New Lattice Calculation for V_{ub} Determination from $B \to \pi$ Semileptonic Decays

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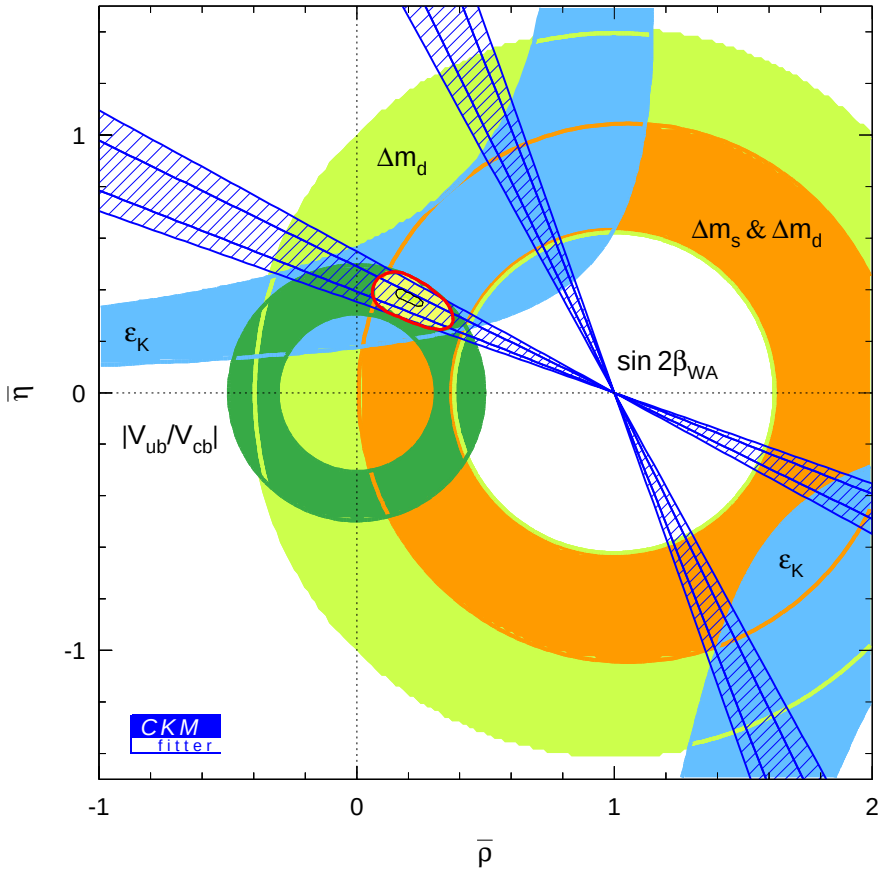
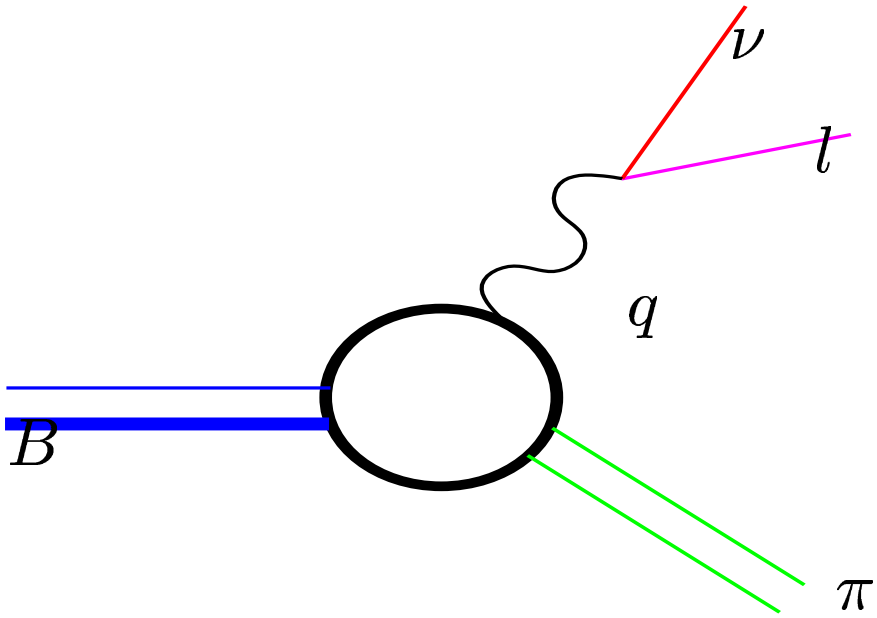
CKM Matrix

V_{ab} : probability $q_a \rightarrow q_b$ via a weak decay

- parameters of Standard Model
- need BOTH theory and experiment to find
- Major experimental effort



Exclusive Semileptonic Decays



- $B \to \pi l \nu \quad \Rightarrow \quad V_{ub}$
- $D \to \pi l \nu \quad \Rightarrow \quad V_{cd}$
- $B \to D l \nu \quad \Rightarrow \quad V_{cb}$

large mass difference $\Rightarrow$ large momentum difference likely

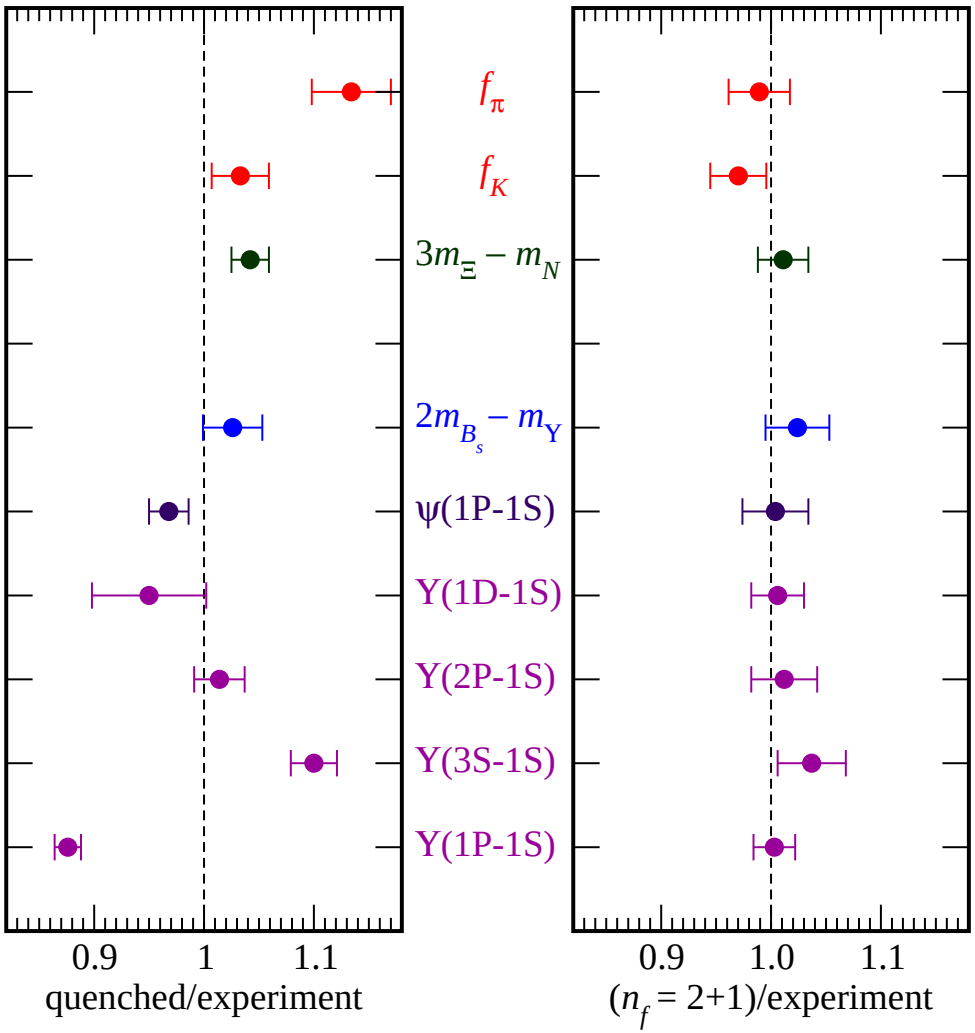
$\Rightarrow$ high recoil region (q^2 small)

Theory: Form Factor

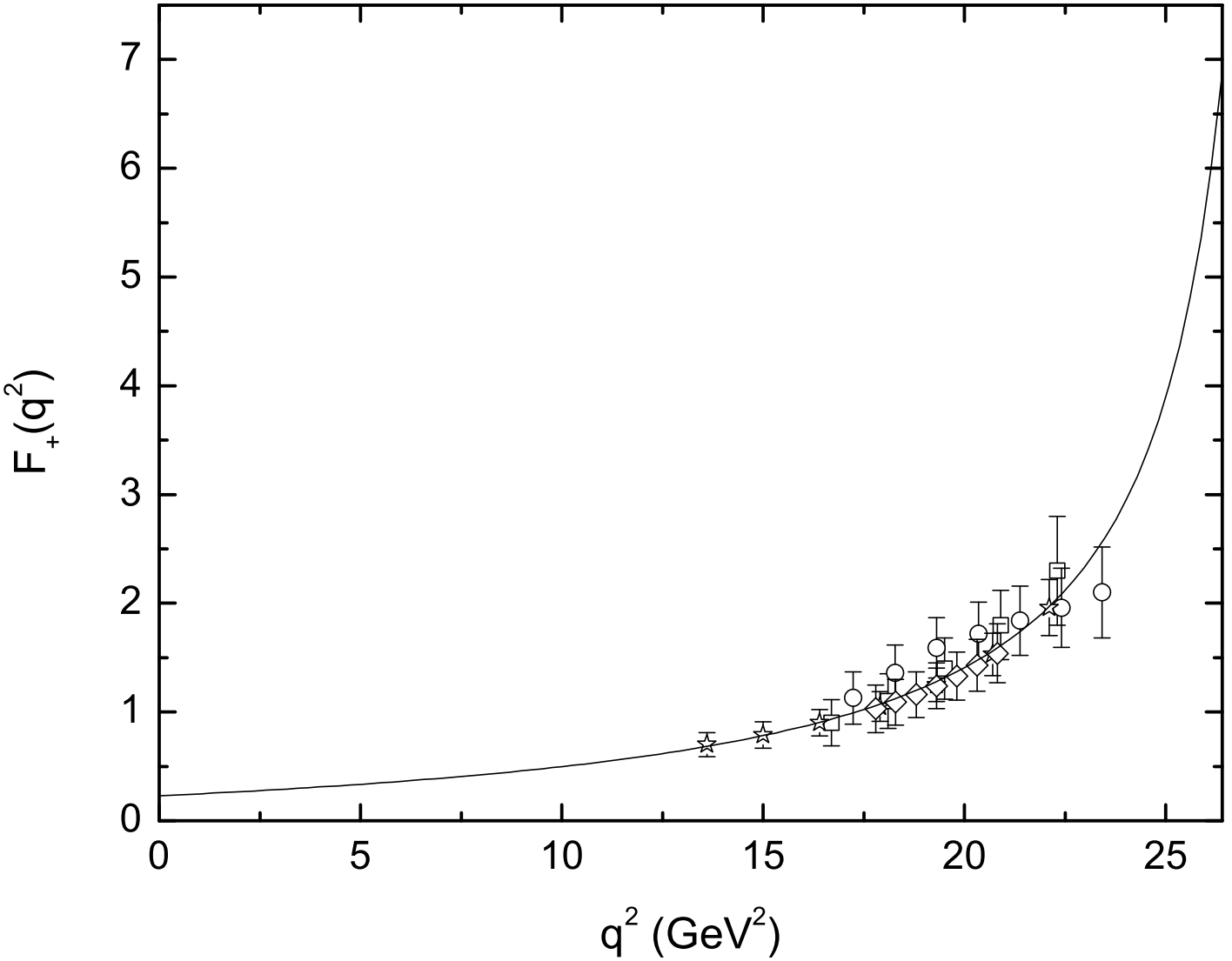
difficult due to hadrons (strong force) $\Rightarrow$ Lattice QCD

Lattice QCD

- solve QCD computationally
- only method for calculating non-perturbative physics
- now high precision results possible



Current Lattice Results



from Rosner hep-ph:/0305262

Why no $q^2 \approx 0$ values?

- Lattice calculations done in rest frame of the initial meson (B meson)

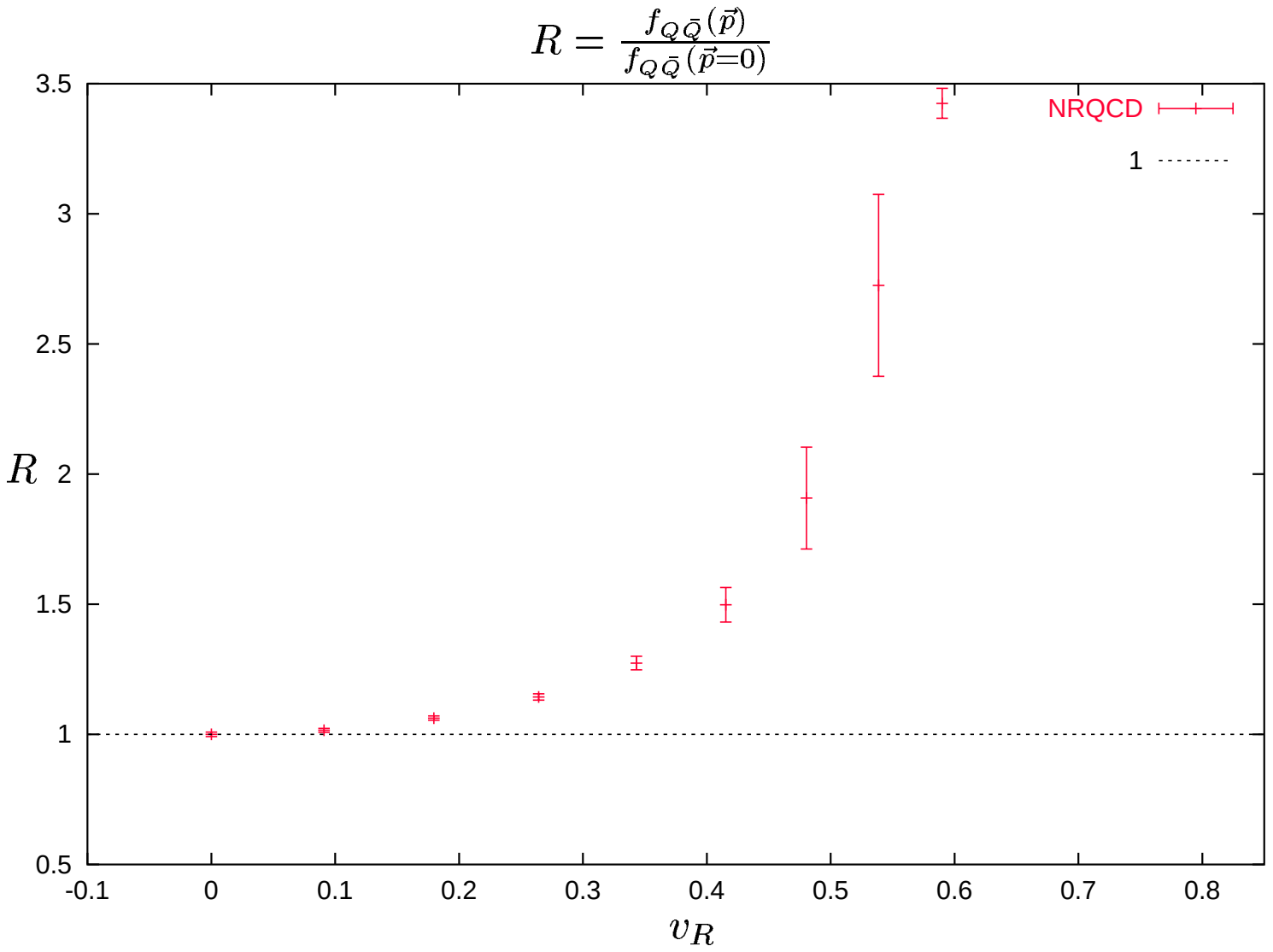
  fast pion

- errors go like $(ap)^2$; p particle momenta, a lattice spacing

- small a computationally unfeasible

  $a \to a/4 \quad \Rightarrow \quad$ 1 month calculation goes to 341 years

Decay constant $f_{Q\bar{Q}}$: related to decay rate for $\Upsilon \to e^+e^-$



Solution: two parts

(1) for light pion: better choice of lattice/reference frame

- share momentum between initial and final mesons
- slower pion $\Rightarrow$ small errors with reasonable a

(2) for moving heavy quark $\Rightarrow$ moving NRQCD

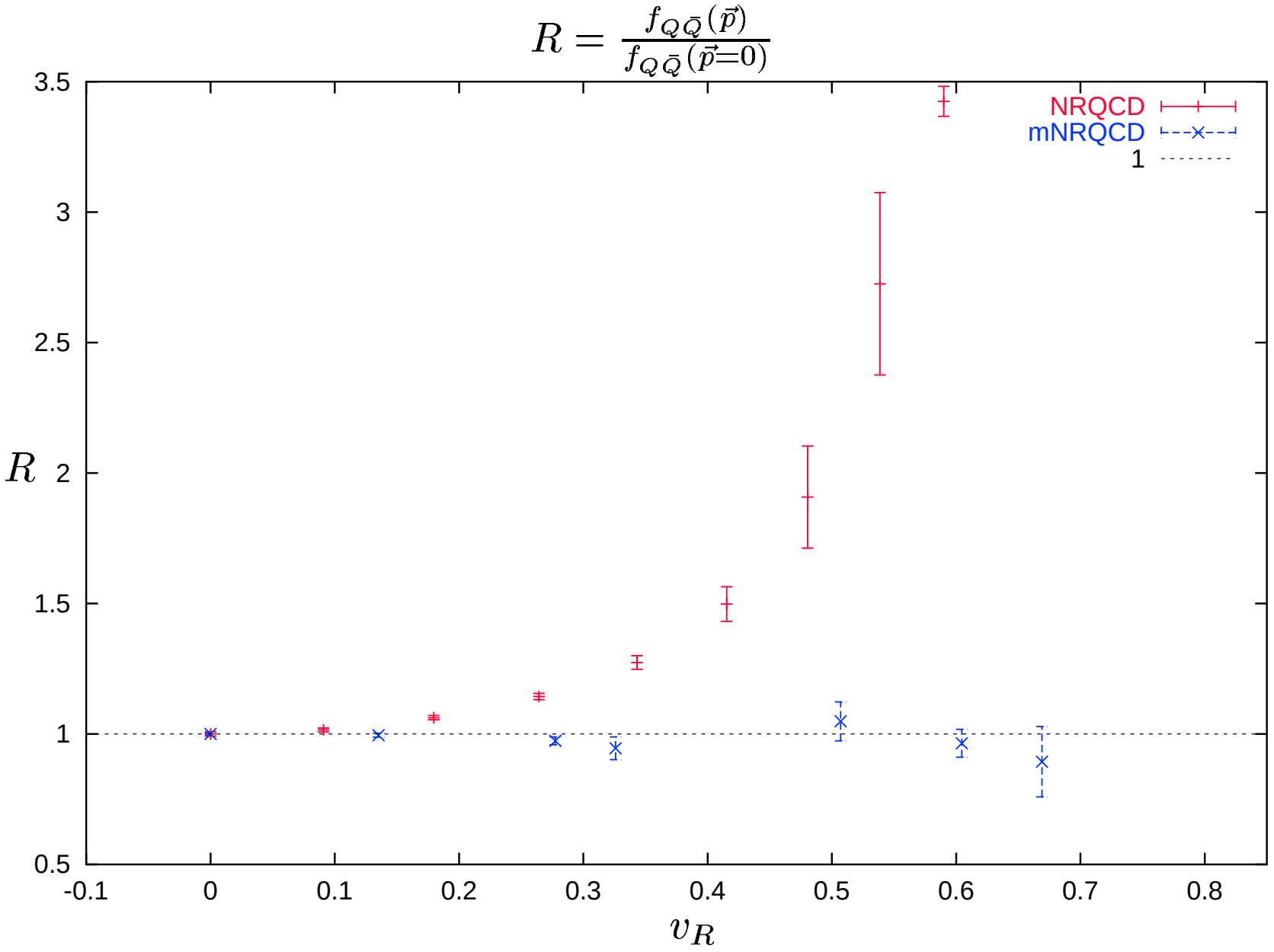
- new effective field theory

moving NRQCD

$P_b^\mu = M_b u^\mu + k^\mu$ where u^μ = 4-velocity of B meson

$\Rightarrow$ $k^\mu \sim \Lambda_{QCD} u^\mu \ll M u^\mu$

- treat $M_b u^\mu$ exactly
- discretize k^μ
- heavy quark errors now same size as light quark errors


$R = \frac{f_{Q\bar{Q}}(\vec{p})}{f_{Q\bar{Q}}(\vec{p}=0)}$
NRQCD
mNRQCD
1
R
v_R
3.5
3
2.5
2
1.5
1
0.5
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Conclusions

Calculation of high recoil form factors now possible

(add to list of high precision results)

- Υ mesons have been analyzed
- B meson calculations in progress
- Form factors at high recoil in near future!