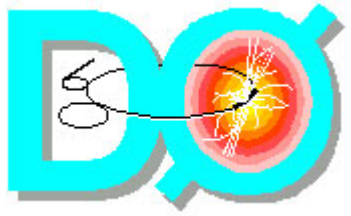


Columbia DØ Group
Snowmass Organizational Meeting

13-Jun-2001 **Columbia / Fermilab**

The Snowmass Workshop

Beyond the SM & B-Physics

Goals of the Columbia Study

Tasks for the Group

The Snowmass Workshop

2001 Workshop: "*The Future of Particle Physics*"

- http://www.snowmass2001.org/
- The latest in a series of workshops beginning in 1982
- 30 June – 21 July in Snowmass, Colorado
- Organized by APS: DPF and Physics of Beams
- Over 500 Physicists expected to attend

Overall Workshop Goals

- **"Snowmass 2001 will be a forum for the critical examination of future projects, and will provide crucial community input to the long-range planning activities undertaken by the science funding agencies and the High Energy Physics Advisory Panel. It will be an ideal place for a broad community of scientists to examine initiatives for new accelerators and new detectors that are being developed throughout the world."**

Working Groups

Accelerators (M1-M6)

- Muon-based Systems
- e^+ - e^- Circular Colliders
- Linear Colliders
- Hadron Colliders
- Lepton-Hadron Colliders
- High-Intensity p Sources

Accelerator Phys /Tech (T1-T9)

- Interaction Regions
- Magnet Technology
- RF Technology
- Particle Sources
- Beam Dynamics
- Environmental Control
- High Perform. Computing
- Advanced Accel Techniques
- Diagnostics

Exp Approaches (E1-E7)

- ν-Factories & μ-Colliders
- e^+-e^- Colliders below the Z
- Linear Colliders
- Hadron & Lept-Had Colliders
- Fixed Target
- Astro/Cosmo/Particle
- Particle Phys & Technology

Physics Issues (P1-P5)

- EW Symmetry Breaking
- Flavor Physics
- Scales beyond 1 TeV
- Astro/Cosmo/Particle
- QCD & Strong Interactions

THIS AGENDA IS PRELIMINARY, INCOMPLETE, AND SUBJECT TO REVISION

Version of 25 April 2001

	Saturday June 30	Sunday July 1	Monday July 2	Tuesday July 3	Wednesday July 4	Thursday July 5	Friday July 6	Saturday July 7
Morning	Arrival	Plenary	Plenary	Working Groups E&M	Working Groups E&M	Working Groups P&T	Working Groups E&M	Working Groups E&M
Noon						NPSS Lecture 1	NPSS Lecture 2	
Afternoon	Arrival	Plenary	Working Groups P&T	Working Groups P&T	Fourth of July Holiday	Teach in Accelerator R&D	Working Groups P&T	Working Groups P&T
Twilight	SVR4 Cookout	Welcome Reception				Informal Reception		
Evening			Lab Directors Forum	Global Accelerator Network		TownMeeting		
Technology School						Topic 1	Topic 2	
Outreach Special Events		< International Laboratory Directors >						SCIENCE WEEKEND
		< Quarknet Teacher Training >						

	Sunday July 8	Monday July 9	Tuesday July 10	Wednesday July 11	Thursday July 12	Friday July 13	Saturday July 14
Morning	OPEN?	Working Groups E&M	Working Groups P&T	Working Groups E&M	Plenary	Working Groups E&M	Working Groups E&M
Noon		NPSS Lecture 3	NPSS Lecture 4	NPSS Lecture 5		NPSS Lecture 6	
Afternoon	OPEN?	Working Groups P&T	Teach in String Theory	Working Groups P&T	Plenary	Teach in Nonaccelerator Experiments	Working Groups P&T
Twilight			Informal Reception		Mid Snowmass Night Party	Informal Reception	Bastille Day
Evening		Outreach & Education		Fagels Lecture?		Physics of the Universe	
Technology School		Topic 3	Topic 4	Topic 5		Topic 6	
		< Nonaccelerator Emphasis ? >					
Outreach Special Events	SCIENCE WEEKEND					HEPAP	HEPAP
		< ? >					

	Sunday July 15	Monday July 16	Tuesday July 17	Wednesday July 18	Thursday July 19	Friday July 20	Saturday July 21
Morning	OPEN?	Working Groups E&M	Working Groups E&M	Working Groups E&M	Working Groups E&M	Plenary	Departure
Noon		NPSS Lecture 7	NPSS Lecture 8	NPSS Lecture 9			
Afternoon	OPEN ?	Working Groups P&T	Working Groups P&T	Working Groups P&T	Plenary	Plenary	Departure
Twilight					END OF RUN PARTY		
Evening		Thematic Survey	Young Physicists Forum	Working With Governments			
Technology School		Topic 7	Topic 8	Topic 9			
		< ? >					
Outreach Special Events		< SLUA Teacher Training >					

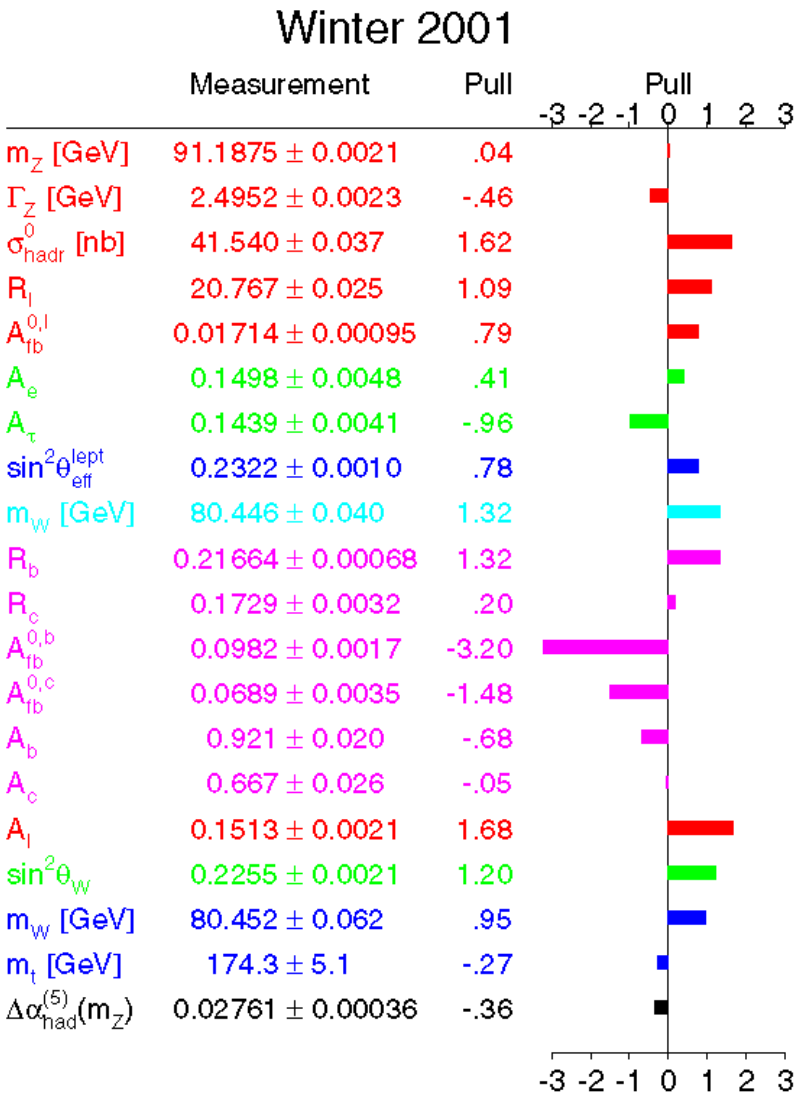
What's it all about?

The broad goal of HEP

- Understand the nature of physics beyond the SM

Why go Beyond the SM?

1. Has 19 arbitrary parameters
2. Higgs Mass not stable to radiative corrections
   - $M_h^2 \sim M_{h0}^2 + \frac{\lambda}{4\pi^2}\Lambda^2 + \delta M_h^2$
   - $\Lambda \sim M_{planck}$ for no new physics
   - $M_h < 800$ GeV $\Rightarrow$ tuning to 10^{-16}
3. Why's? of EW Symmetry Breaking
4. What about Gravity?
   - Why $M_{pl}(10^{18}\text{GeV}) \gg M_{EW}(250\text{GeV})$?



Where do we look?

Concentrate on areas where

- **we don't have complete understanding**
- **measurements are few**

1. **EW Symmetry Breaking** — **Higgs in SM**
   a. **direct searches for Higgs / new particles**
      * **need highest possible energy (or lowest)**
   b. **precision measurements of EW param's**
      * **sensitivity to H.O. effects from Higgs/New Phys**
   c. **effects in rare processes**
      * **New Phys couples to mass ⇒ t-,b-decays**
2. **Quark Weak vs. Mass Eigenstates** — **CKM Matrix in SM**
   - **Mixing, CP Violation,…**
     * **B^0, K^0 decays**
3. **Lepton Weak vs. Mass Eigenstates** — **same in SM**
   - **neutrino mass, mixing & CP**
4. **Strong Interactions** — **QCD in SM**
   - **Perturbative vs. Non-perturb.**

Quarks are all mixed up !

Quark Weak ≠ Mass Eigenstates

- CKM Mixing Matrix

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

- Independent param's
  - 3 angles
  - 1 complex phase
    ⇒ CP-viol

$$\begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

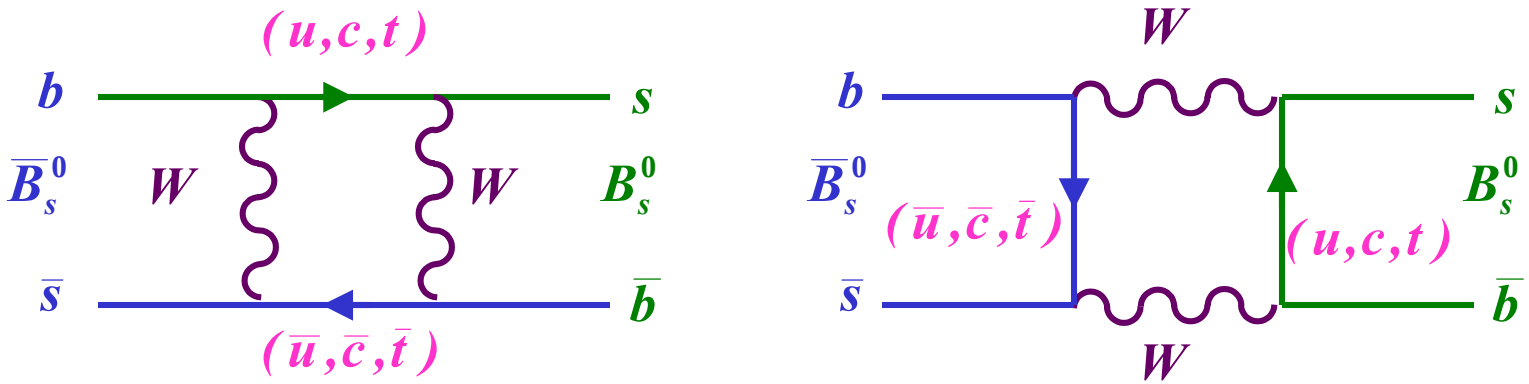
⇒ $B^0_{d,s} - \overline{B}^0_{d,s}$ Mixing

⇒ CP violation in K^0, B^0 systs

- parameterized graphically by the Unitarity Triangle

Magical Transformations

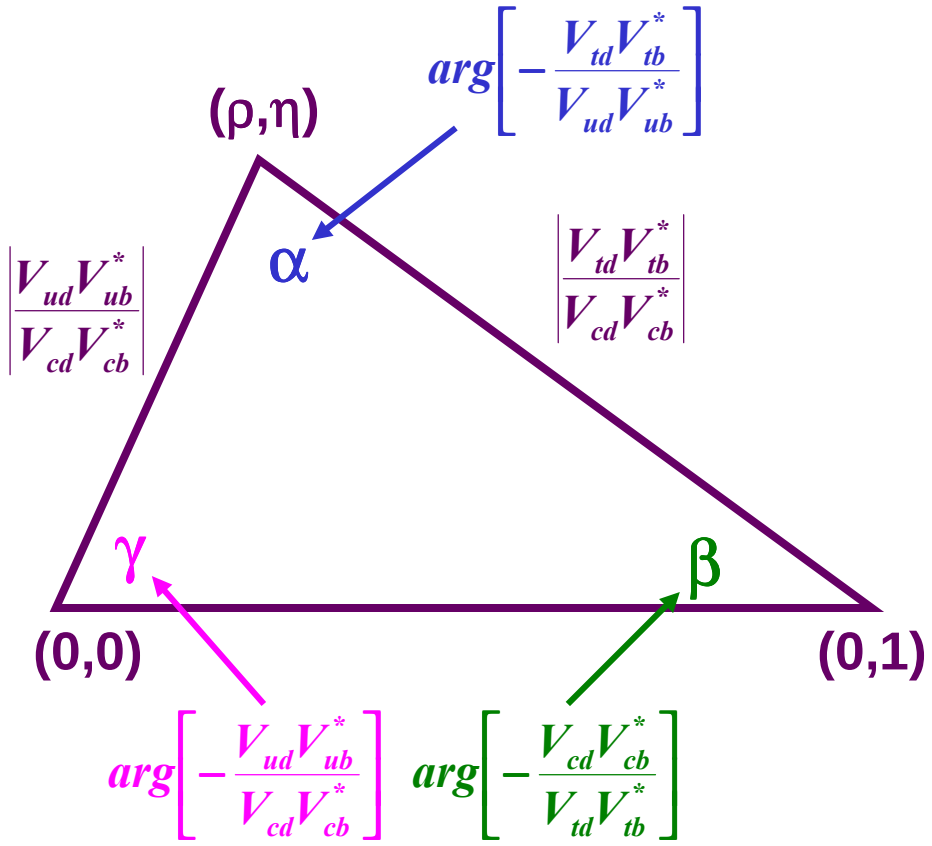
- **For neutral B-Hadrons**
  - eigenstates of flavor (produce / decay): $B_q^0 = \bar{b}q\,(q = d, s)$
    ≠ physical eigenstates (mass and width): B_H, B_L
  - a hadron that is produced as a $B_{d,s}$ can decay as an anti-$B_{d,s}$
- **Important parameters to measure**
  - $\Delta m_q = M_H^{(q)} - M_L^{(q)}$ $\quad \Delta m_d << \Delta m_s$
  - $\Delta\Gamma_q = \Gamma_H^{(q)} - \Gamma_L^{(q)}$ $\quad \Delta\Gamma_d / \Gamma_d << \Delta\Gamma_s / \Gamma_s << 1$
  - $x_q \equiv \Delta m_q / \langle \Gamma_q \rangle$



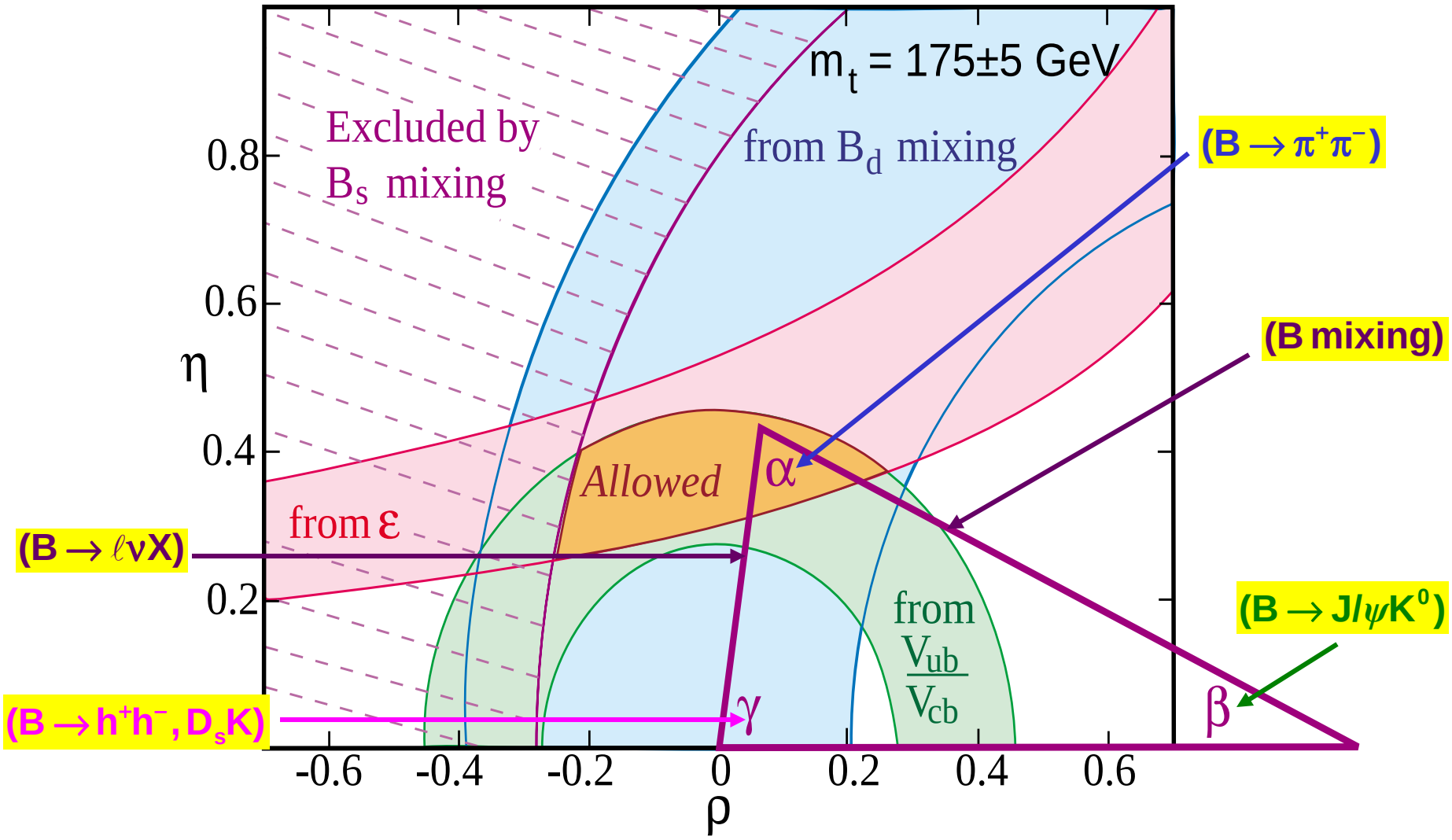
The Unitarity Triangle

Unitarity of $V_{CKM} \Rightarrow$ 12 eqn's

- ***the*** **Unitarity Triangle is one:** $V_{ub}V_{ud}^{*} + V_{cb}V_{cd}^{*} + V_{tb}V_{td}^{*} = 0$



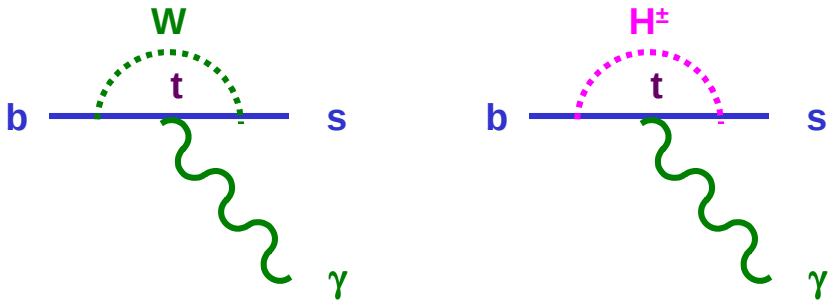
How to Build a Triangle



Rare Decays and FCNCs

Theoretically

- FCNC B^0 decays forbidden at tree level in SM

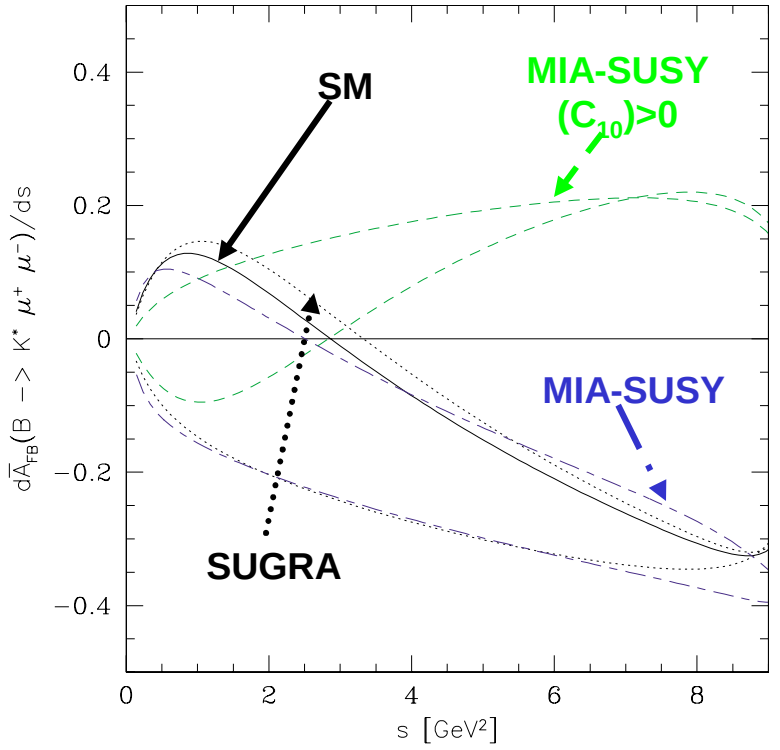


Mode	BR(B_d)	BR(B_s)
$\mu^+\mu^-$	1×10^{-10}	4×10^{-9}
$\mu^+\mu^- K^*$ (ϕ)	1.5×10^{-6}	1×10^{-6}
$\mu^+\mu^- X_s$	6×10^{-6}	
$K^*\gamma$	4.4×10^{-5}	

- Beyond SM effects could be large !

$\mu^+\mu^- K^*$

$$A = \frac{N(p^+ > p^-) - N(p^+ < p^-)}{N(p^+ > p^-) + N(p^+ < p^-)}$$



Ali,Ball,Handoko,Hiller – hep-ph/9910221

Goals of Our Studies

Main Objective of Accelerator-based HEP in the Future

- Understand the nature of physics beyond the SM

Broad Question to be Addressed by Us – Money

- Will it be useful to include requirements from B-physics into the design of beyond-LHC accelerators and experiments?
- Or will we meet our objective more effectively by other means (direct study of new particles,…)?

Two Specific Questions

1. How large are beyond-the-SM effects in various B-physics measurements?
   - will compare these with other types of measurement
2. What are the experimental or theoretical limitations on the measurements?
   - when do we run into limiting systematics

Current & Future Exp's

Exp	Type	E [GeV]	When	(some) Goals
H1/Zeus	e-p	28-920	92–	New Phenom,…
BaBar/Belle	e^+-e^-	10.58	99–	B-Physics
CDF/DØ	p-$\bar{p}$	2000	01–07	EW Sym, B-Phys,…
BTev	p-$\bar{p}$	2000	05/06–	B-Physics
Boone/Minos	$\pi \rightarrow \nu$	0.5	03–	ν Mixing
Atlas/CMS	p-p	14000	06–	EW Sym, B-Phys,…
LHCb	p-p	14000	06?–	B-Physics
Under Discussion				
Tesla/NLC	e^+-e^-	500-1000		Meas. New Phys par's
VLHC	p-p	100 TeV		Meas. New Phys par's
ν Factory	$\mu \rightarrow \nu$	20-50		ν Mixing
μ Collider	μ^+-μ^-	*O(TeV)*		Meas. New Phys par's

How to Start

1. **Literature search for info on beyond-SM sensitivity & exp. limitations for specific modes**
   - see Hal's "Research References" page
     - http://www.nevis.columbia.edu/~evans/
   - web pages for experiments
   - general B-Physics information (see Research Ref's)
     - BaBar Physics Book
     - Tevatron Run II B-Physics Working Group
2. **Present first findings in ~2 weeks**
   - 25 or 26 June ???
   - ~10 minute presentations
     - any info on beyond SM sensitivity
     - evolution of expected accuracy with experiments
     - any glaring limitations: exp or theoretical
     - references
3. **Decide where to go from there**

(some) Possible Topics

Topic	Modes	Who
β	$J/\psi\ K_s$, $J/\psi\ K^*$, $J/\psi\ \eta$	Gabrielle & Hal
α	$\pi^+\pi^-$, $\rho\pi$	
γ	*hh* $B_d \rightarrow D\ K^*$, $D^*\ \pi$ $B_s \rightarrow D_s\ K$	
Other Unitarity Triang's	$B_s \rightarrow J/\psi\ \phi$	Tulika
Mixing	x_s & x_d $\Delta\Gamma_s$	Georg & Silas Christos
Rare Decays	$l^+l^-\ K^*$, $l^+l^-\ K$ l^+l^-	Burair
	$\gamma\ K^*$	Mike
Direct Measurements	SUSY Technicolor	Leslie