The Future of US Flavor Physics

APS April 2008 Meeting

R. Tschirhart
April 14^{th}, 2008

Will this be a short talk??

- Fermilab fixed target analyses are essentially complete.
- CLEO-c: End of an era! Operations ended last month. 450 papers published so far.
- BaBar operations ended last week, transitioning to final data analysis phase.
- CDF/D0 operations scheduled to end October 2009.
- CKM/BTeV/KOPIO/MECO initiatives stopped.
- Active flavor program and promising initiatives "Off-shore" …but can they retain and gain traction in the US with the excitement of the emerging energy frontier at CERN?

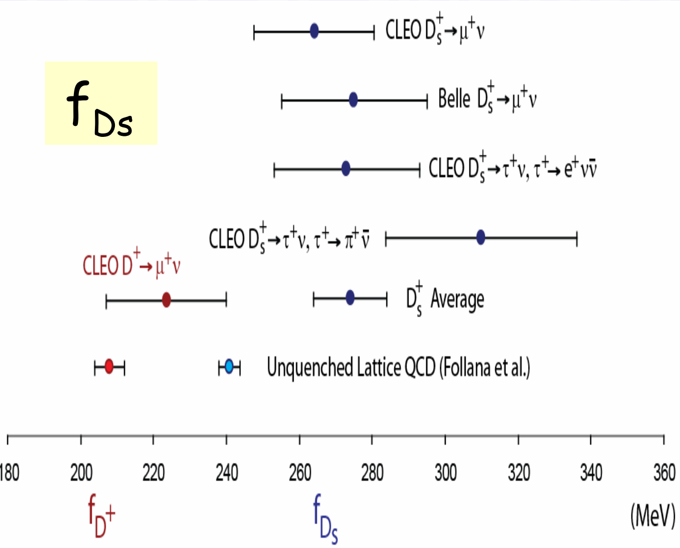
But there is an avalanche of Flavor Physics at this meeting…

- Saturday AM: Session B11: B Physics I, **9 talks.**
- Saturday PM: Session D2: Charm & Beauty, **3 talks.**
- Saturday PM: Session E12: B Physics II, **9 talks.**
- Saturday PM: Session D3: Quantum Chromodynamics, **1 talk.**
- Sunday AM: Session H2: B Physics III, **3 talks.**
- Sunday AM: Session J7: Recent High'ts in Had. Physics. **3 talks.**
- Sunday PM: Session L11: Charm Physics, **9 talks.**
- Sunday PM: Session M12: Top III, **8 talks.**
- Monday AM: Session R9: Lattice QCD in Elem'ry Part Phys, **3 talks.**
- Monday PM: Session T11: Miscellaneous Searches II, **2 talks.**
- Tuesday AM: Session W12: D and B Physics, **9 talks.**
- Tuesday AM: Session W15: Hadronic Physics, **3 talks.**
- Tuesday PM: Session X11: Top II, **2 talks.**

There have been and continue to be hints of new physics…

CLEO-c

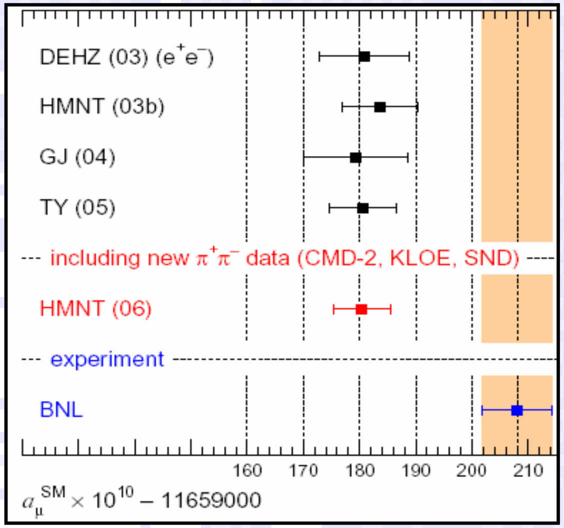
f_{D_s}

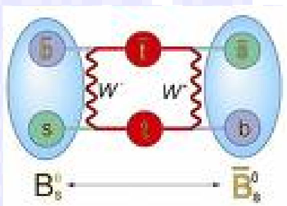


~3σ above LQCD prediction: Follana(arXiv:0706.1726)

- $(g_\mu - 2)$ anomaly?
- D_s decay rates?
- CP phases in Bs mixing?

g-2





CDF & D0

FIRST EVIDENCE OF NEW PHYSICS IN b ↔ s TRANSITIONS

(UT*fit* Collaboration)

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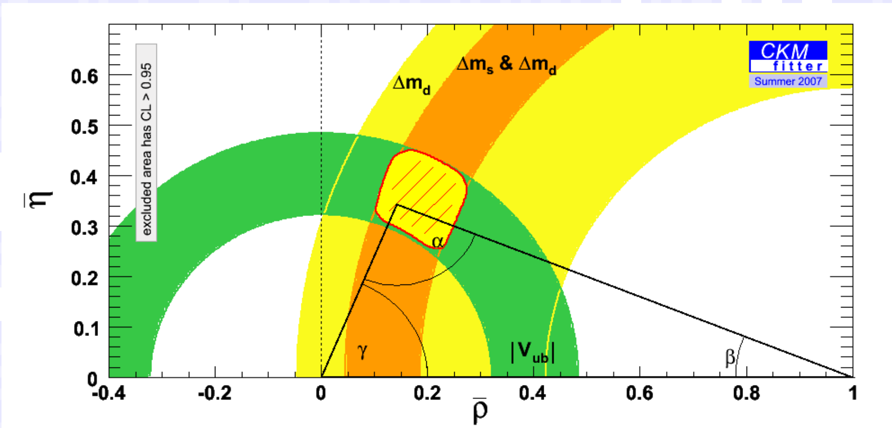
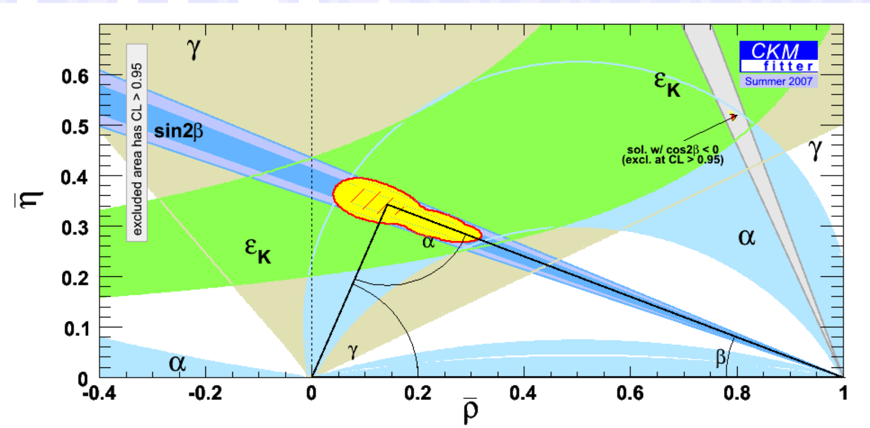
We combine all the available experimental information on B_s mixing, including the very recent tagged analyses of $B_s \to J/\Psi\phi$ by the CDF and DØ collaborations. We find that the phase of the B_s mixing amplitude deviates more than 3σ from the Standard Model prediction. While no single measurement has a 3σ significance yet, all the constraints show a remarkable agreement with the combined result. This is a first evidence of physics beyond the Standard Model. This result disfavours New Physics models with Minimal Flavour Violation with the same significance.

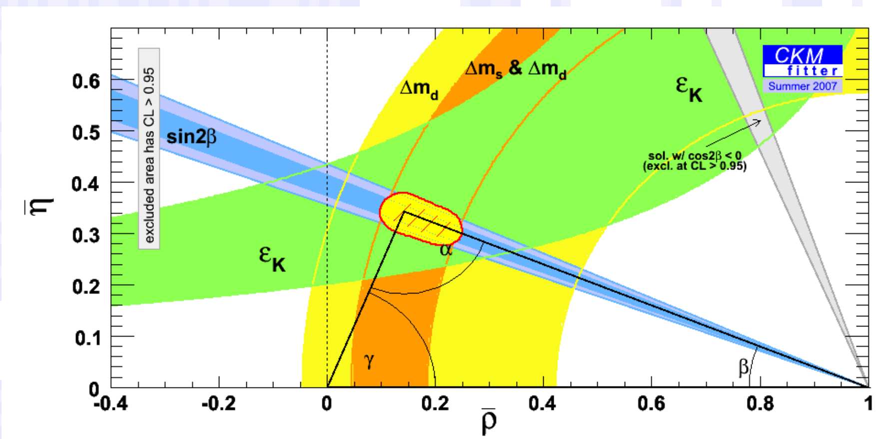
But *More* Striking: The dog that did not bark...



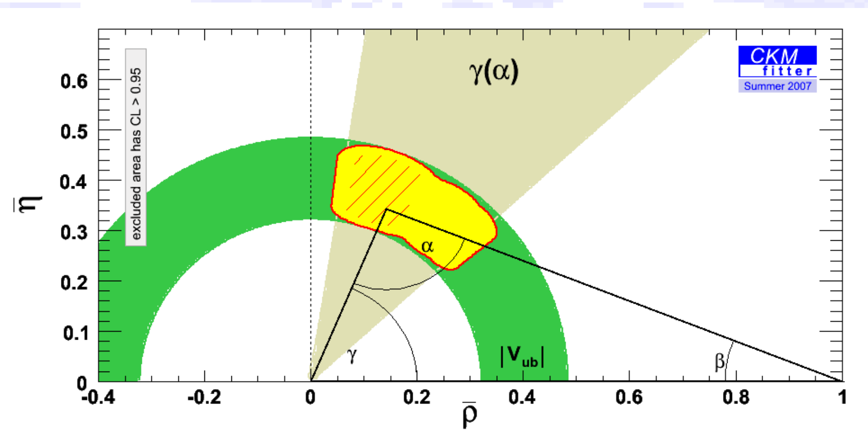
CP Conserving



CP Violating



Loop Processes



Tree Level

(ρ,η) is a 2d parameterization of quark-flavor mixing

The Data has put us on the hot seat: Motivates a "Minimal Flavor Violating" Framework

$$M(B_d\text{-}\bar{B}_d) \sim \frac{(y_t V_{tb}{}^* V_{td})^2}{16\,\pi^2 M_W{}^2} + c_{NP}\frac{1}{\Lambda^2}$$

contrbution of the new heavy degrees of freedom

c_{NP}:

- ~ 1 — tree / strong + generic flavour → $\Lambda \gtrsim 2{\times}10^4$ TeV [K]
- $\sim 1/(16\,\pi^2)$ — loop + generic flavour → $\Lambda \gtrsim 2{\times}10^3$ TeV [K]
- $\sim (y_t V_{ti}{}^* V_{tj})^2$ — tree / strong + MFV → $\Lambda \gtrsim 5$ TeV [K & B]
- $\sim (y_t V_{ti}{}^* V_{tj})^2/(16\,\pi^2)$ — loop + MFV → $\Lambda \gtrsim 0.5$ TeV [K & B]

If you don't think this is an accident of $\Delta F=2$... $\Rightarrow$ MFV

recent analysis: Bona *et al.* '07

G. Isidori, LP-2007

Minimal Flavor Violation limits New Physics enhancements to less than x2 in most cases.

Branching Ratios	MFV (95%)	SM (68%)	SM (95%)
$Br(K^+ \to \pi^+ \nu\bar{\nu}) \times 10^{11}$	< 11.9	8.3 ± 1.2	$[6.1, 10.9]$
$Br(K_L \to \pi^0 \nu\bar{\nu}) \times 10^{11}$	< 4.59	3.08 ± 0.56	$[2.03, 4.26]$
$Br(K_L \to \mu^+\mu^-)_{SD} \times 10^{9}$	< 1.36	0.87 ± 0.13	$[0.63, 1.15]$
$Br(B \to X_s \nu\bar{\nu}) \times 10^{5}$	< 5.17	3.66 ± 0.21	$[3.25, 4.09]$
$Br(B \to X_d \nu\bar{\nu}) \times 10^{6}$	< 2.17	1.50 ± 0.19	$[1.12, 1.91]$
$Br(B_s \to \mu^+\mu^-) \times 10^{9}$	< 7.42	3.67 ± 1.01	$[1.91, 5.91]$
$Br(B_d \to \mu^+\mu^-) \times 10^{10}$	< 2.20	1.04 ± 0.34	$[0.47, 1.81]$

Bobeth et, al. Nucl.Phys. B726 (2005) 252-274C, hep-ph/0505110

High Premium on flavor physics probes with rock-solid SM predictions.

Future Facilities for Flavor Physics

Future Experiments

- Kaon experiments - J-Parc, CERN, Project X
- BESIII (e^+e^- ~ 4 GeV)
  - First data in 2008 - eventually 20x CLEO-c
- LHCb
  - First data in 2008 - 10x luminosity upgrade after 2013
- Belle at upgraded KEKB (e^+e^- ~10 GeV)
  - Resume data taking 2012 - at $L = 2\times10^{35}$
- SuperB at Tor Vergata (e^+e^- ~4 GeV & ~10 GeV)
  - First data after 2014 - at $L>10^{36}$ ~10 GeV

See David MacFarlane's talk Tues PM!

SuperB physics in tables

Observable	B factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi\, K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi\, K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi\, \pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K^0_S K^0_S K^0_S)$	0.15	0.02 (∗)
$S(K^0_S \pi^0)$	0.15	0.02 (∗)
$S(\omega K^0_S)$	0.17	0.03 (∗)
$S(f_0 K^0_S)$	0.12	0.02 (∗)
γ $(B \to DK,\, D \to CP$ eigenstates)	$\sim 15^\circ$	2.5°
γ $(B \to DK,\, D \to$ suppressed states)	$\sim 12^\circ$	2.0°
γ $(B \to DK,\, D \to$ multibody states)	$\sim 9^\circ$	1.5°
γ $(B \to DK$, combined)	$\sim 6^\circ$	1–2°
α $(B \to \pi\pi)$	$\sim 16^\circ$	3°
α $(B \to \rho\rho)$	$\sim 7^\circ$	1–2° (∗)
α $(B \to \rho\pi)$	$\sim 12^\circ$	2°
α (combined)	$\sim 6^\circ$	1–2° (∗)
$2\beta + \gamma$ $(D^{(*)\pm}\pi^\mp,\, D^\pm K^0_S \pi^\mp)$	20°	5°
$\|V_{cb}\|$ (exclusive)	4% (∗)	1.0% (∗)
$\|V_{cb}\|$ (inclusive)	1% (∗)	0.5% (∗)
$\|V_{ub}\|$ (exclusive)	8% (∗)	3.0% (∗)
$\|V_{ub}\|$ (inclusive)	8% (∗)	2.0% (∗)
$BR(B \to \tau\nu)$	20%	4% (†)
$BR(B \to \mu\nu)$	visible	5%
$BR(B \to D\tau\nu)$	10%	2%
$BR(B \to \rho\gamma)$	15%	3% (†)
$BR(B \to \omega\gamma)$	30%	5%
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B \to \rho\gamma)$	~ 0.20	0.05
$A_{CP}(b \to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b \to (s+d)\gamma)$	0.03	0.006 (†)
$S(K^0_S \pi^0 \gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B \to K^*\ell\ell)$	7%	1%
$A^{FB}(B \to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B \to X_s\ell\ell)s_0$	35%	5%
$BR(B \to K\nu\overline{\nu})$	visible	20%
$BR(B \to \pi\nu\bar{\nu})$	–	possible

Mode	Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$D^0 \to K^+K^-$	y_{CP}	2–3×10^{-3}	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	2–3×10^{-3}	7×10^{-4}
	x'^2_D	1–2×10^{-4}	3×10^{-5}
$D^0 \to K^0_S\pi^+\pi^-$	y_D	2–3×10^{-3}	5×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}
Average	y_D	1–2×10^{-3}	3×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}

	Sensitivity
$D^0 \to e^+e^-,\, D^0 \to \mu^+\mu^-$	1×10^{-8}
$D^0 \to \pi^0 e^+e^-,\, D^0 \to \pi^0\mu^+\mu^-$	2×10^{-8}
$D^0 \to \eta e^+e^-,\, D^0 \to \eta\mu^+\mu^-$	3×10^{-8}
$D^0 \to K^0_S e^+e^-,\, D^0 \to K^0_S\mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+e^+e^-,\, D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}
$D^0 \to e^\pm\mu^\mp$	1×10^{-8}
$D^+ \to \pi^+e^\pm\mu^\mp$	1×10^{-8}
$D^0 \to \pi^0 e^\pm\mu^\mp$	2×10^{-8}
$D^0 \to \eta e^\pm\mu^\mp$	3×10^{-8}
$D^0 \to K^0_S e^\pm\mu^\mp$	3×10^{-8}
$D^+ \to \pi^-e^+e^+,\, D^+ \to K^-e^+e^+$	1×10^{-8}
$D^+ \to \pi^-\mu^+\mu^+,\, D^+ \to K^-\mu^+\mu^+$	1×10^{-8}
$D^+ \to \pi^-e^\pm\mu^\mp,\, D^+ \to K^-e^\pm\mu^\mp$	1×10^{-8}

5-10x improvement

Process	Sensitivity
$\mathcal{B}(\tau \to \mu\,\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e\,\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to \mu\,\mu\,\mu)$	2×10^{-10}
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau \to \ell K^0_S)$	2×10^{-10}

+ τ FC physics (CPV, ...)

Observable	Error with 1 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}
Γ	0.07 ps^{-1}
β_s from angular analysis	20°
$A^s_{\rm SL}$	0.006
$A_{\rm CH}$	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-
$\|V_{td}/V_{ts}\|$	0.08
$\mathcal{B}(B_s \to \gamma\gamma)$	38%
β_s from $J/\psi\phi$	10°

Super Flavour Factory

a "treasure chest" of new physics-sensitive observables

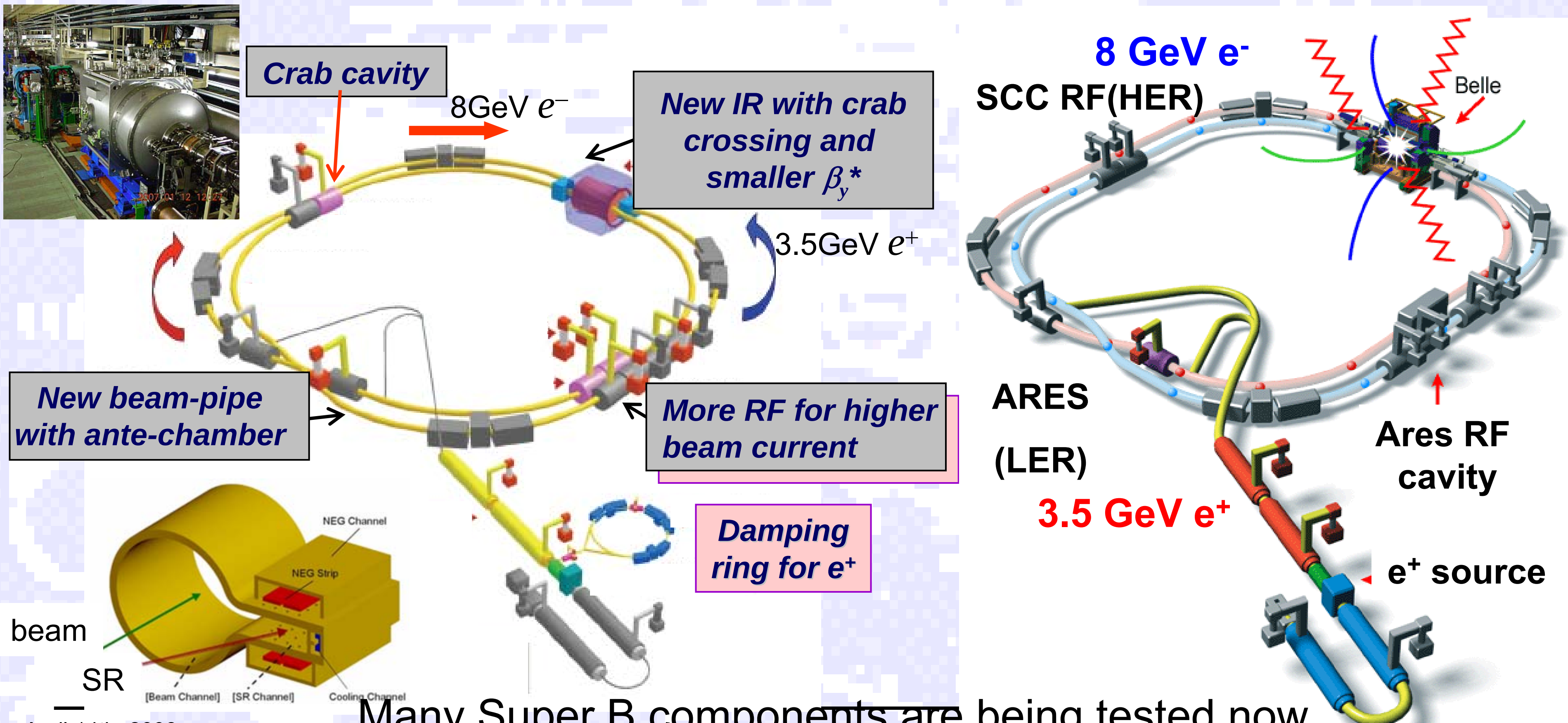
Ciuchini

KEKB Upgrade Plan

A Super-B Factory at KEK

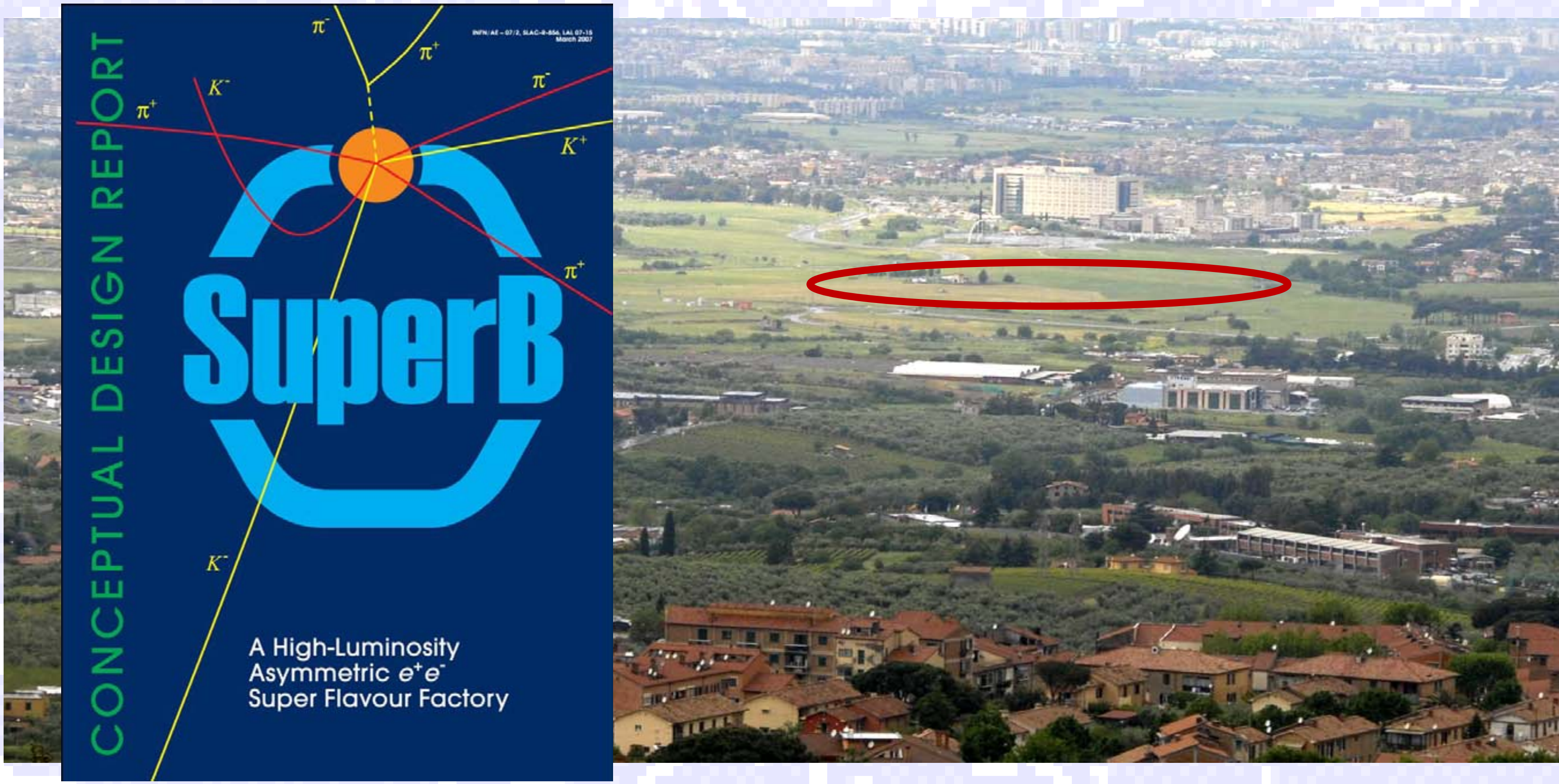
after 3 year shutdown

- *Asymmetric energy e^+e^- collider at $E_{CM}=m(\Upsilon(4S))$ to be realized by upgrading the existing KEKB collider.*
- *Initial target: 10× higher luminosity* $\cong 2\times10^{35}/cm^2/sec \rightarrow 2\times10^9$ $B\bar{B}$ *and* $\tau^+\tau^-$ *per yr.*
- *Final goal: $L=8\times10^{35}/cm^2/sec$ and $\int L\,dt = 50\ ab^{-1}$*

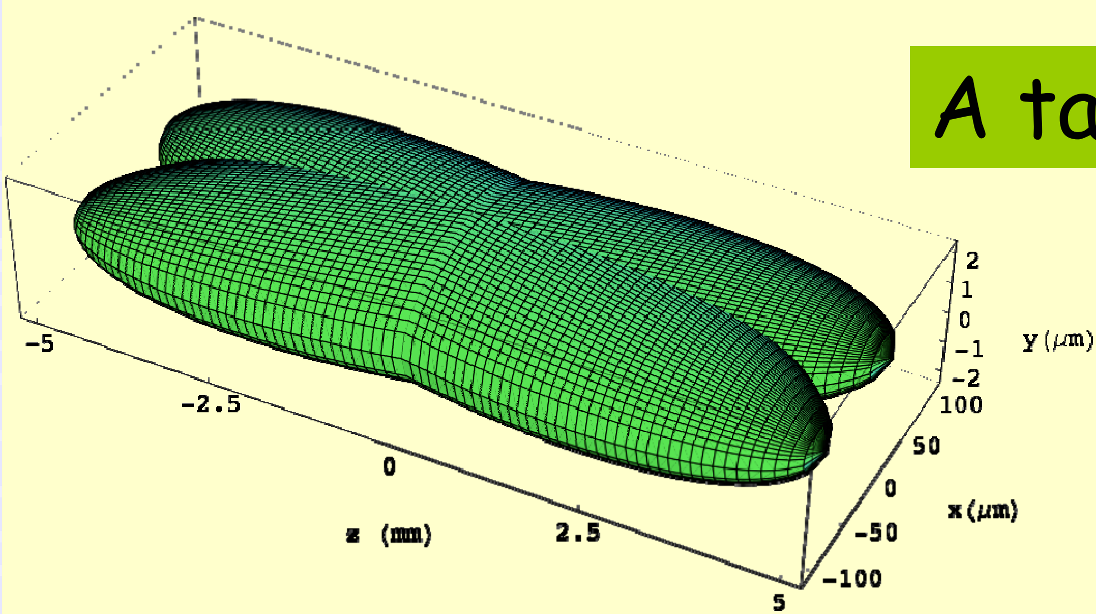


Many Super B components are being tested now

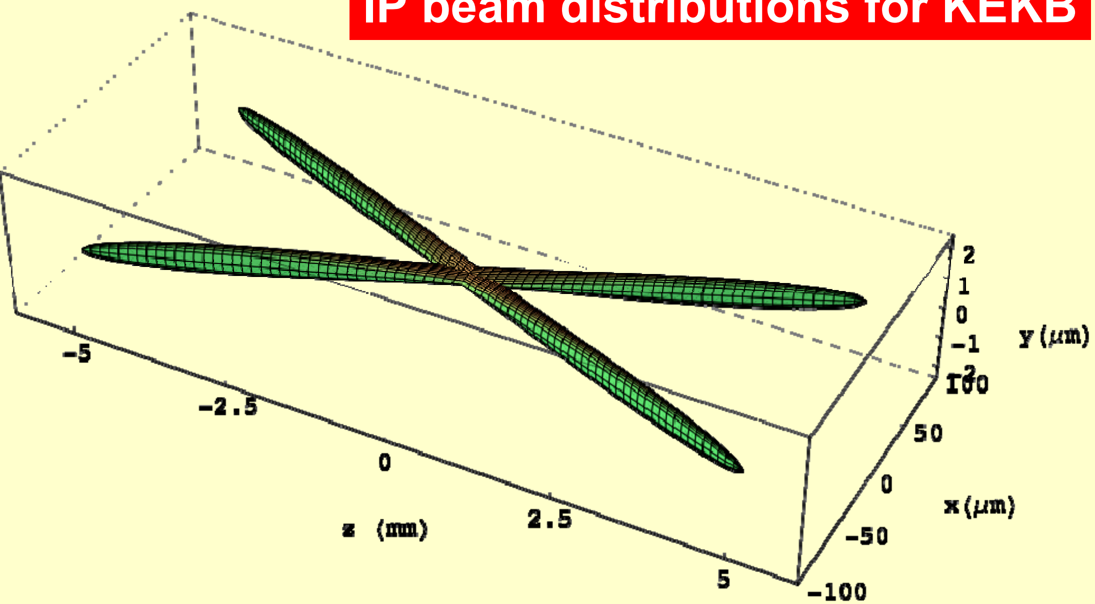
Discussion of a new Super Flavor Physics Laboratory at Tor Vergata:



A tale of two beams…



IP beam distributions for KEKB



IP beam distributions for SuperB

Beam envelopes

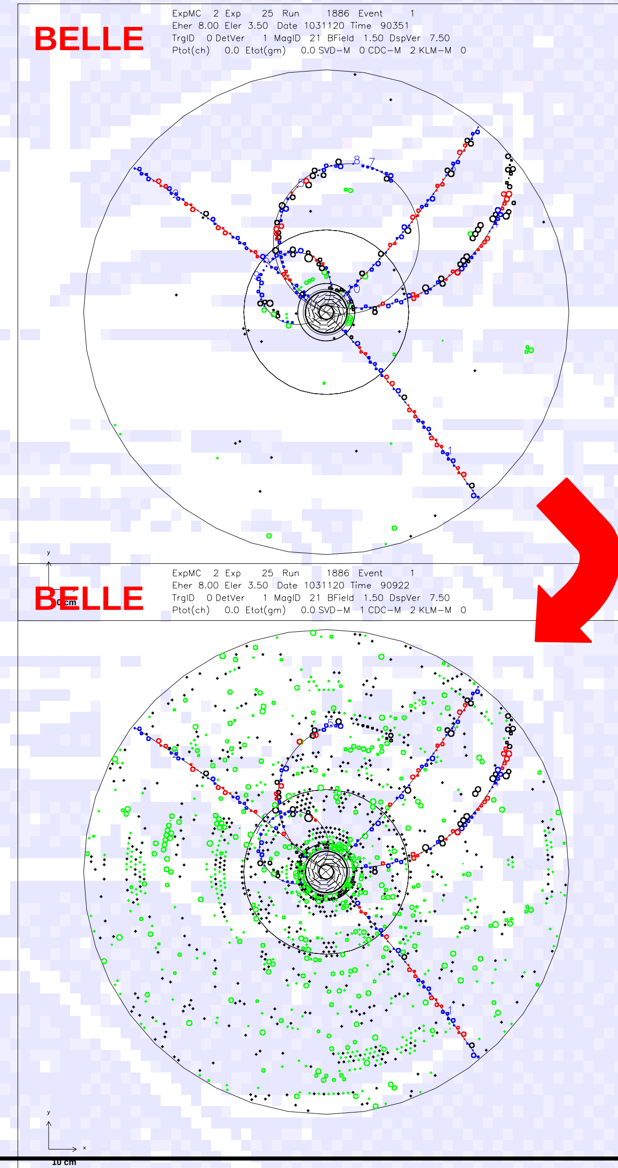
	KEKB	SuperB
I (A)	1.7	2.
β_y^* (mm)	6	0.3
β_x^* (mm)	300	20
σ_y^* (μm)	3	0.035
σ_x^* (μm)	80	6
σ_z (mm)	6	5
L ($cm^{-2}s^{-1}$)	1.7×10^{34}	$1.\times10^{36}$

Raimondi

Detector Challenges at Super Flavor Factories

In contrast to LHCb, superb neutral detection capibilities.

e.g. $B \rightarrow K_S \pi^0 \gamma$ can be used to detect right-handed currents

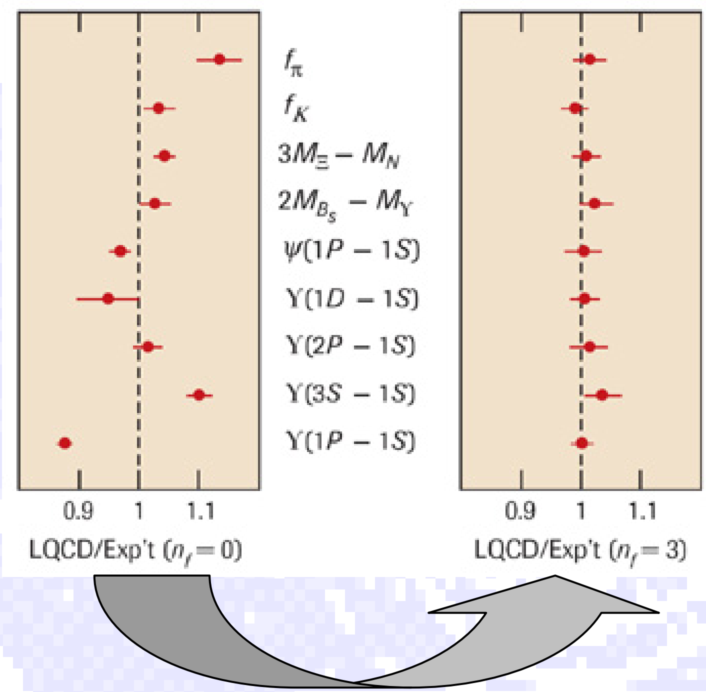


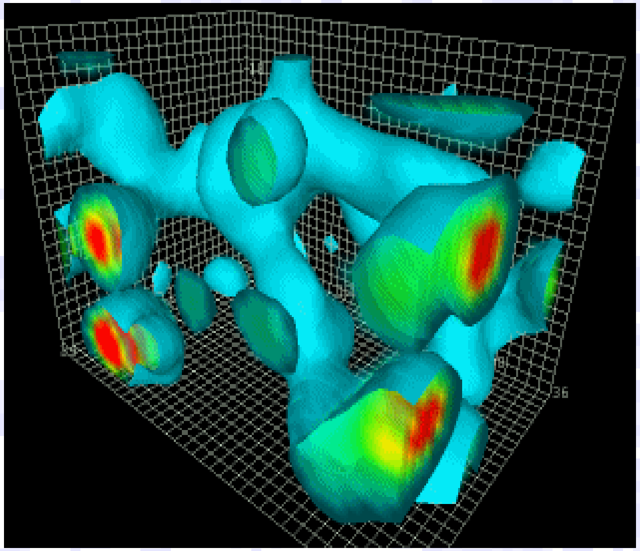
Capable of observing rare "missing energy modes" such as $B \rightarrow K \nu \bar{\nu}$ with B tags. Hermiticity is critical.

Issues for Super Belle:

- Higher background (x 20)
- Radiation damage and occupancy
- Fake hits and pile-up in EM cal
- Higher event rate (x 50)

Lattice QCD A Key Tool of a Precision Future



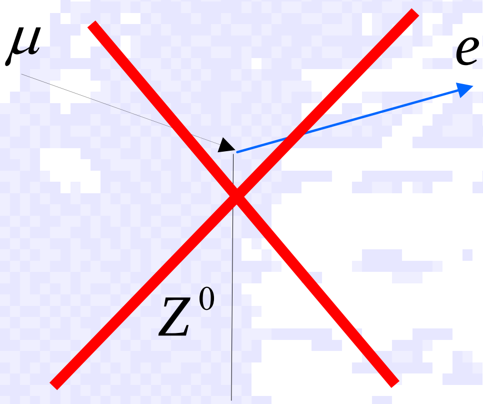


Quenched to Unquenched:
10's of Tera-flops.....

•This is the QCD "Lava Lamp." It is an animation of the 4 dimensional structure of the long-distance aspects of the QCD vacuum. (courtesy Derek B Leinweber)

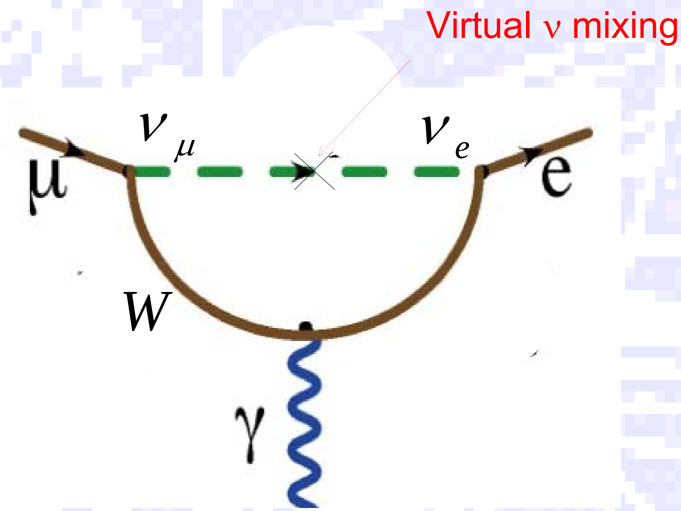
The deepest probe of Lepton Flavor Physics: Ultra-rare μ-Decays:

First Order FCNC:



- **Forbidden in Standard Model**

Higher order dipole "penguin":



- **Observation of neutrino mixing shows this can occur at a very small rate**
- **Photon can be real (μ->eγ) or virtual (μN->eN)**

$$Br(\mu \to e\gamma) = \frac{3\alpha}{32\pi}\left|\sum_{i=2,3} U^*_{\mu i} U_{ei} \frac{\Delta m^2_{1i}}{M^2_W}\right|^2 < 10^{-54}$$

The MEG(PSI) experiment can probe to 10^{-13} level.

World-wide flavor program...
What will the next decade look like?

- LHC will probe the rarest B decays and continue B_s exploration.
  Clear US participation.

- There is strong motivation for next generation B and charm factories to carry the rich legacy of the current generation forward.
  Opportunity for US participation.

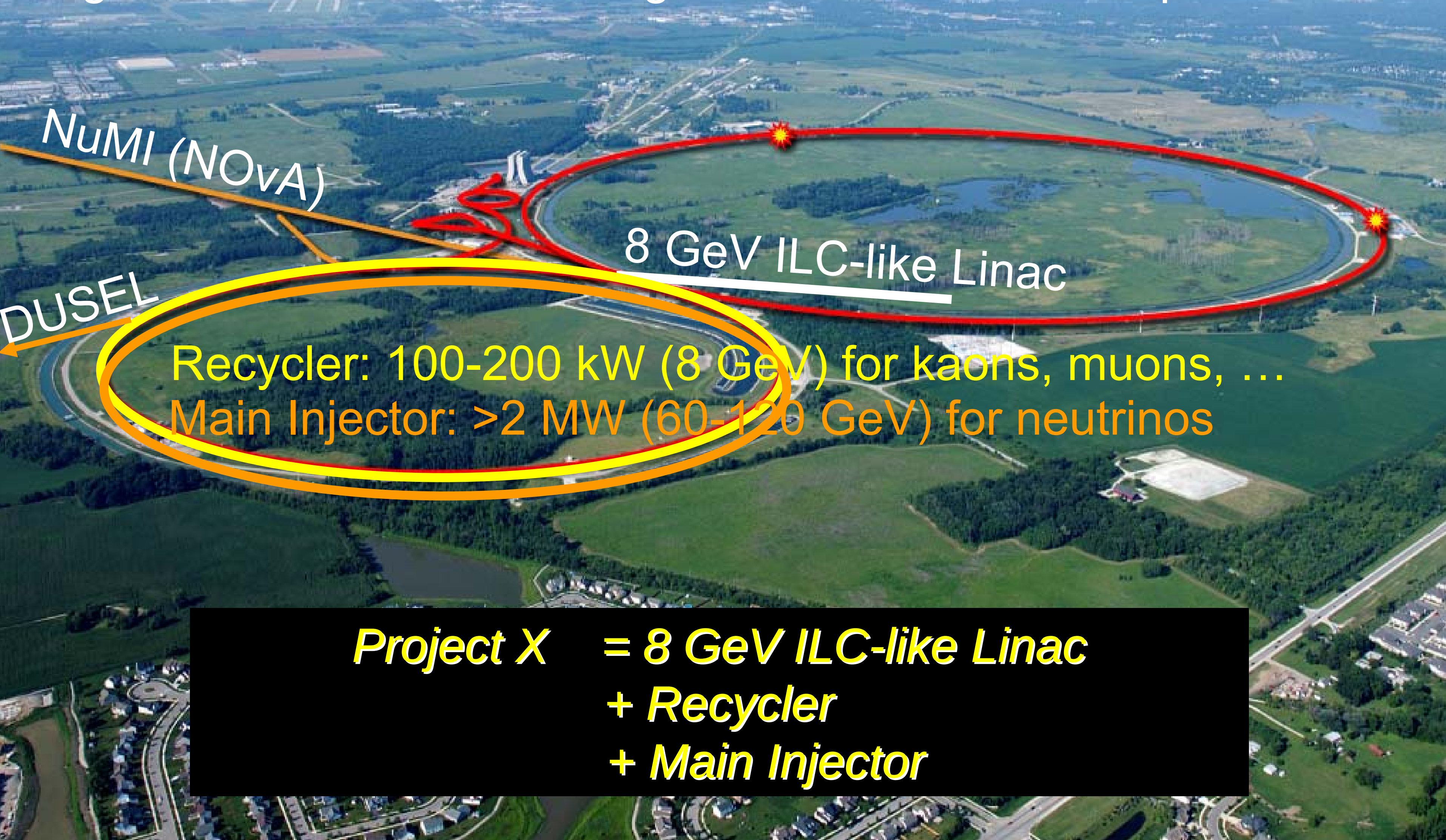
- CERN, PSI, and JPARC are operating and mounting next generation ultra-rare kaon and muon decay experiments.
  Opportunity for US participation.

- ***Are there opportunities for US leadership??***

High Intensity Proton Accelerator – Project X

National Project with International Collaboration

Alignment with ILC Technologies for a shared development effort



Project X = 8 GeV ILC-like Linac
+ Recycler
+ Main Injector

Opportunities for US Leadership

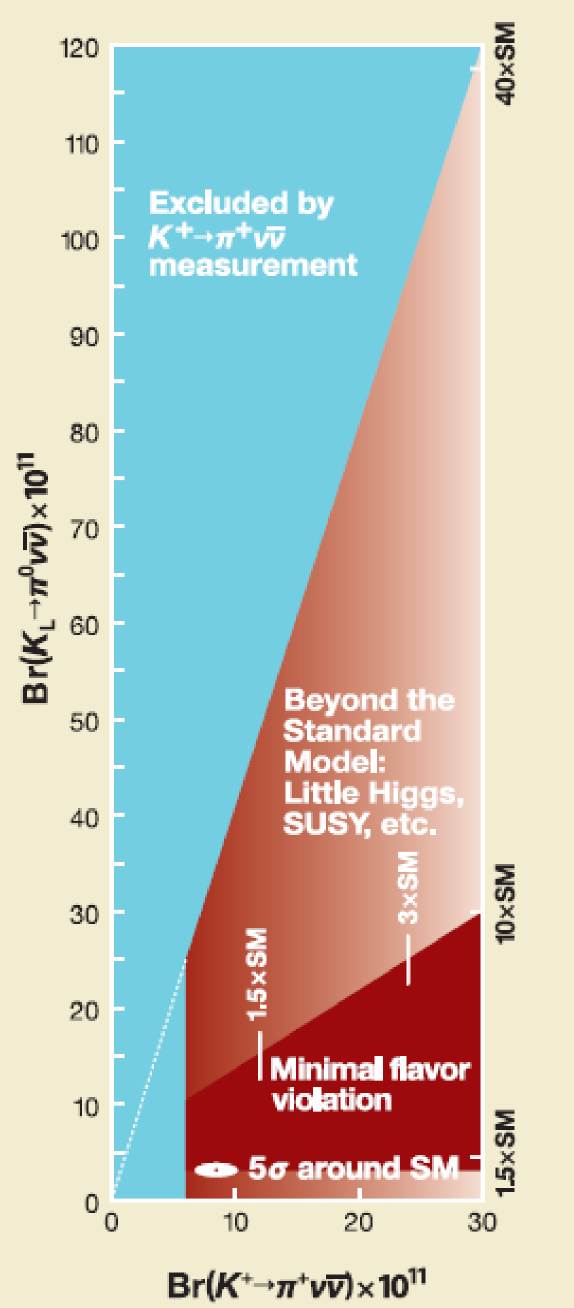
- For flavor physics Project-X is an opportunity to drive world-leading experiments that require high intensity, high duty factor muon and kaon beams.

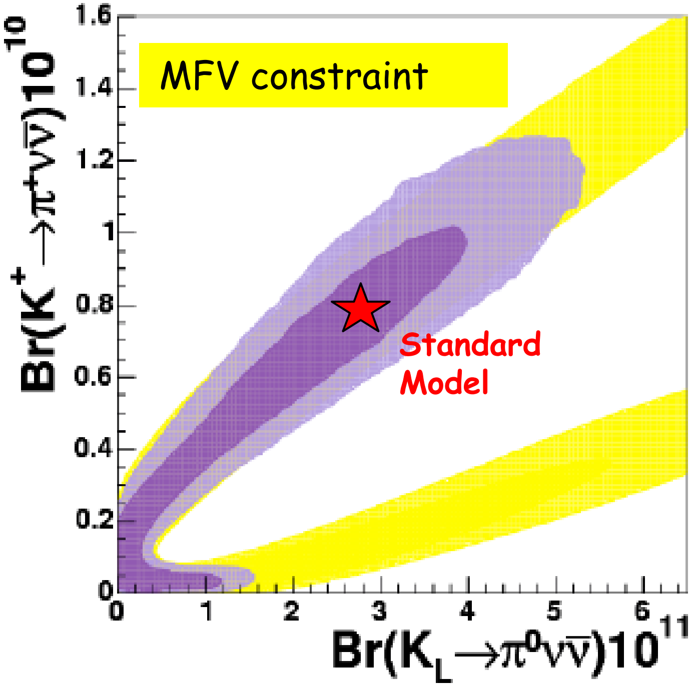
- These experiments can be sensitive to energy scales far beyond the LHC and provide incisive tests of Minimum Flavor Violation in the quark sector.

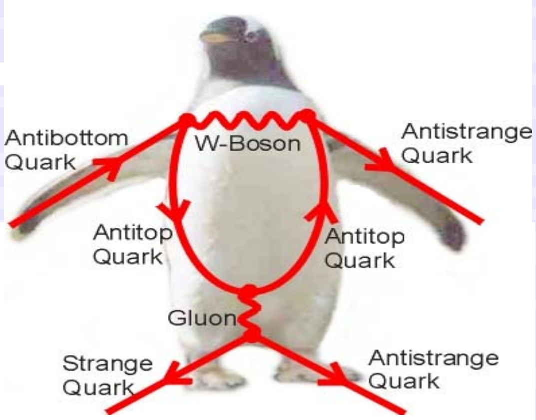
- This opportunity can be realized with an evolution of the Fermilab complex that can simultaneously drive a world leading neutrino physics program.

- ***See Andy Lankford's talk on Tuesday afternoon!***

$K \to \pi \nu \bar{\nu}$







Powerful probe of Minimum Flavor Violation where enhancements are less than x2-x3

C. Bobeth, M. Bona, A. Buras, T. Ewerth, M. Pierini, L. Silvestrini, A. Weiler, hep-ph/0505110

Uniqueness: Theoretical error <2% for neutral, <4% charged modes motivate 1000-event experiments---conceivable with Project-X!

Project-X: A blow-torch of protons...all the time!

Per year

Facility	Duty Factor	Clock hours	Beam hours	Projected # of $K \rightarrow \pi\nu\bar{\nu}$
☆ CERN-SPS (450 GeV)	30%	1420	405	40 (charged)
Booster Stretcher (8GeV, 16kW)	90%	5550	5000	40 (charged)
Tevatron-Stretcher (120 GeV)	90%	5550	5000	200 (charged)
ProjectX Stretcher (8GeV, 200kW)	90%	5550	5000	250 (charged)
☆ JPARC-I (30 GeV)	21%	2780	580	~1 (neutral)
BNL AGS (24 GeV)	50%	1200	600	20 (neutral)
JPARC-II (30 GeV)	21%	2780	580	30 (neutral)
Booster Stretcher (8GeV, 16kW)	90%	5550	5000	30 (neutral)
ProjectX Stretcher (8GeV, 200kW)	90%	5550	5000	300 (neutral)

☆ Moving toward full approval.

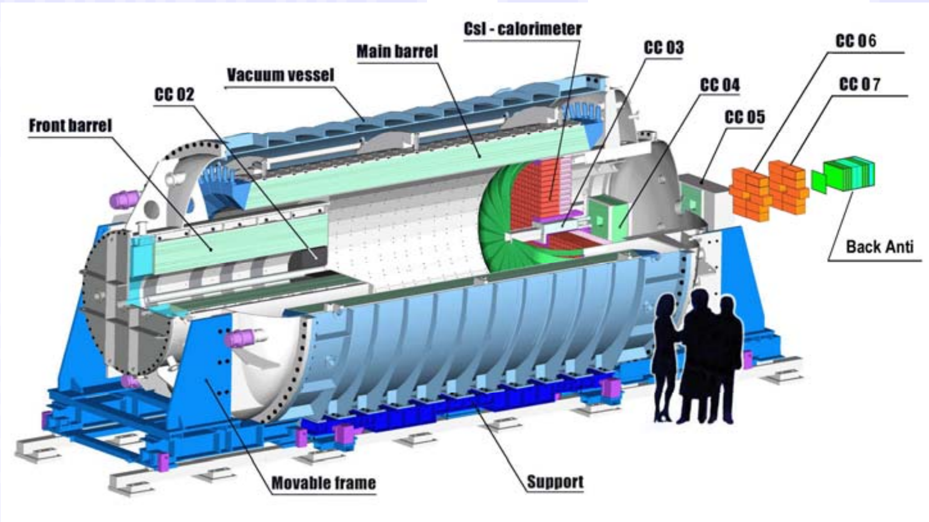
J-PARC - Neutrino:Kaon = 50%:50%

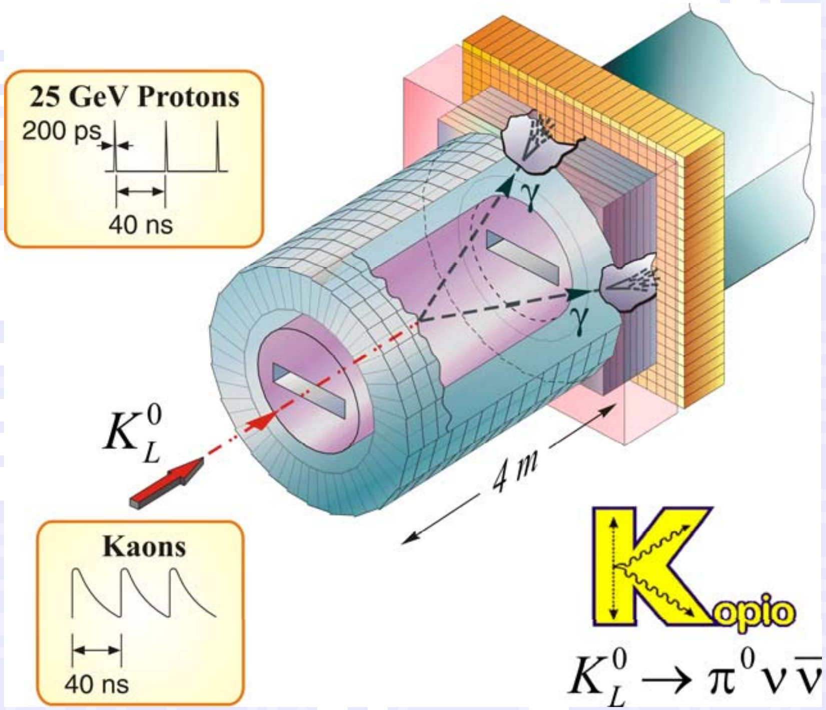
$K_L \to \pi^0 \nu \bar{\nu}$ Neutral Mode: "Nothing-in, Nothing-out"

•JPARC approach emphasizes high acceptance for the two decay photons while vetoing everything else:

A hermetic "bottle" approach.

•The original KOPIO concept measures the kaon momentum and photon direction…Good! But costs detector acceptance and requires a large beam to compensate in flux.





Kaon Physics Opportunities with the Fermilab Complex

- Much activity in Europe and Japan towards mounting the next generation of $K\rightarrow\pi\nu\nu$ experiments. This is motivated by the deep physics reach of these golden modes.

- An evolution of beam power at Fermilab can grow a program towards an ultimate measurement of the neutral mode that captures the strengths of both the "hermetic bottle" approach at JPARC and the innovative approach developed for KOPIO.

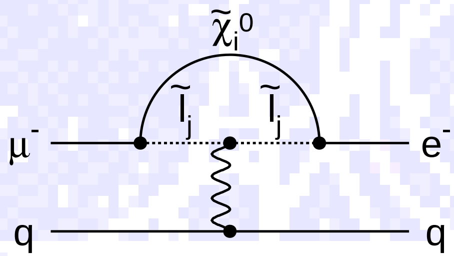
- This evolution can also grow a program towards an ultimate measurement of the charged mode based on the demonstrated successes of the BNL and CERN programs.

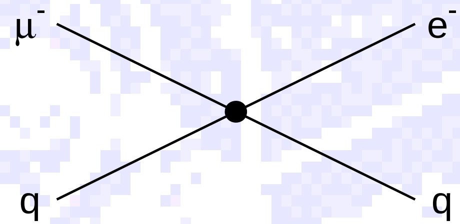
- Project-X is an opportunity to mount several world-leading program **in parallel**: Long-baseline neutrino oscillations, ultra-rare kaon decays and muon physics.

Rare muon decays in Project-X: $\mu^- N \rightarrow e^- N$ Sensitivity to New Physics

Supersymmetry

Predictions at 10^{-15}



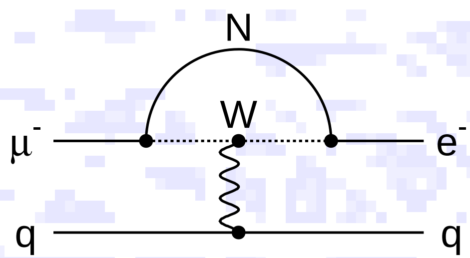


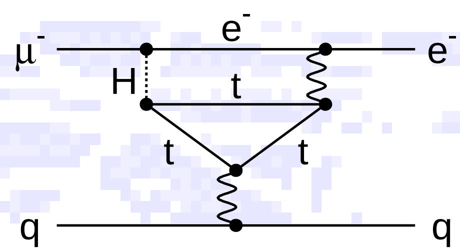
Compositeness

$\Lambda_C = 3000$ TeV

Heavy Neutrinos

$\left|U^*_{\mu N} U_{eN}\right|^2 = 8 \times 10^{-13}$



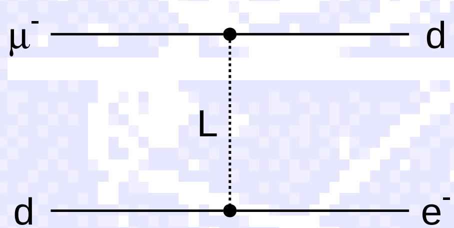


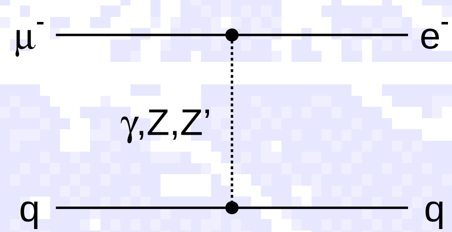
Second Higgs doublet

$g_{H_{\mu e}} = 10^{-4} \times g_{H_{\mu\mu}}$

Leptoquarks

$M_L = 3000\sqrt{\lambda_{\mu d}\lambda_{ed}}$ TeV/c^2





Heavy Z', Anomalous Z coupling

$M_{Z'} = 3000$ TeV/c^2

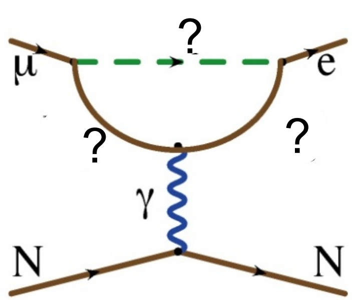
$B(Z \rightarrow \mu e) < 10^{-17}$

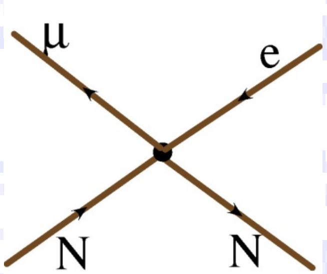
After W. Marciano

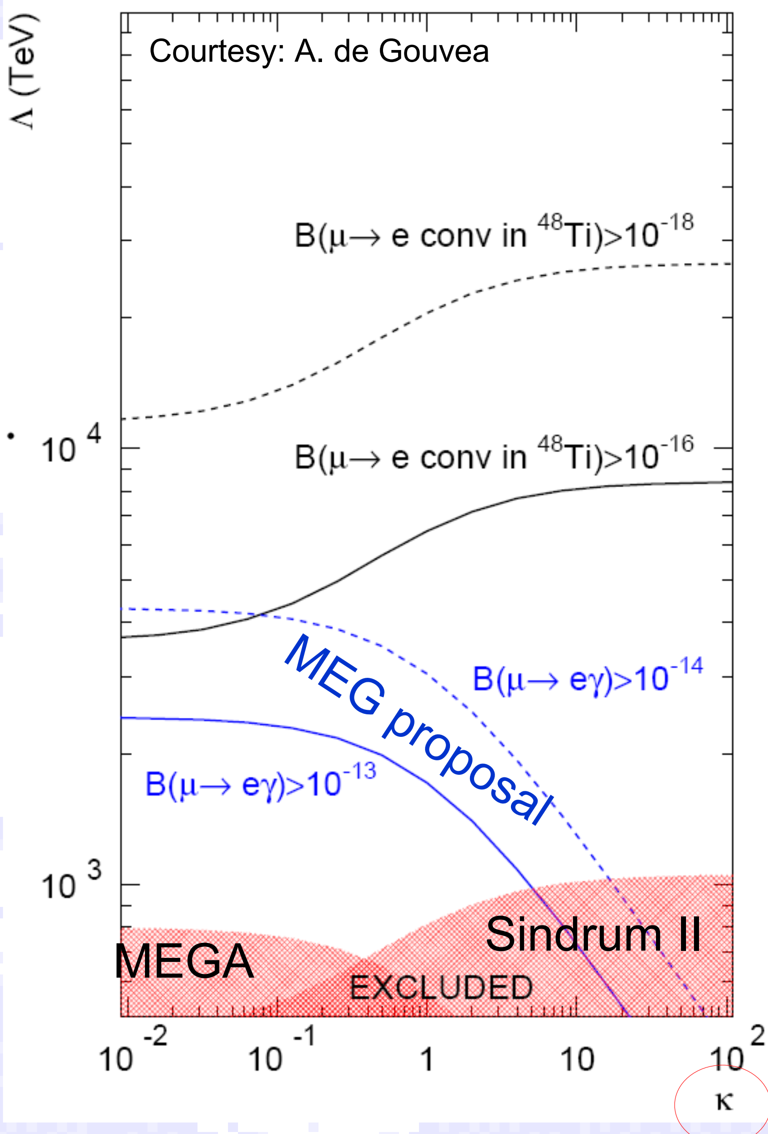
μ→e Conversion vs. μ→eγ

- We can parameterize the relative strength of the dipole and four-fermi interactions.

$$\frac{m_\mu}{(\kappa+1)\Lambda^2}\bar{\mu}_R\sigma_{\mu\nu}e_L F^{\mu\nu} + \frac{\kappa}{(1+\kappa)\Lambda^2}\bar{\mu}_L\gamma_\mu e_L\left(\bar{u}_L\gamma^\mu u_L + \bar{d}_L\gamma^\mu d_L\right).$$

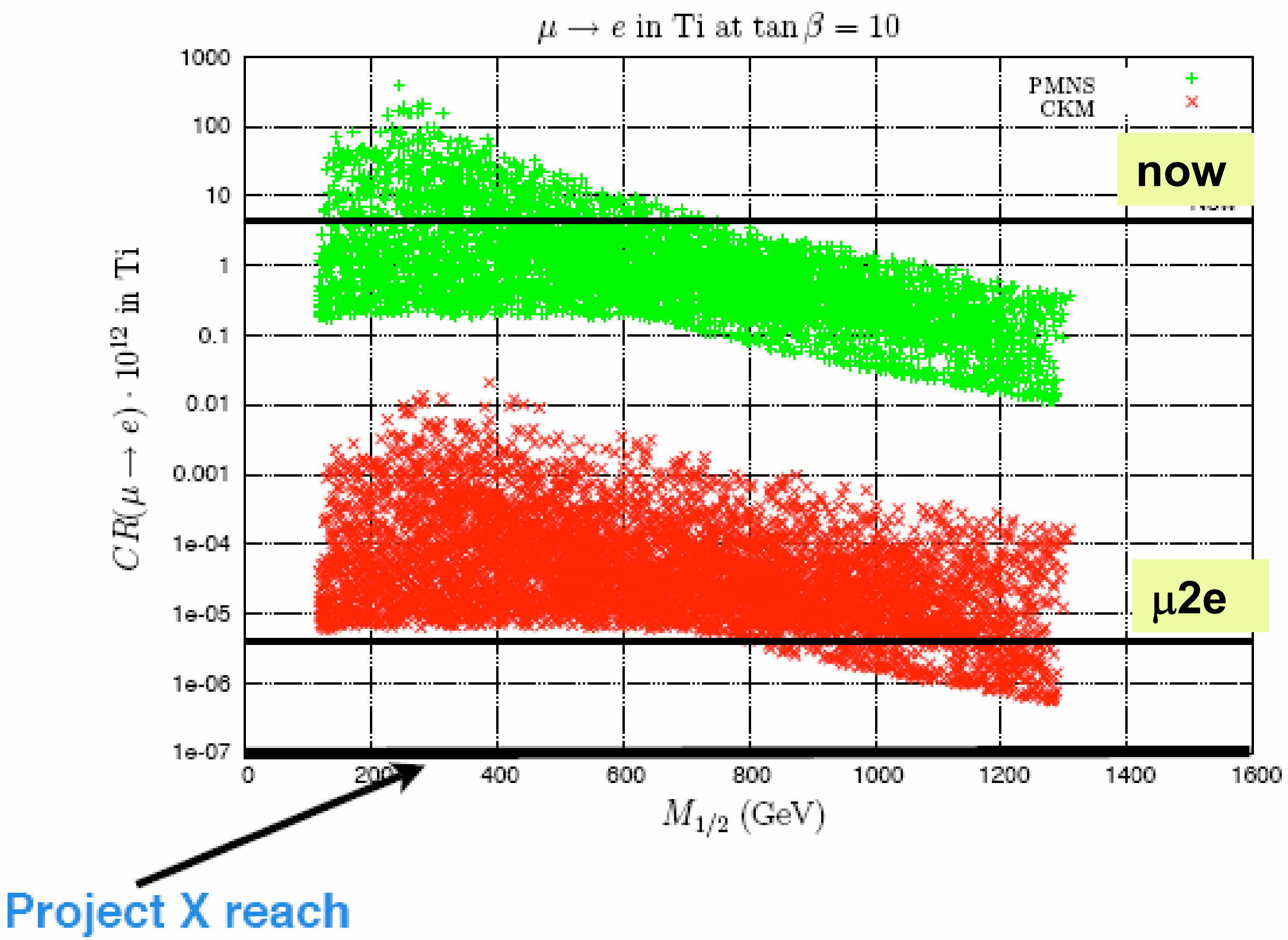






- This is useful for comparing relative rates for μN→eN and μ→eγ

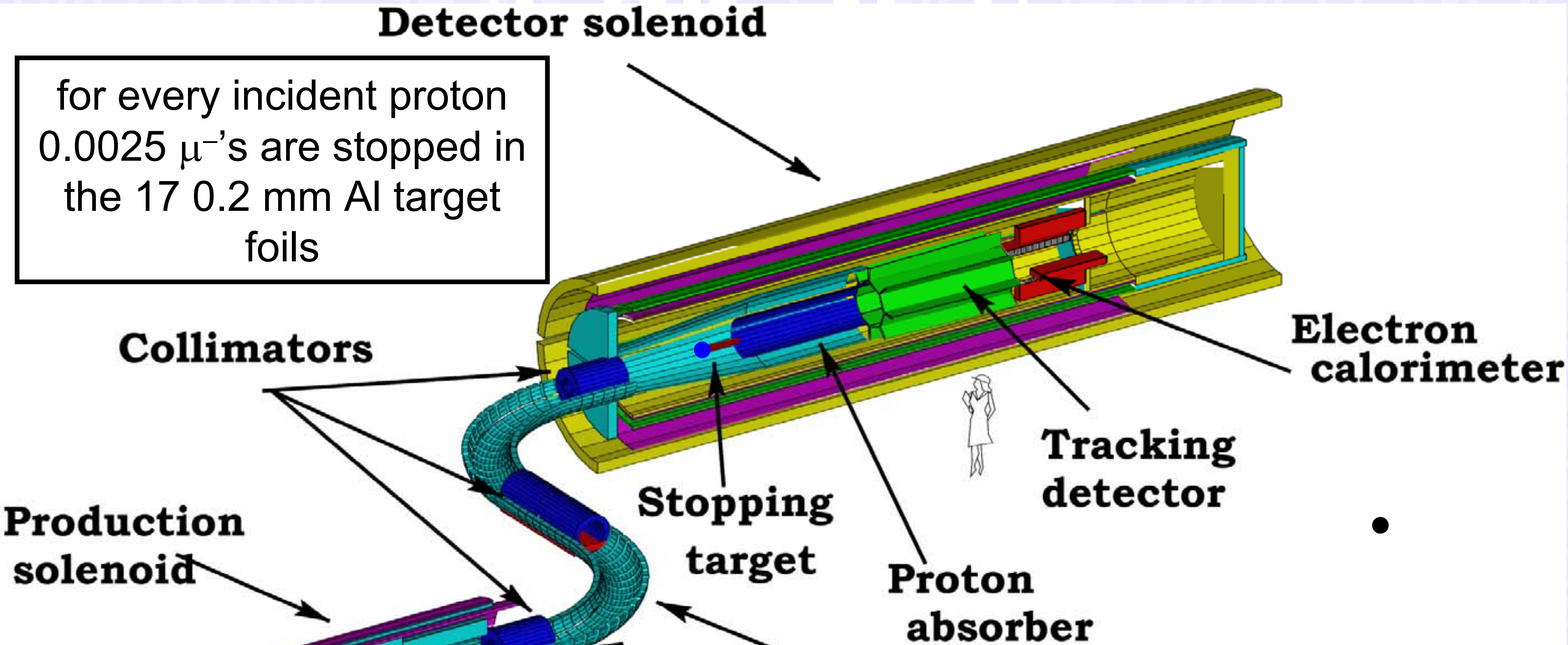
Measuring couplings of SUSY observed at the LHC.

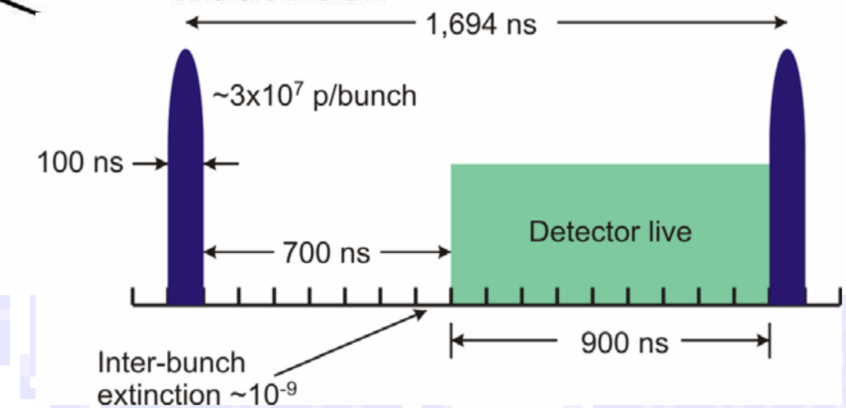


L. Calibbi, A. Faccia, A. Masiero, S. Vempati, hep-ph/0605139

mu2e Muon Beam and Detector

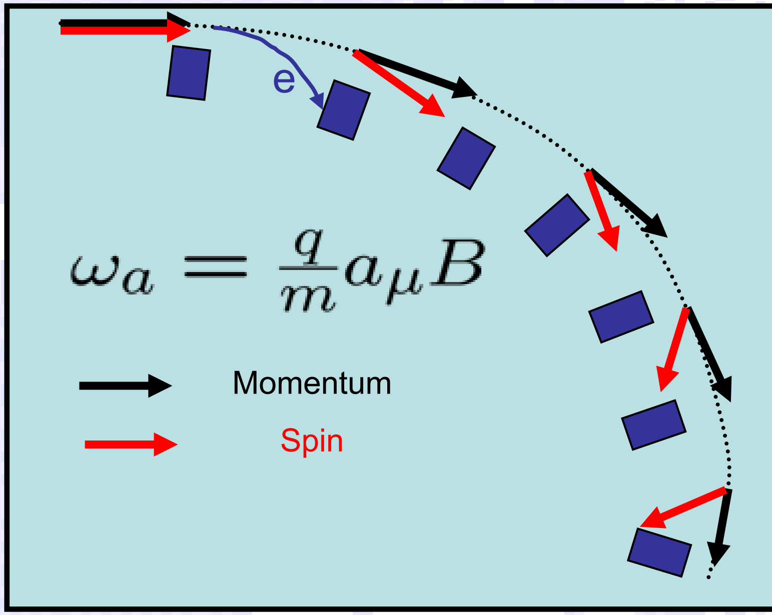
for every incident proton 0.0025 μ^{-}'s are stopped in the 17 0.2 mm Al target foils

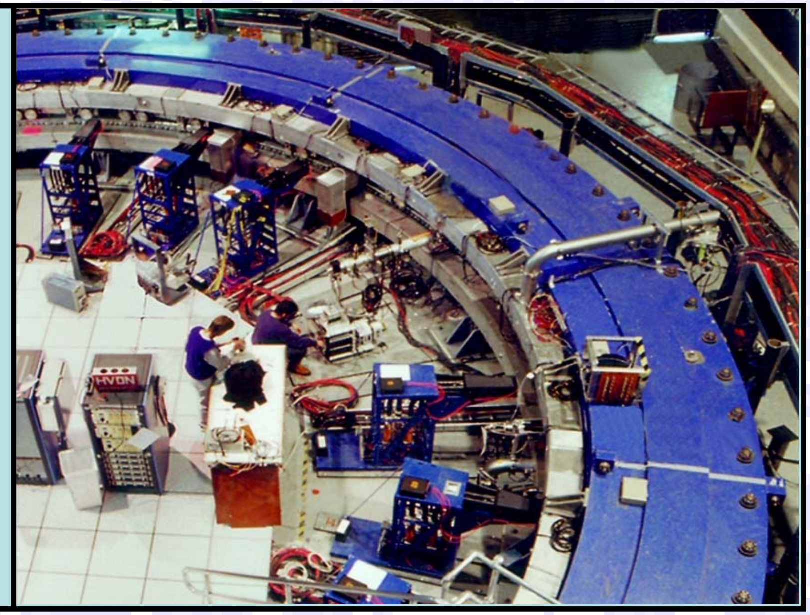


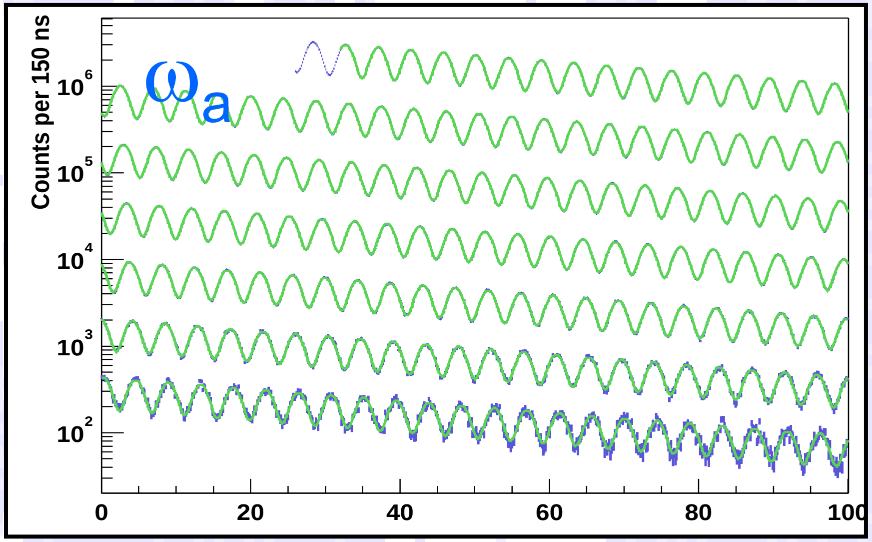


MECO spectrometer design

Measurement of g-2

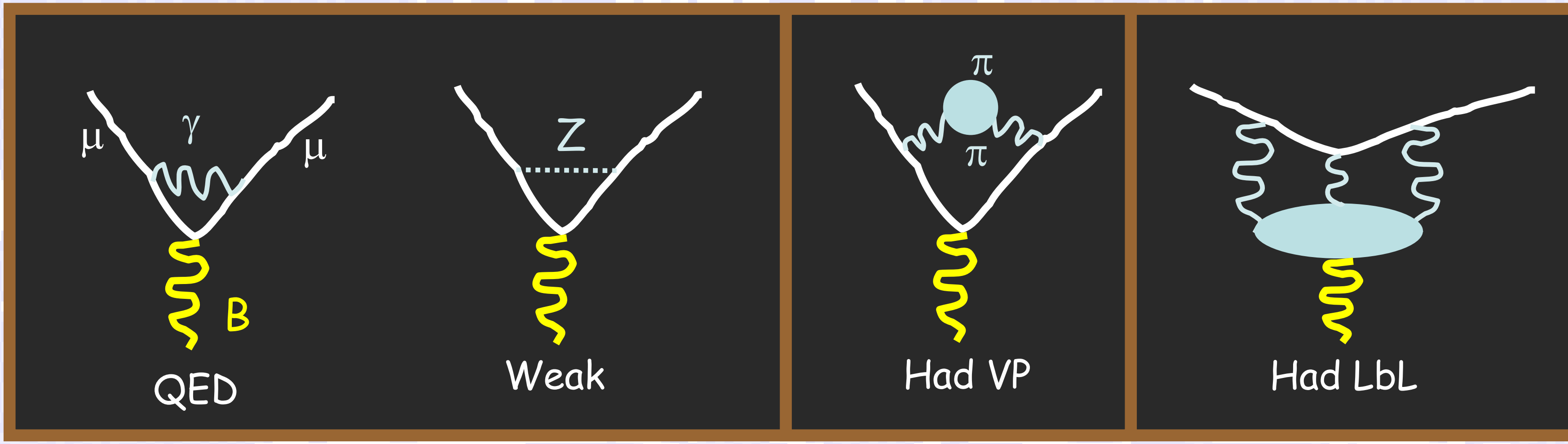






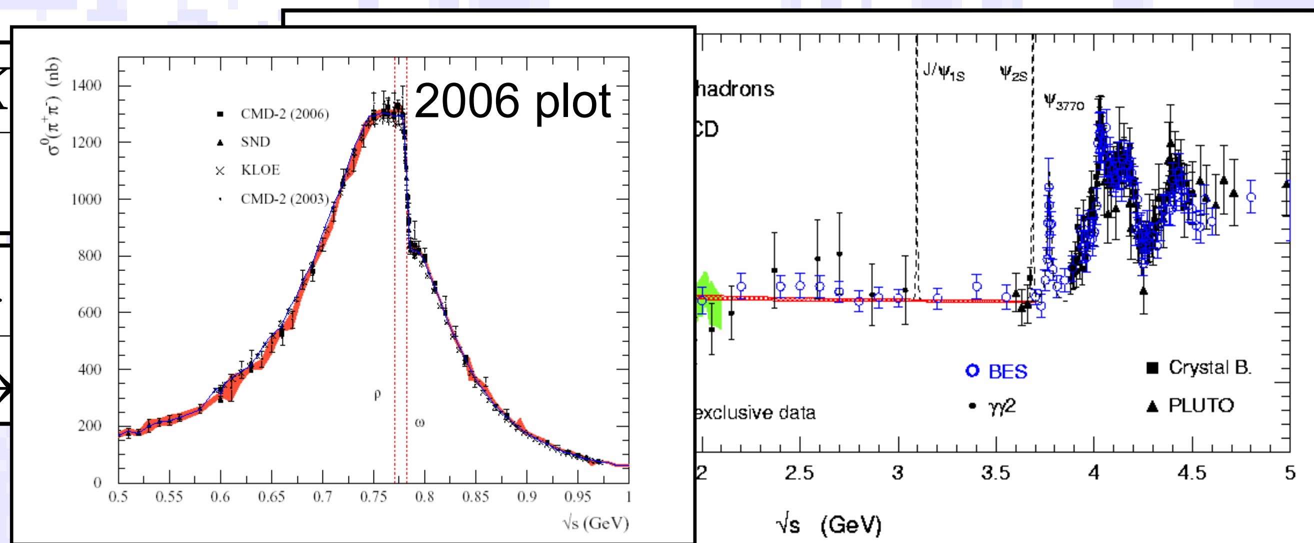
- α_μ is determined from the ratio of the muon precession frequency (ω_a) and the magnetic field (*B*).

Standard Model Contributions to a_μ

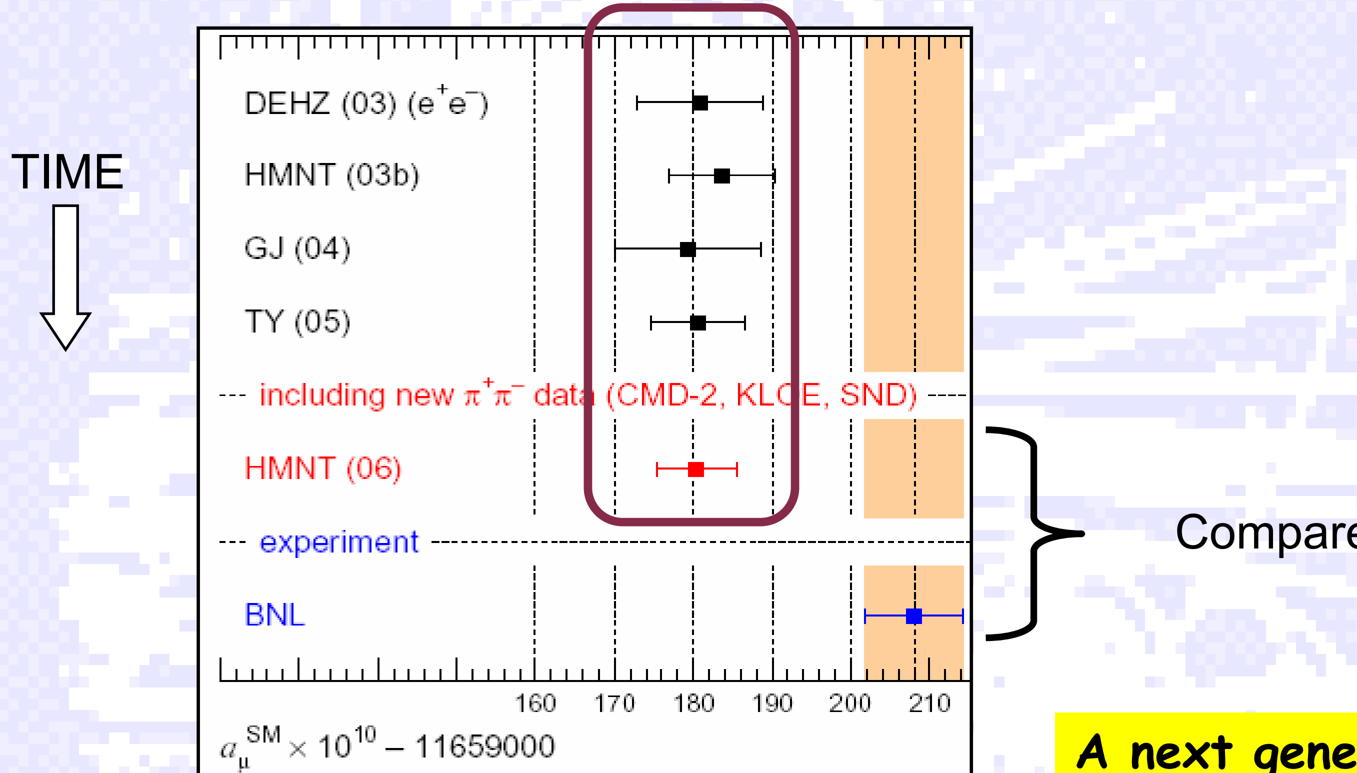


$$a_\mu^{had,1} \propto \int_{2m_\pi}^{\infty} ds \, \frac{K}{\ldots}$$

$$R(s) = \frac{\sigma\left(e^+e^- \rightarrow \ldots\right)}{\sigma\left(e^+e^- \rightarrow \ldots\right)}$$



Status of g-2



K. Hagiwara, A.D. Martin, Daisuke Nomura, T. Teubner

Rep.Prog.Phys. 70, 795 (2007).

A next generation experiment could reduce the measurement error by x5!

$$\alpha_\mu(\text{expt.}) = 11659208.(6.3)\times 10^{-10}\,(0.54\text{ ppm})$$

$$\alpha_\mu(\text{theor.}) = 11658180.(5.6)\times 10^{-10}\,(0.48\text{ ppm})$$

$$\Delta\alpha_\mu \equiv \alpha_\mu(\text{expt.}) - \alpha_\mu(\text{theor.}) = (295 \pm 88)\times 10^{-11}\quad (3.4\sigma)$$

The Road Ahead

- The world is pursing the next generation of quark and lepton flavor physics at BES, CERN, PSI, KEK, Frascati, JPARC, GSI and possibly Tor Vergata.

  There is no shortage of interest and opportunity.

- Evolution of the Fermilab complex is a unique domestic opportunity to lead the world flavor program in the deepest probes of energy scales far beyond the LHC, and incisive probes of the Minimum Flavor Violation conundrum in the quark sector.

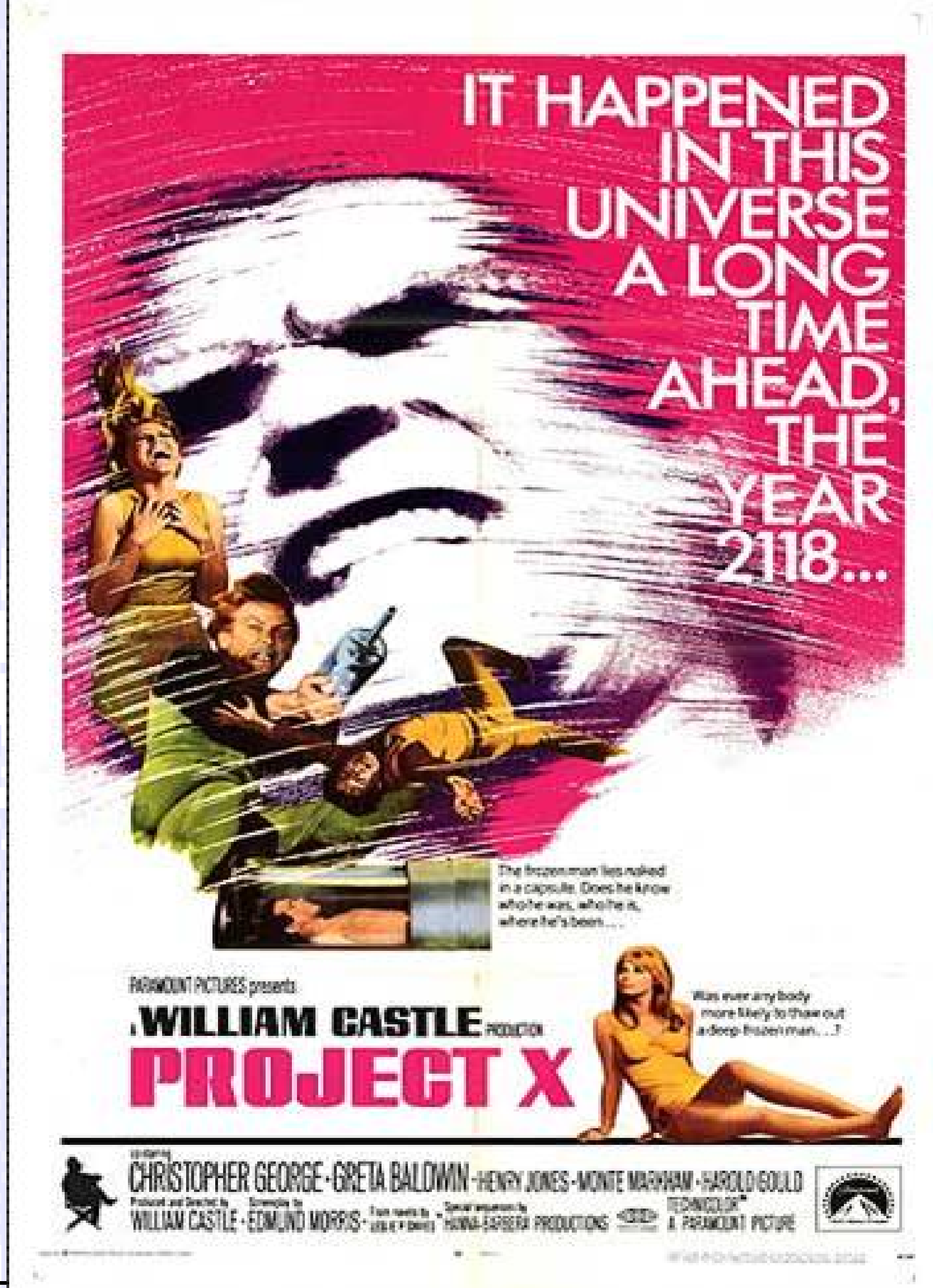
- The Project-X vision is platform to grow and support a compelling suite of experiments and the Intensity Frontier.

- Join the efforts!

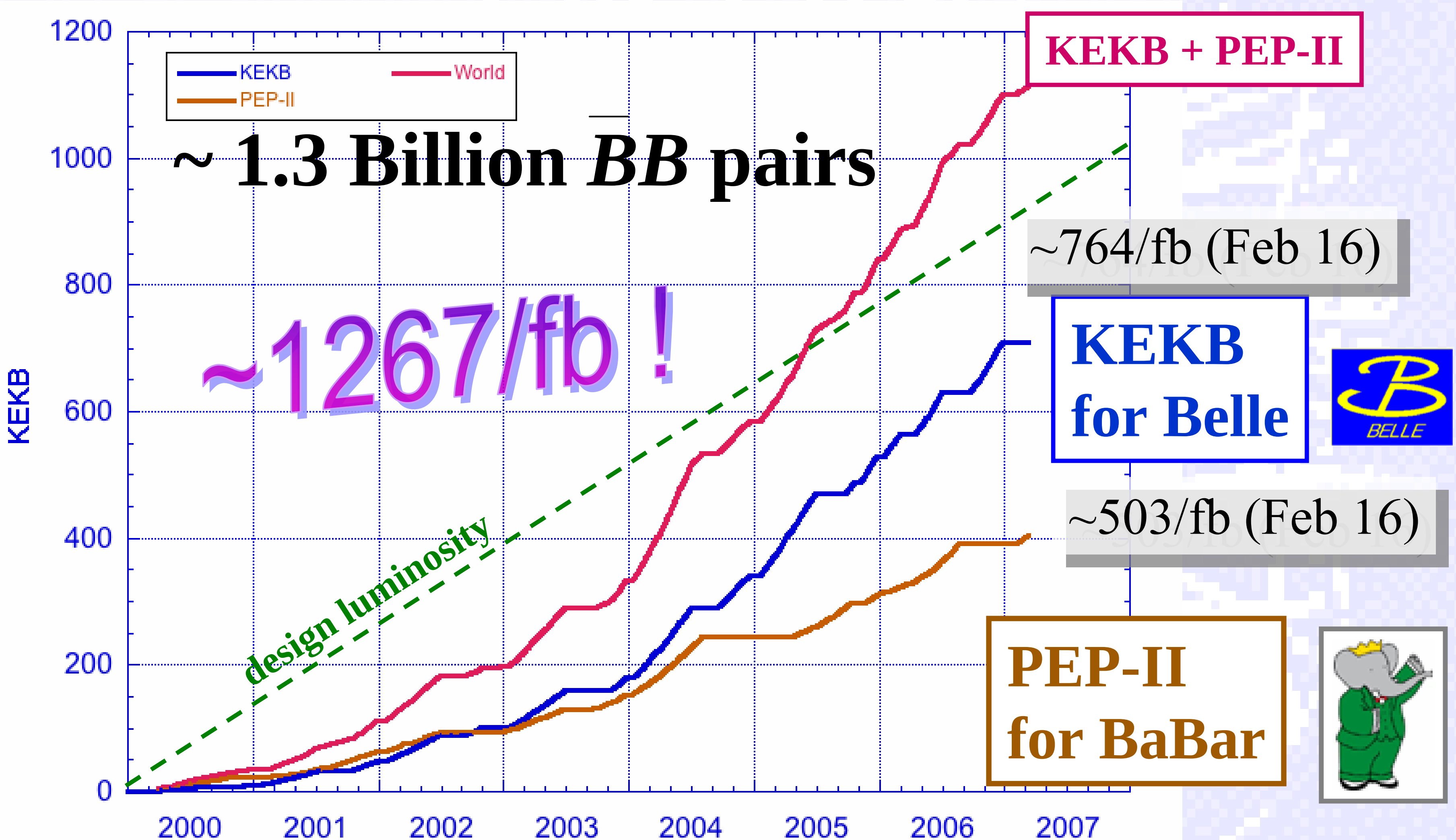
  Come hear more at the "lunch" meeting following in Promenade-A

  Goggle "Project-X Physics" to find conveners.

Spare Slides


IT HAPPENED IN THIS UNIVERSE A LONG TIME AHEAD, THE YEAR 2118...
PARAMOUNT PICTURES presents
A WILLIAM CASTLE PRODUCTION
PROJECT X
CHRISTOPHER GEORGE · GRETA BALDWIN · HENRY JONES · MONTE MARKHAM · HAROLD GOULD
WILLIAM CASTLE · EDMUND MORRIS · HANNA-BARBERA PRODUCTIONS
TECHNICOLOR
A PARAMOUNT PICTURE

KEKB's Track Record

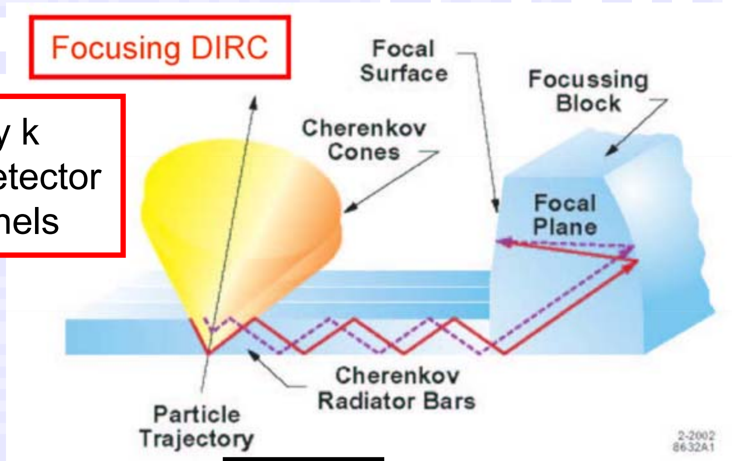


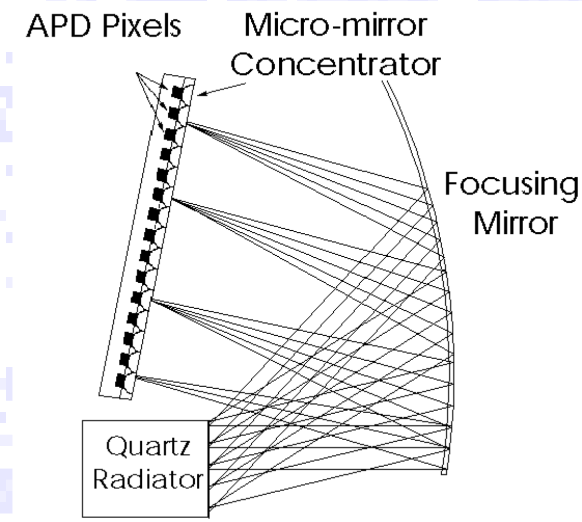
~~L_{peak}(KEKB) = 1.7 x 10^{34}/cm^2/sec (design 1.0)~~

May be time to switch units to ab^{-1}

Focusing-DIRC Array Concept (Cincinnati)

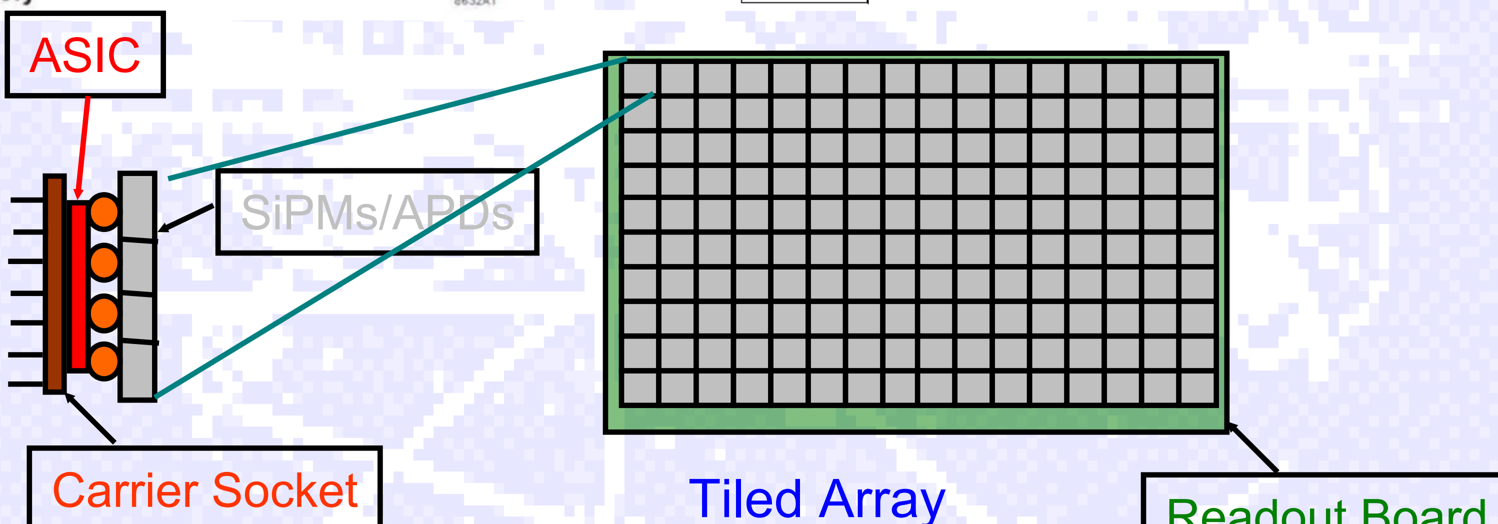
Many k Photodetector channels





Make full use of new pixelated photodetectors

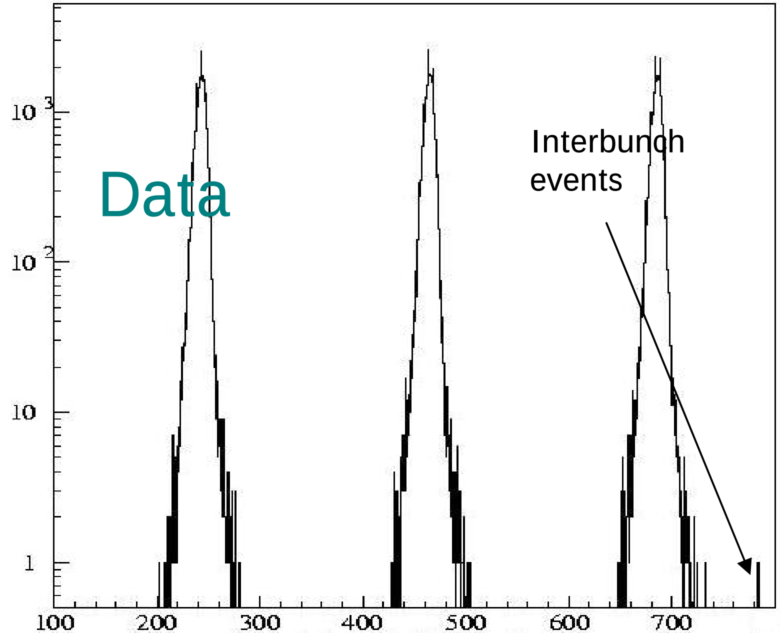
(Sumiyoshi et al)



AGS Test Beam Results: Interbunch Extinction

Data

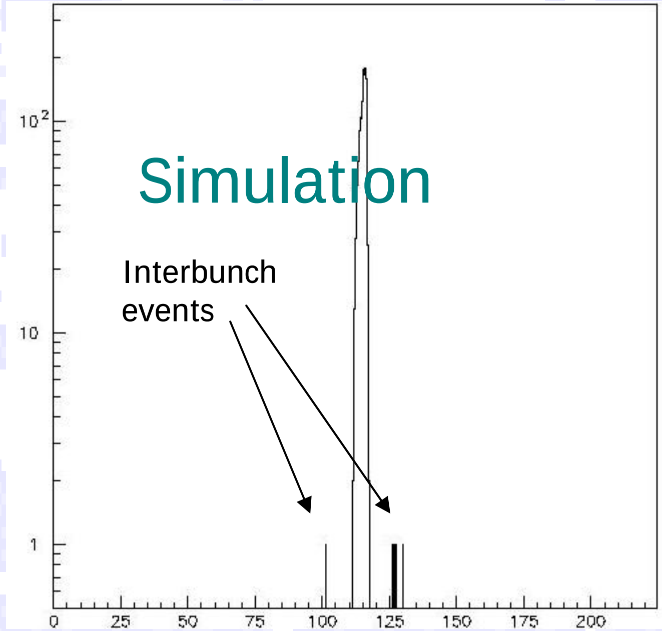
4.5 MHz cavity at 130 kV gave $\varepsilon = 8$ (+/- 6) x 10^{-6}



Microbunch time, in ns

Simulation

4.5 MHz cavity at 130 kV gave $\varepsilon = 1.7$ (+/- 0.9) x 10^{-3}.



Microbunch time, in ns

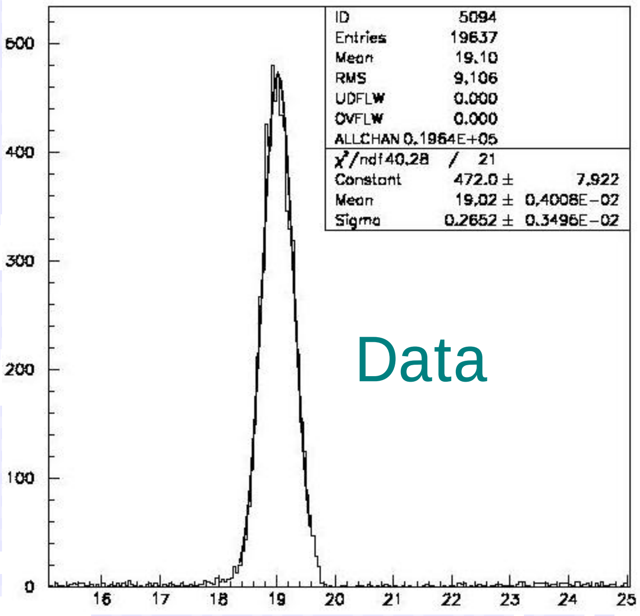
AGS Test Beam Results: Microbunch Width

Data

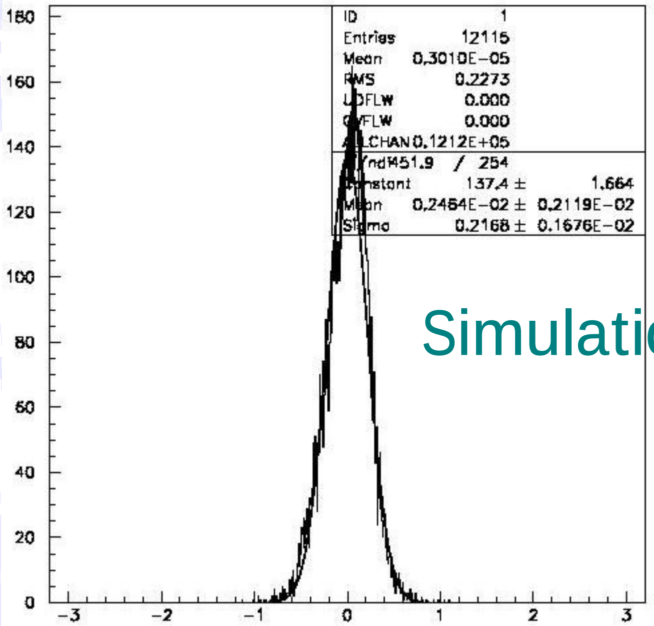
93 MHz cavity at 22 kV gave σ = 240 ps.

Simulation

93 MHz cavity at 22 kV gave σ = 217 ps.



Microbunch time, in ns



Microbunch time, in ns

Charged Mode, Where we are at Today

BNL program★ has established the process.

The CERN NA48 program evolves **step-by-step** down the sensitivity ladder.

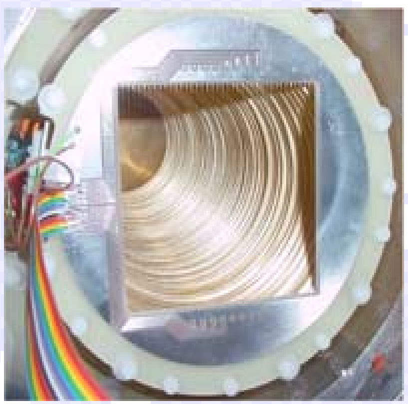
Next generation concepts and designs developed by R&D for the Fermilab CKM experiment.

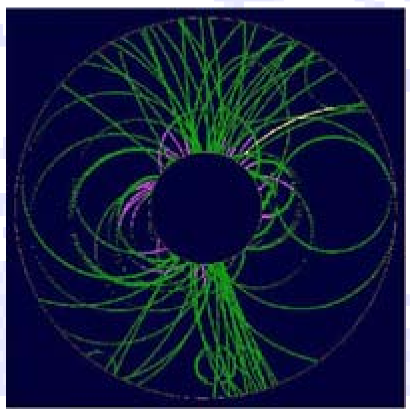
→ The now approved CERN NA62 experiment marches toward a 100 event measurement early next decade

★ **Measurement of the $K^+ \to \pi^+ \nu\nu$ branching ratio. (March 2008) Phys.Rev.D77:052003,2008, FERMILAB-PUB-08-065-CD-E**

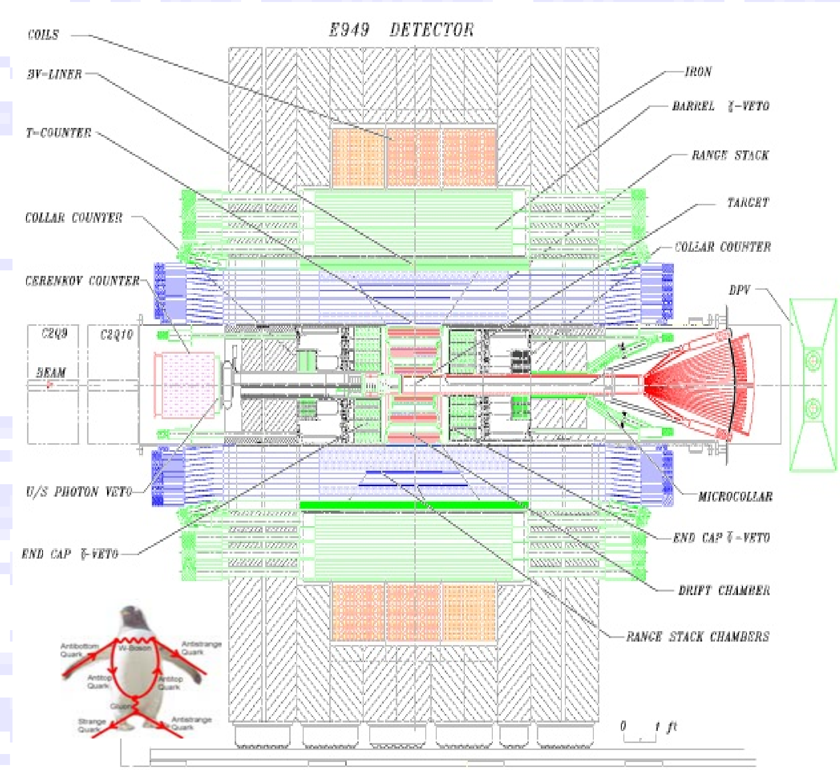
New Charged Mode Ideas Discussed at this Workshop

- Exploit Project-X proton intensities to develop a next-generation stopped K+ experiment built from modern detector technology. Examples include ultra-low mass ILC trackers in high (>3T) solenoidal tracking volumes.





Ultra-low-mass TPC tracking technology developed by the LCTPC collaboration. (photos courtesy of Cornell)

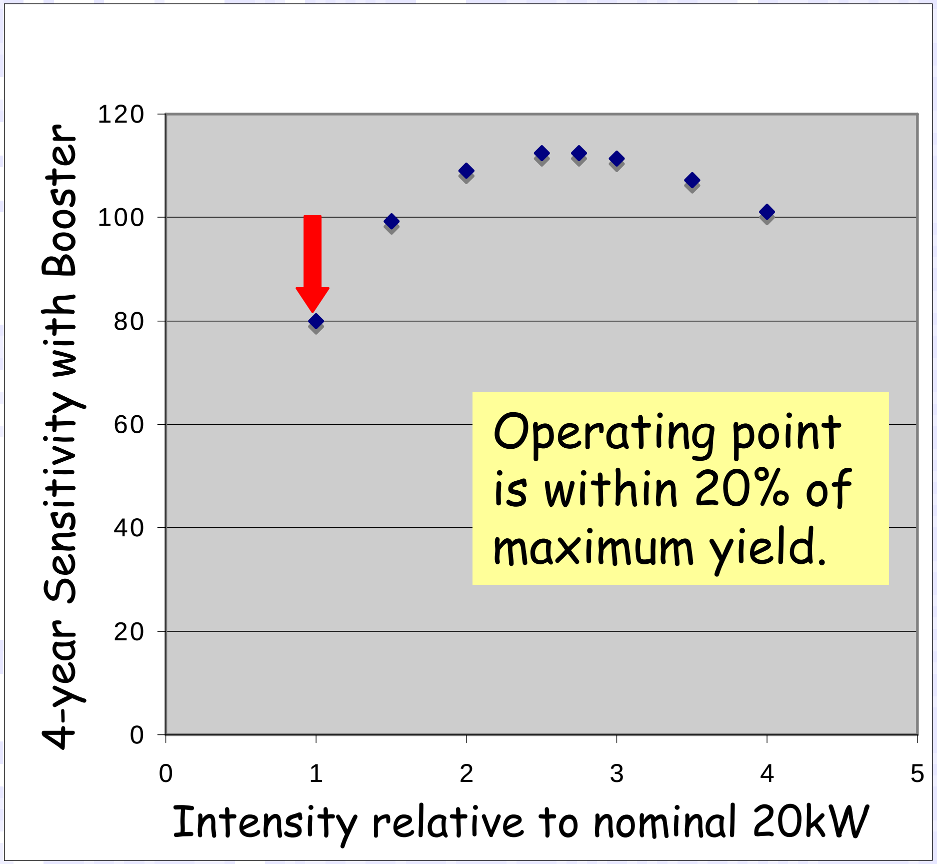


BNL E787/E949 Detector

1000 events conceivable with next generation stopped expt driven by Project-X.

Intensity Dependence of the KOPIO Design

- The KOPIO design is instantaneous rate-limited, primarily due to the large aperture of the neutral beam.
- The sensitivity could be increased by improved detector resolutions.
- **But** the KOPIO design is already not a cheap experiment, large area of detectors, many constraints.
- Could the potentially huge intensity increases of Project-X qualitatively change the picture?



Improved Rate Performance of a "Pencil Beam" TOF Experiment.

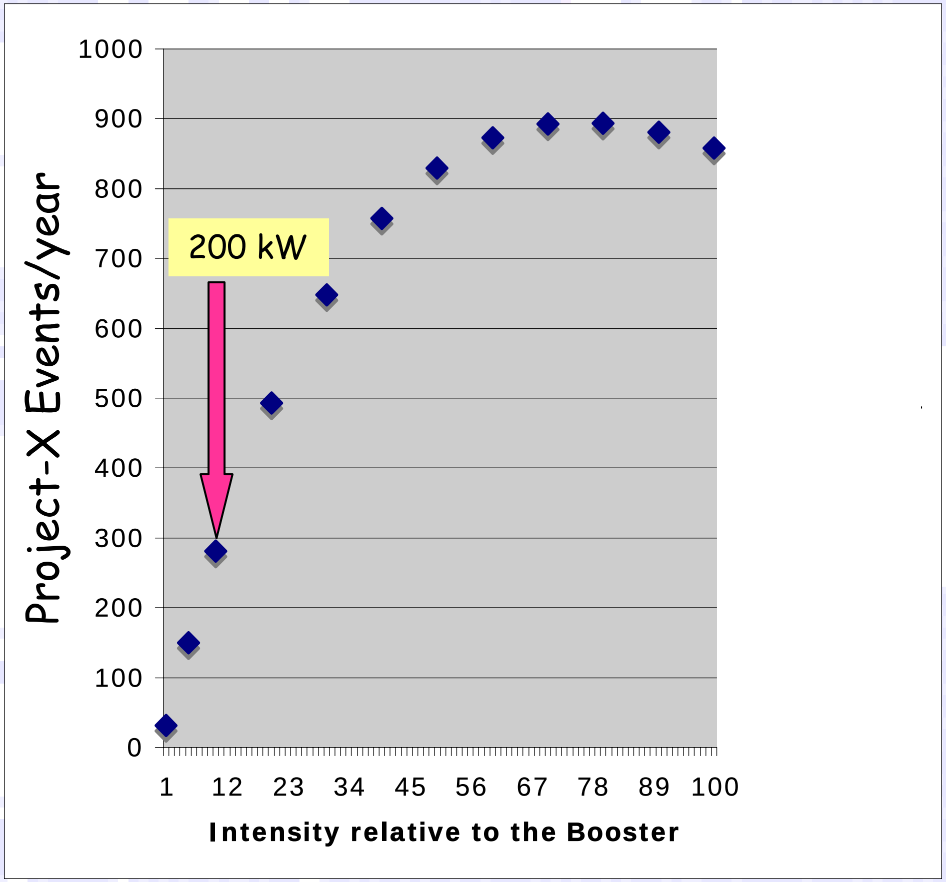
- Booster Power (20 kW):

30 equivalent events per year

- Project-X (200 kW):

300 equivalent events per year

- 200 kW operating point has robust rate performance which can be scaled to much higher beam power.
- Experiment designed with a pencil beam has substantially lower technical risk and likely lower cost.



Charged Mode, Where Fermilab and Project-X could go…

- In-flight experiment driven by the Main Injector or Tevatron: Follow-up the CERN NA62 with a high-energy separated K^+ beam. 200-events/year plausible based on the NA62 and CKM designs. Does not require Project-X but would compete directly for Main Injector and/or Tevatron protons.

- Next-generation stopped kaon experiment based on the demosntrated BNL-E787 technique upgraded with modern detector technology. About 40-events/year achievable with a 20 kW 8 GeV beam, 250-events/year plausible with a 200 kW 8 GeV beam.

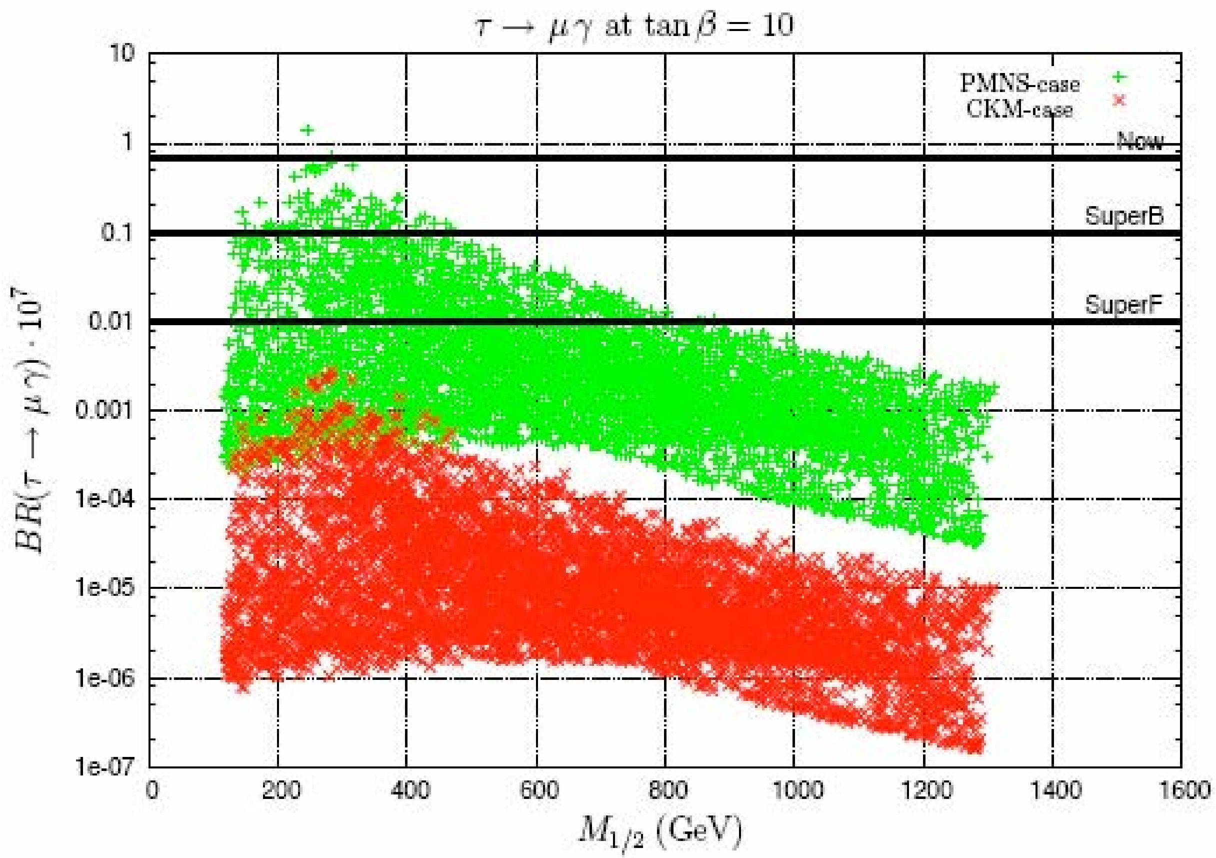
- Both options have an existing solid basis for design and costing, the stopped technique has a demonstrated feasibility.

Neutral Mode, Where Fermilab and Project-X Could go…

- The very high 8-GeV proton flux from Project-X permits an evolution of the KOPIO detector concept with a small solid angle "pencil" neutral kaon beam which recovers the hermetic bottle veto coverage, increases the detector acceptance, and **reduces risk**.
- Such an experiment can start at the Booster with sensitivity of about 20-30 Standard Model events per year. This detector can be designed with Project-X in mind, which would follow with a precision measurement of about 300 events/year.
- A next-generation TOF-based experiment has a solid basis for design and costing.

Rare τ: Measuring couplings of SUSY observed at the LHC.

Super B reach is interesting but not comprehensive



L. Calibbi, A. Faccia, A. Masiero, S. Vempati, hep-ph/0605139