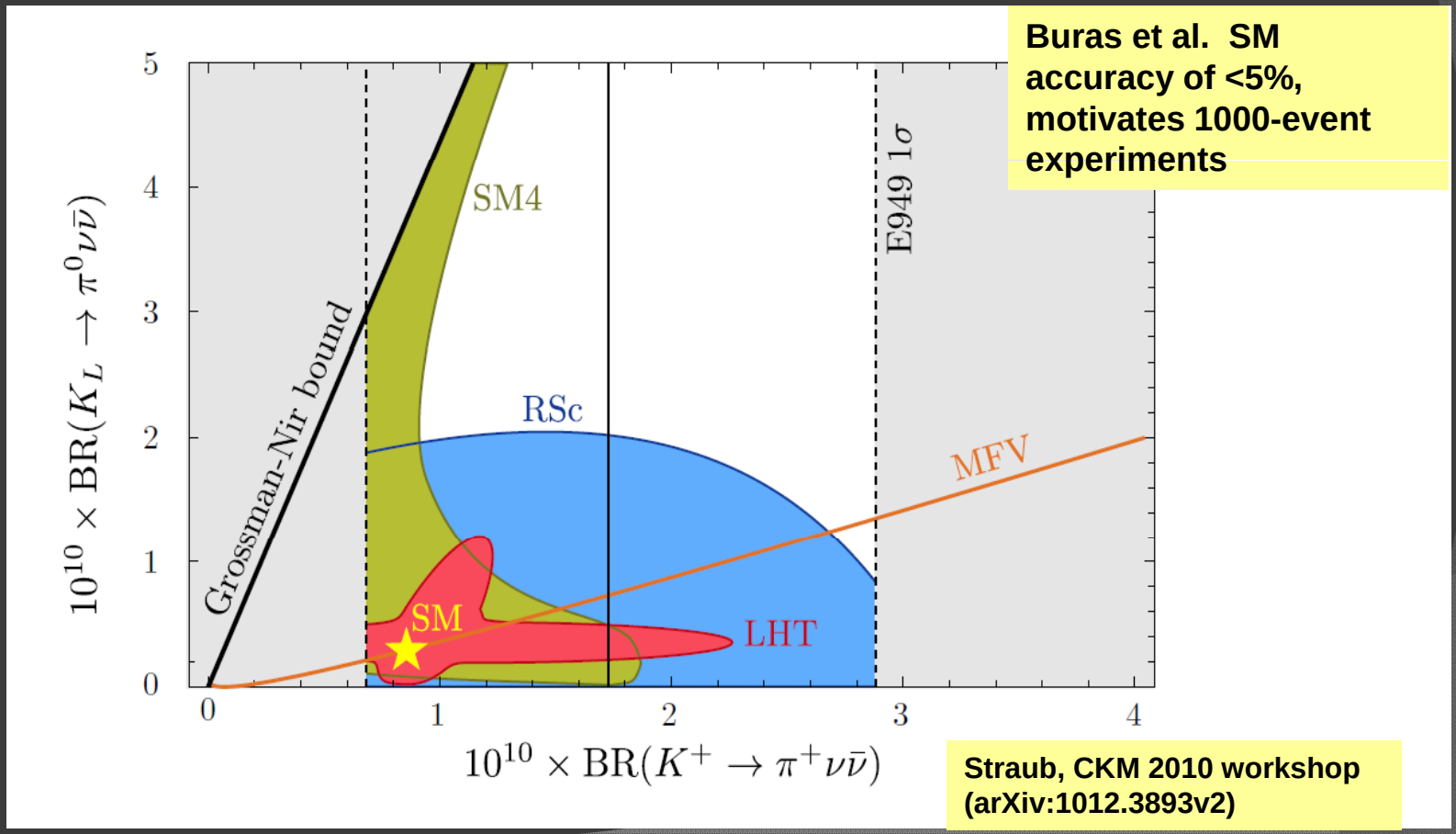
$$B_{SM}\left(K^+ \to \pi^+ \nu\bar{\nu}\right) = (7.8 \pm 0.8) \times 10^{-11}$$



- A single effective operator: $(s_L \gamma^\mu d_L)(\nu_L \gamma_\mu \nu_L)$
- Dominated by top quark
- Hadronic matrix element shared with $K^+ \to \pi^0 e^+ \nu$
- Dominant uncertainty from CKM matrix elements
  - Expect prediction to improve to ~5%

BSM Constraints

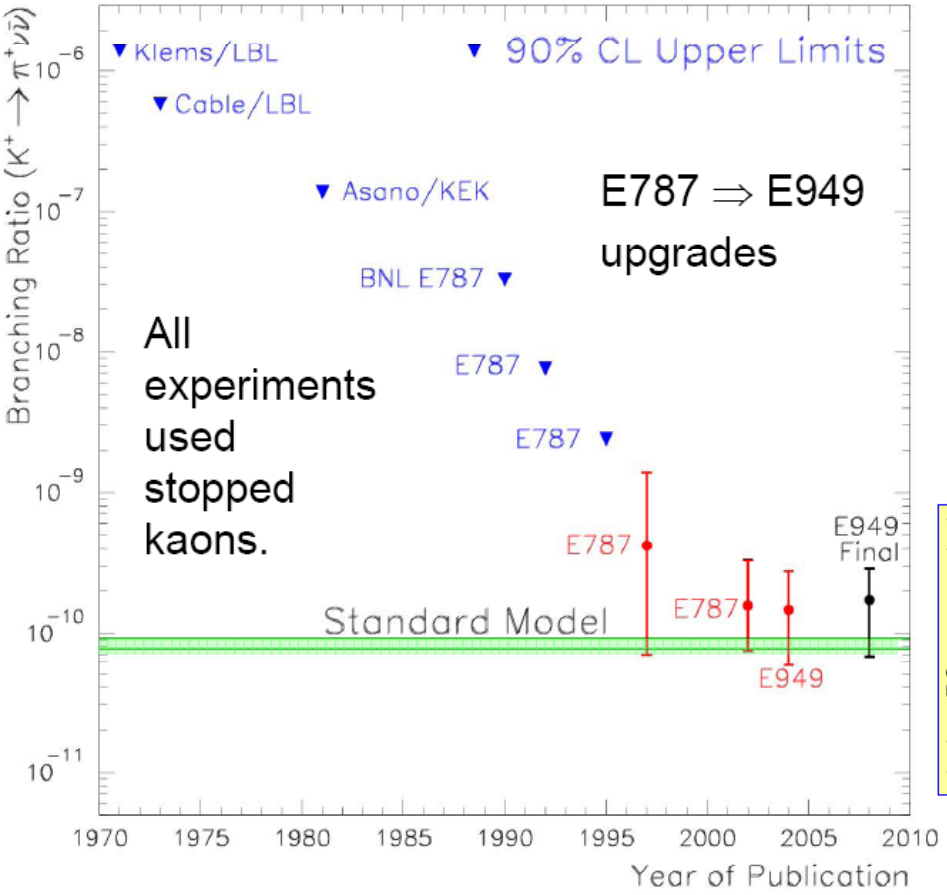
- Measuring both of $K^+ \to \pi^+ \nu\bar{\nu}$ and of $K_L^0 \to \pi^0 \nu\bar{\nu}$ puts tight constraints on New Physics

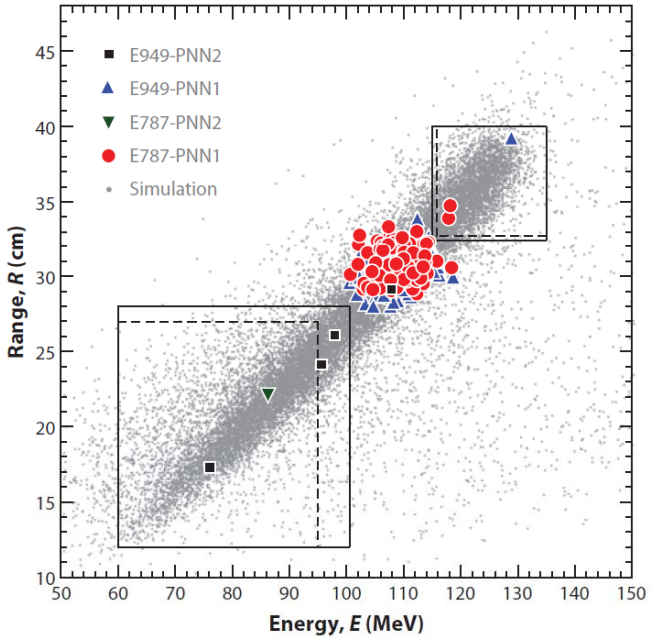


Buras et al. SM accuracy of <5%, motivates 1000-event experiments

Straub, CKM 2010 workshop (arXiv:1012.3893v2)

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





E787/E949 Final: 7 events observed

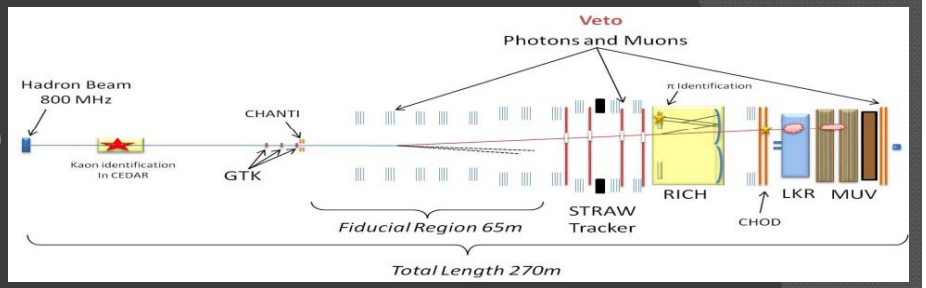
$B(K^+ \to \pi^+ \nu\bar{\nu}) = 1.73^{+1.15}_{-1.05} x10^{-10}$

Standard Model:

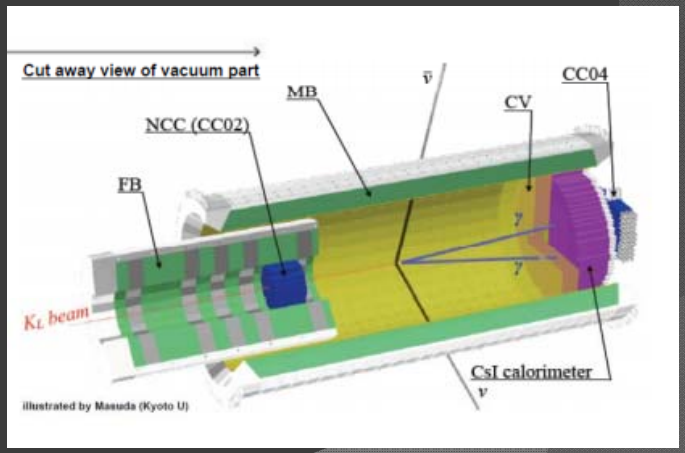
$B(K^+ \to \pi^+ \nu\bar{\nu}) = (0.78 \pm 0.08)\ x10^{-10}$

Other Experiments

- CERN NA-62 ($K^+ \to \pi^+ \nu\bar{\nu}$)
  - Decay-in-flight experiment
    - Complementary technique to ORKA
  - Expect 10% measurement of $K^+ \to \pi^+ \nu\bar{\nu}$ BR
    - ~55 $K^+ \to \pi^+ \nu\nu$ events per year (SM)
    - ~7 bg events per year
    - ~100 total events



- J-PARC E14 "KOTO" ($K^0 \to \pi^0 \nu\bar{\nu}$)
  - Pencil beam decay-in-flight experiment
  - Improved J-PARC beam line
  - 2nd generation detector building on E391 at KEK
  - Re-using KTeV CsI crystals to improve calorimeter
  - Expect ~3 $K^0 \to \pi^0 \nu\bar{\nu}$ events (SM rate)

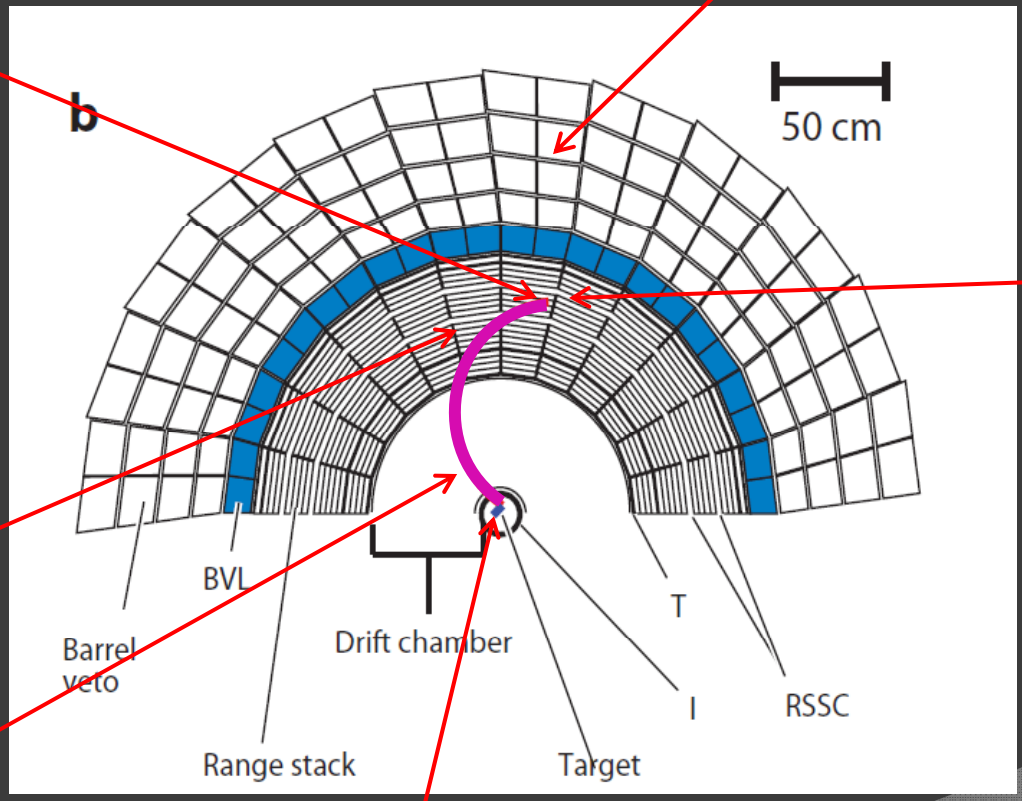


Stopped Kaon Technique

- Measure Everything!

4π photon veto

Delayed electron from muon decay



Muon stopping pulse from pion decay

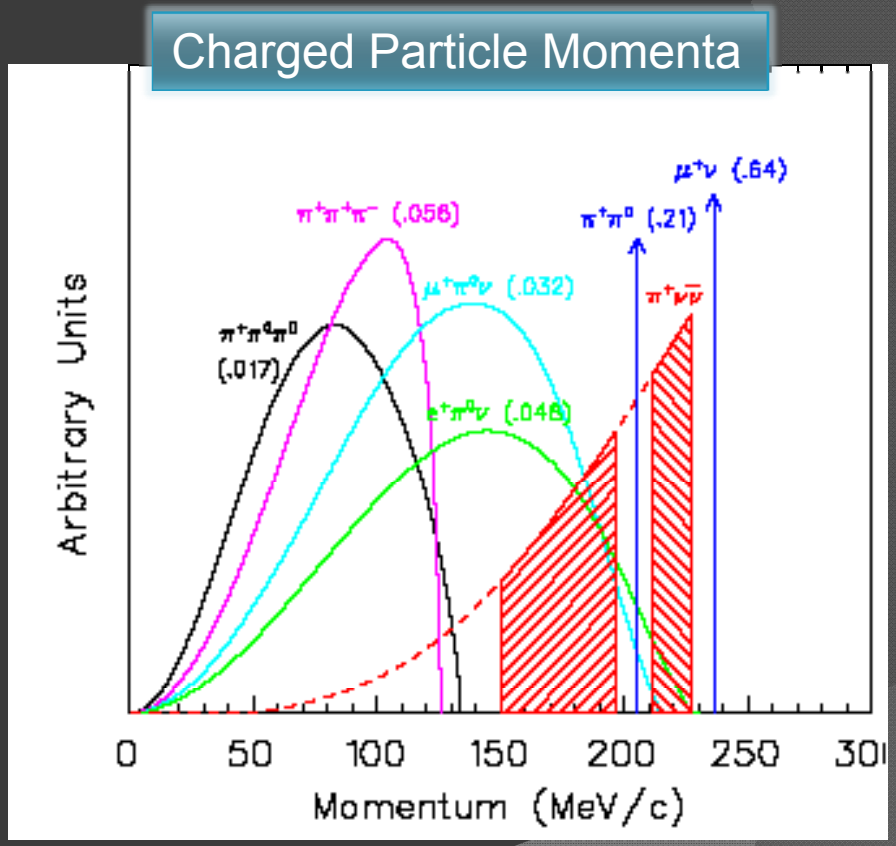
Pion energy in range stack

Pion momentum in drift chamber

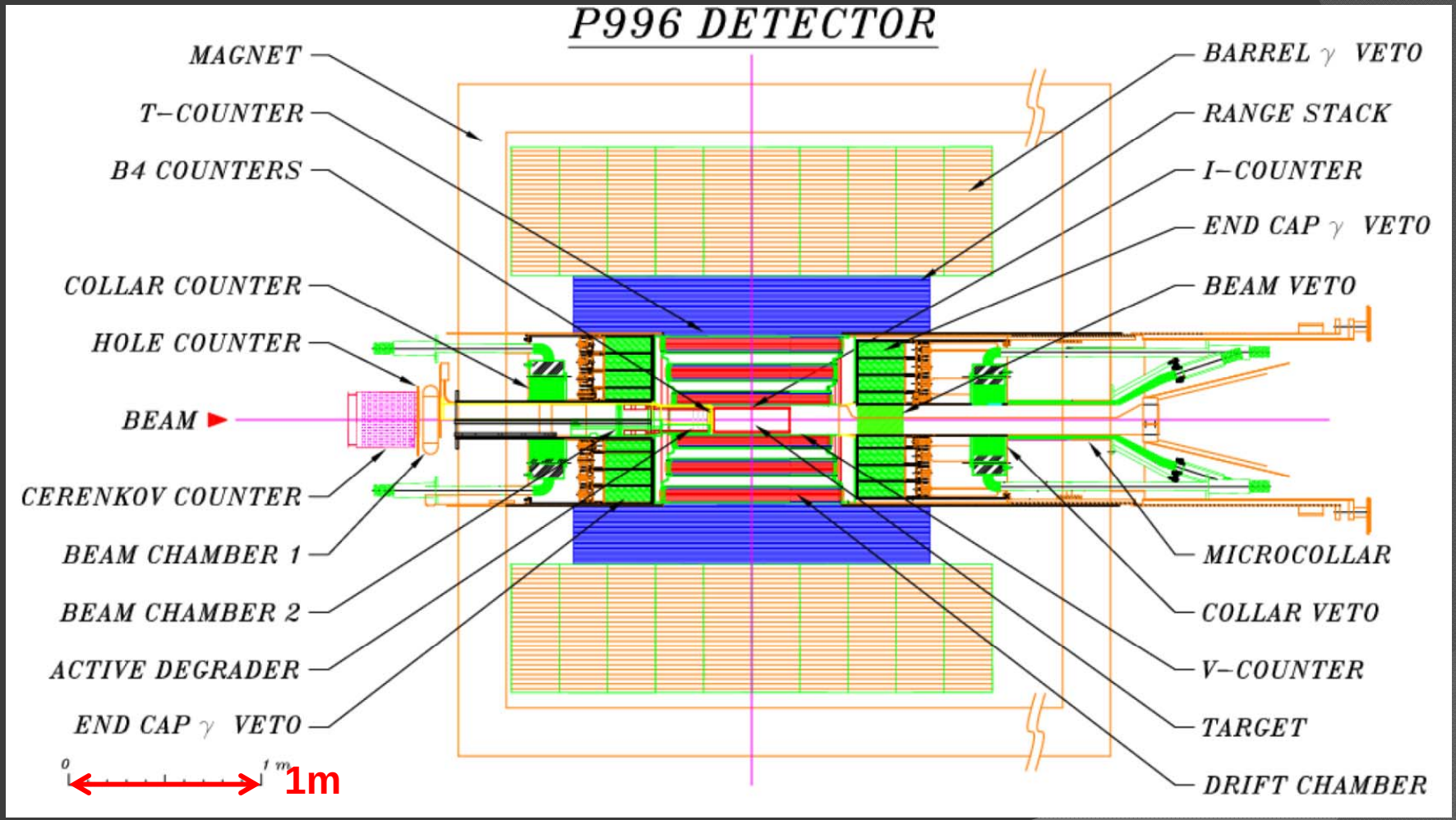
Signal from incident kaon and exiting pion in stopping target

Background Suppression Critical

- Observed signal is $K^+ \rightarrow \pi^+ \rightarrow \mu^+ \rightarrow e^+$
- Background exceeds signal by > 10^{10}
- Requires suppression of background well below expected signal (S/N ~10)
- Requires π/μ/e particle ID > 10^6
- Requires π^0 inefficiency < 10^{-6}



ORKA improves on E949



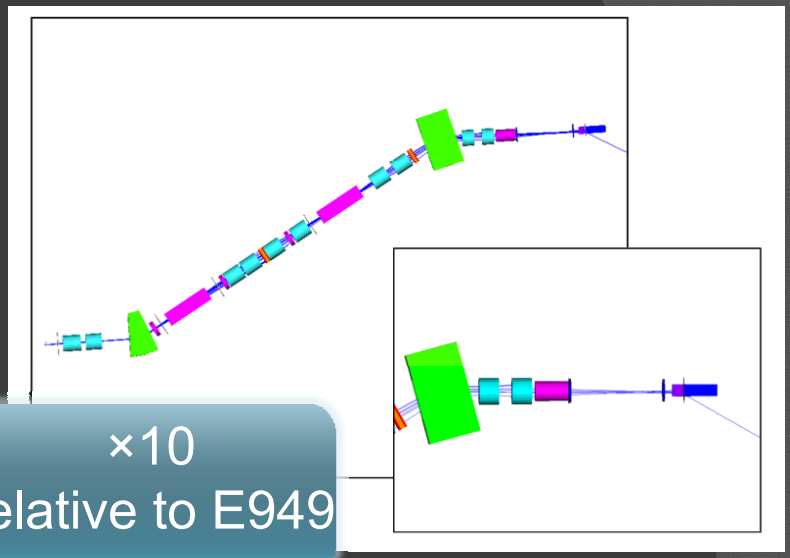
ORKA improves on E949

- Acceptance better by factor ~10

Component	Acceptance factor
$\pi \longrightarrow \mu \longrightarrow e$	2.24 ± 0.07
Deadtimeless DAQ	1.35
Larger solid angle	1.38
1.25-T B field	1.12 ± 0.05
Range stack segmentation	1.12 ± 0.06
Photon veto	$1.65^{+0.39}_{-0.18}$
Improved target	1.06 ± 0.06
Macro-efficiency	1.11 ± 0.07
Delayed coincidence	1.11 ± 0.05
Product (R_{acc})	$11.28^{+3.25}_{-2.22}$

Slow Extraction at Main Injector

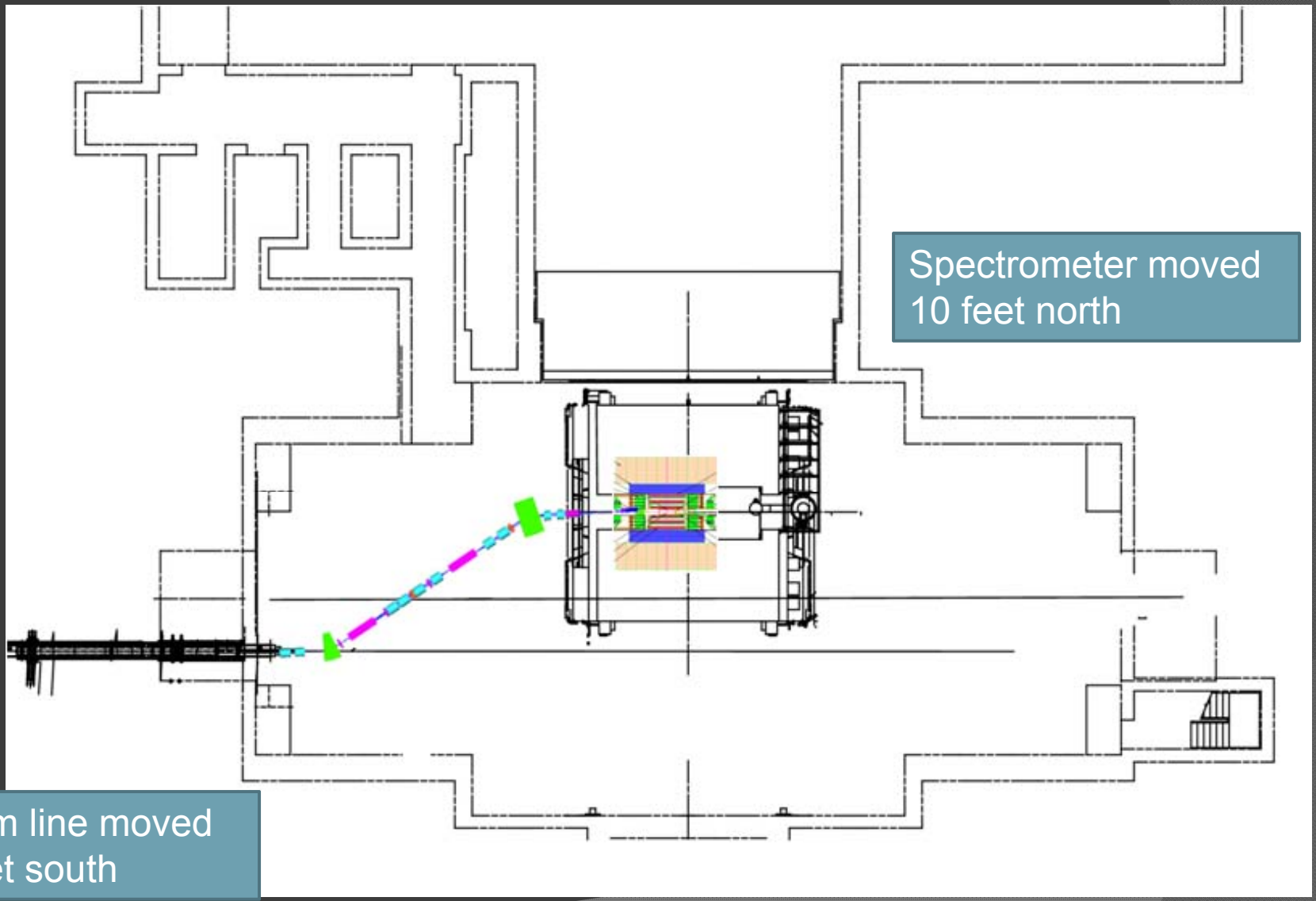
- Primary Beam
  - 95 GeV/c protons
  - 50-75 kW
  - 48 × 10^{12} protons per spill
  - Duty factor of ~45%
  - # of protons/spill (×0.74)
- Secondary Beam Line
  - 600 MeV/c K^+ particles
  - Increased number of kaons/proton from longer target, increased angular acceptance, increased momentum acceptance (×4.3)
  - Larger kaon survival fraction (×1.4)
  - Increased fraction of stopped kaons (×2.6)
- Increased veto losses due to higher instantaneous rate (×0.87)



ORKA at CDF

- Rebuild A sector of Main Ring for primary beam transport
  - Detailed cost and schedule estimates complete
  - All magnets available
    - Require refurbishing
  - Well shielded transport and experimental enclosures
- Use CDF magnet
  - Solenoid and associated services available
  - Experimental hall with power, cooling, HVAC, counting room

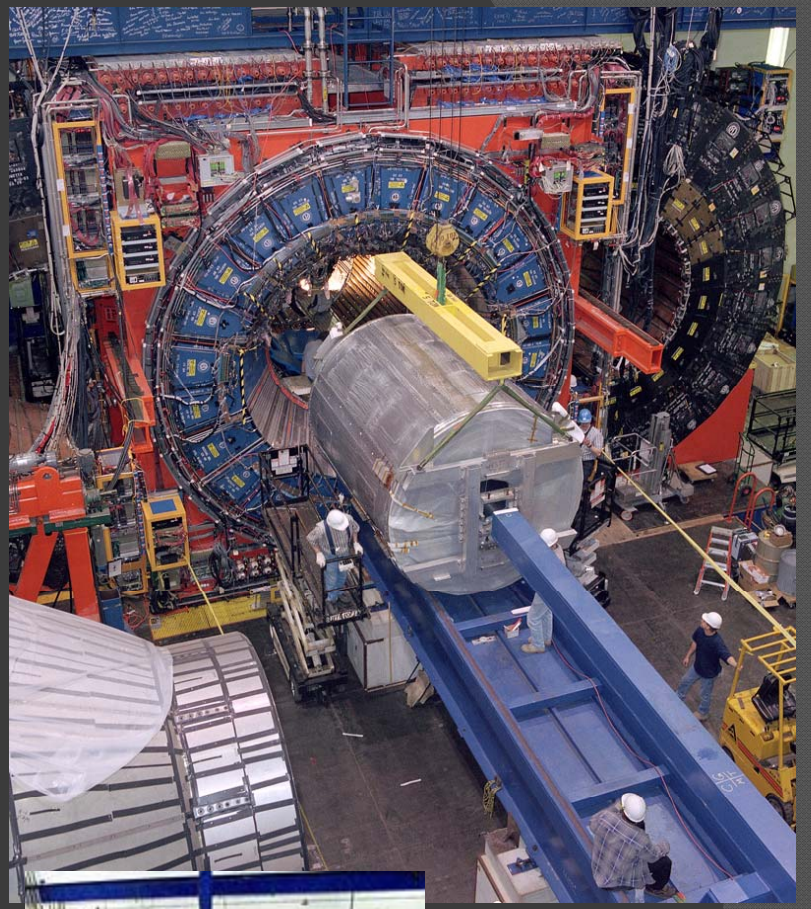
ORKA at CDF

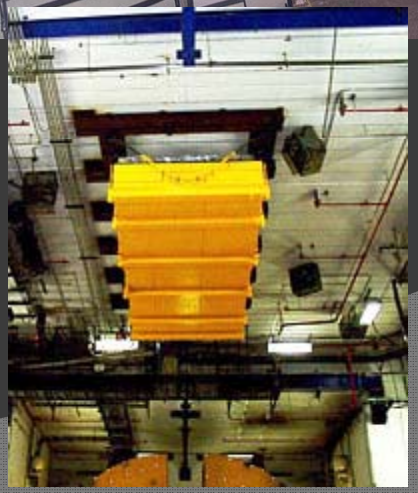

Spectrometer moved
10 feet north
Beam line moved
6 feet south

Preparations have begun!

- Illinois Accelerator Research Center will start using CDF assembly hall in FY15
  - Narrow window to prepare for ORKA
  - Even prior to CD0, need to decommission CDF
    - Provides lab with 3m diameter, 1.4 T solenoid in a shielded hall for ORKA or any other experiment
- Extensive work
  - Remove trackers
  - Demolish external muon systems
  - Remove cable bridge
  - Strip off electronics
- Recovering equipment for other experiments
  - IF@FNAL, FTBF, KEK, LHC, CF, JLab

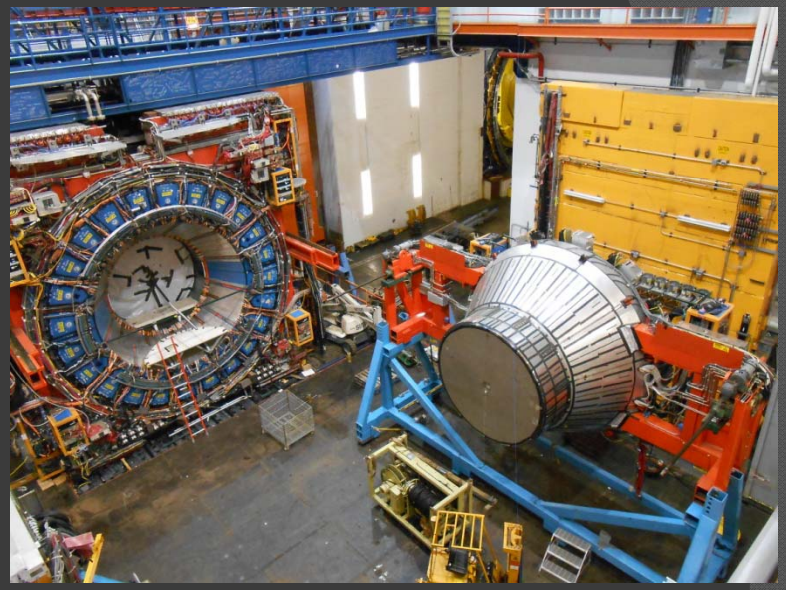
Demolition Scope





Decommissioning Status

- Central Detector and muon walls now in assembly pit
  - Cable bridge nearly empty
  - West plug dismounted
  - Working on removing hair from end walls and plugs
- Construction area. Sorry no visitors!



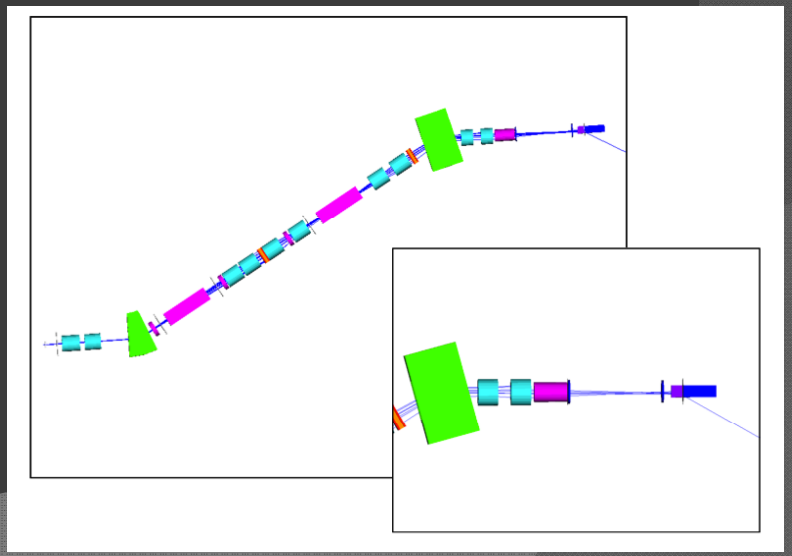
ORKA Collaboration is active and growing

Cost review

- Bottom-up review of all ORKA subsystems
  - Significantly better understanding of costs than in P996 proposal
    - Included external experts as reviewers and consultants to help refine costs
  - Maintain $50M neighborhood
  - Beamline moved to a set of AIP projects
    - Similar strategy to muon campus
    - Can begin primary beam quickly if funding is available

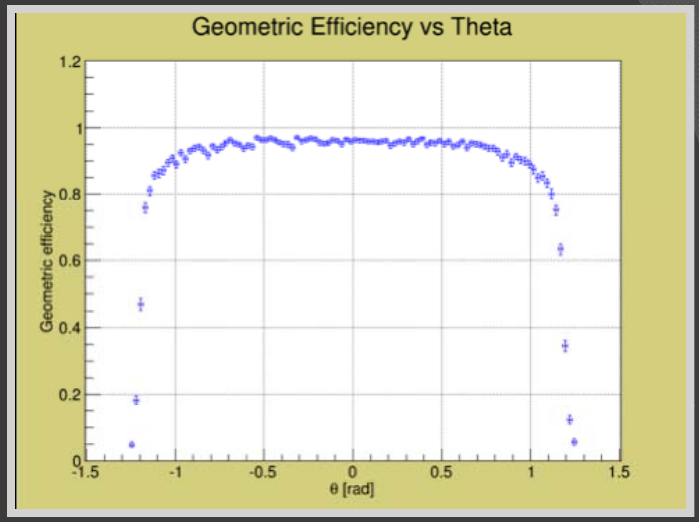
Secondary Beam Line Design

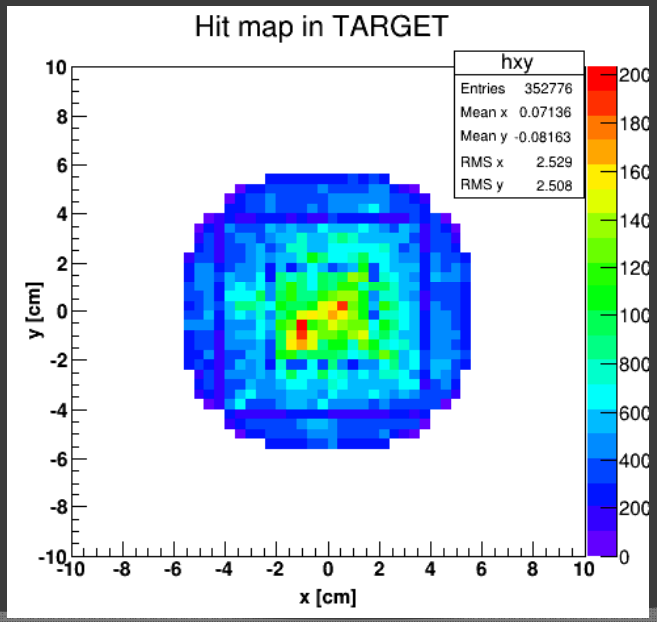
- Detailed simulation work of beam from production target to stopping target
  - G4Beamline, Transport, Turtle
  - Redesigned from BNL-style 90-degree bend to dog-leg configuration
- Studies show encouraging K/π ratio
- MARS target studies show acceptable backgrounds



Detector Simulations

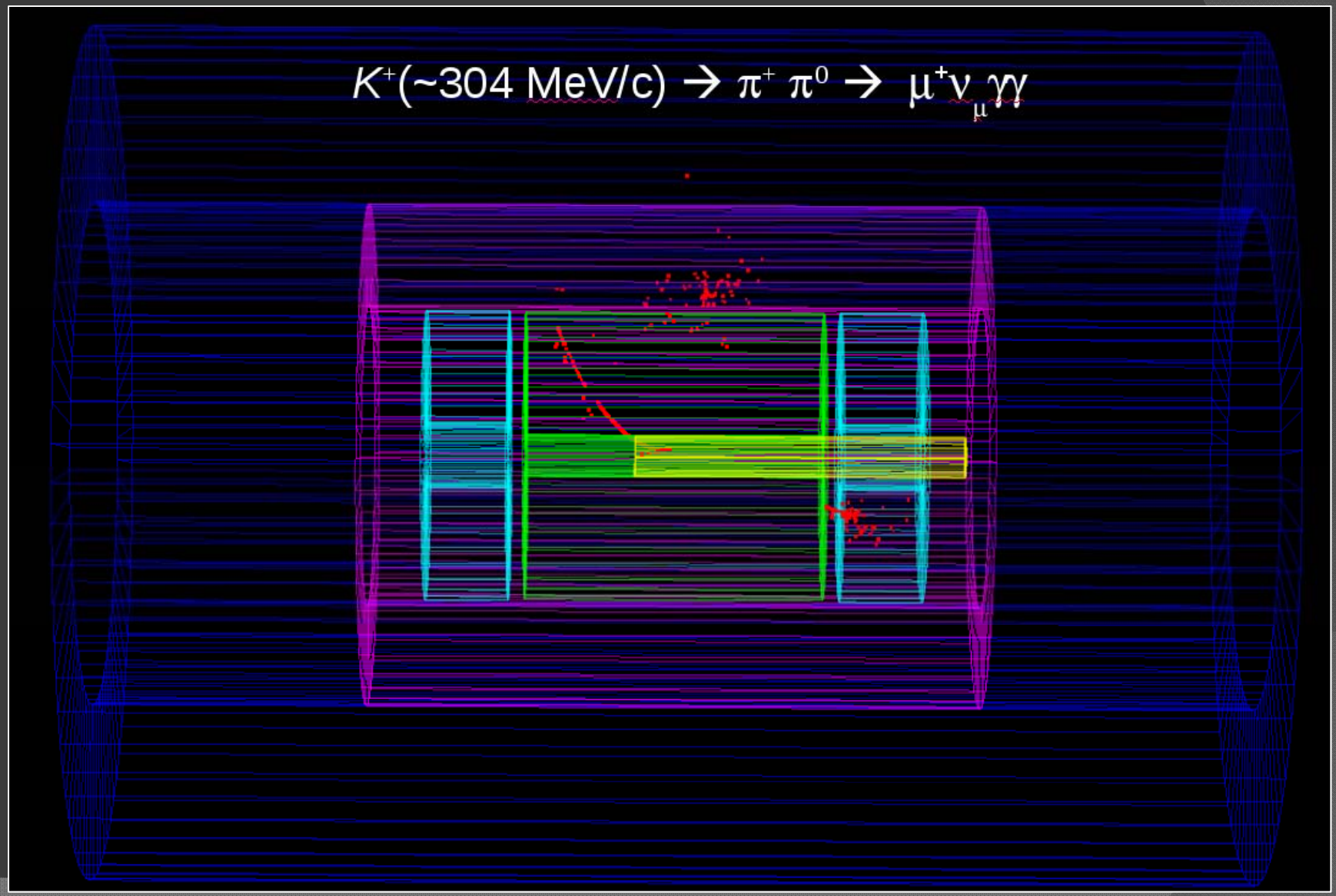
- Implemented in ILCRoot framework
- Verify improvements relative to E949 reference





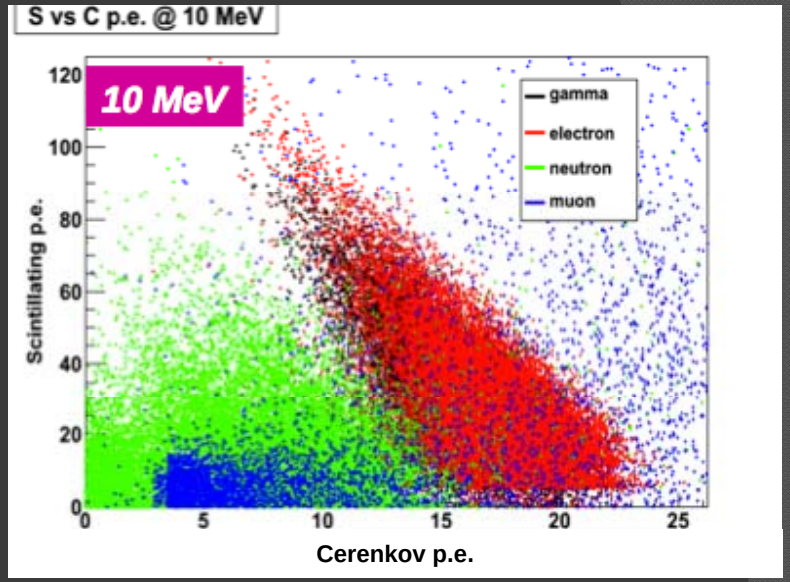
- Detector optimization studies
  - Length, depth and segmentation
  - Technology options
    - Shashlyk vs. Adriano calorimeter
    - Scintillator vs. high-pressure gas stopping target

ILCRoot at work

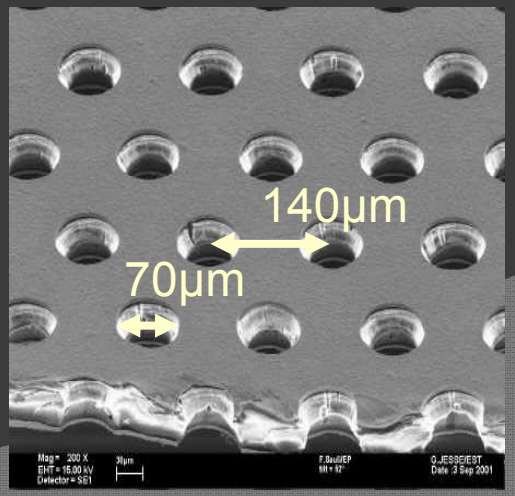


Active R&D Program

- ADRIANO fully-active calorimeter
  - Cerenkov light from layers of lead glass
  - Scintillation light from layers of plastic scintillator
  - Potential to improve photon-veto efficiency
  - Potential for particle identification
  - T-1015 running in December
- Tracking with GEM
  - Gas electron multiplier
  - Low cost, low HV, high gain
- SiPM readout
  - Low cost, low HV, high gain
  - Double-pulse resolution
  - Temperature sensitivity
  - Direct coupling to cast scintillator
    - Best possible time resolution



GEM foil:



R&D

- Front-end electronics
  - Hope to partner with other IF experiments
  - Most channels need 500MHz wave-form digitizers
  - Timing critical for background rejection
- Drift chamber
  - Reduce mass with He-based gas
  - Reduce mass of support structure
- Data acquisition
  - Enormous data throughput
    - Triggerless system
    - High-rate digitizers
    - Long time depth for muon decay
  - Investigate region-of-interest and compression algorithms to sparsify data

Summary

- High precision measurement of $K^+ \to \pi^+ \nu\bar{\nu}$ at FNAL MI
  - Discovery potential for new physics at and above LHC mass scale
- Timescale: 3-4 years for construction
  - Requires modest accelerator improvements and no civil construction
  - Total project cost: ~$50M
- Expect ~1000 events and 5% precision on BR measurement with 5 years of data
- Flavor community, FNAL management and US funding agencies are enthusiastic about ORKA and working to find a way to make it possible.
- ORKA proposal:
  - http://www.fnal.gov/directorate/program_planning/Dec2011PACPublic/ORKA_Proposal.pdf
- The tradition of flavor physics at Fermilab and B0 continues
- New collaborators welcome!

Shameless Plug

What Can PREP Do for You?

Today during the lunch break
Race Track -- WH7X

Backup

Vote for your favorite ORKA logo