Kaon Fitting and Beam Energy

- Minuit can fit any set of data to a given parameterization
  $\Rightarrow \chi^2$ value indicates how good fit is
  - Bad χ^2 can come from poor parameterization, inconsistent data, or poor estimates of data errors

- Almost no data at or below 10 GeV beam energies
  - Cross section prediction for MiniBooNE sensitive to assumed beam energy dependence in parameterization, especially for K^0

MiniBooNE in Beam Fragmentation Region

- "Sweet Spot" for K^+ production that produces ν_e in MiniBooNE
  - $P_k = 2.8$ GeV , $\theta_k = 0.106$, $x_F = 0.320$, $p_t = 0.234$ GeV
    ($P_{beam} = 8.89$ GeV , $E_{cm} = 4.3$ GeV)

- In "Beam Fragmentation" region

For π^+: $p \to n\,\pi^+$ $\Rightarrow$ uud $\to$ ($u\,\bar{d}$) $\Rightarrow$ π^+ has a majority valence quark

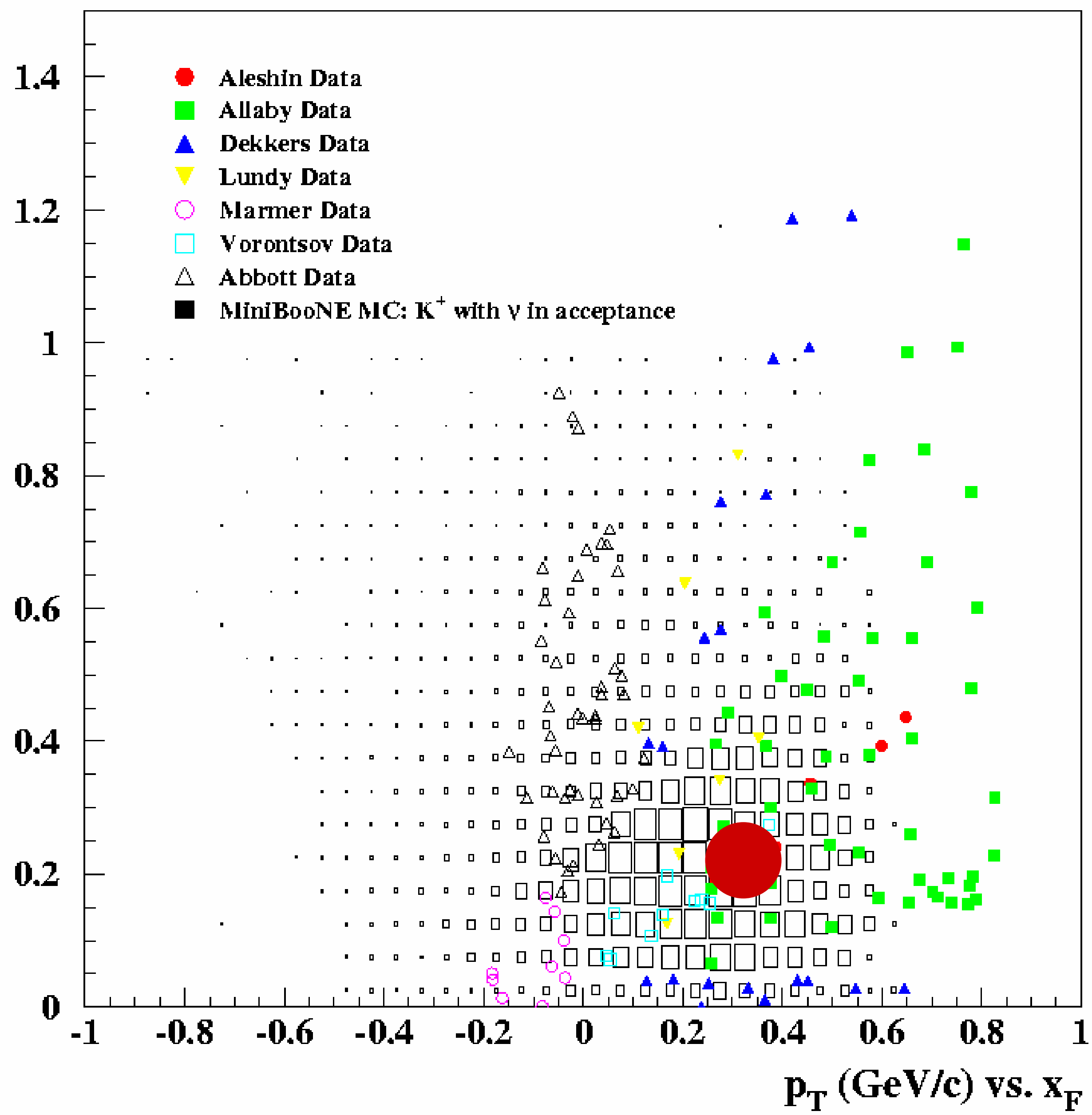
For π^-: $p \to p\,\pi^+\pi^-$ $\Rightarrow$ uud $\to$ ($d\,\bar{u}$) $\Rightarrow$ π^- has a minority valence quark

For K^+: $p \to \Lambda^0 K^+$ $\Rightarrow$ uud $\to$ ($u\,\bar{s}$) $\Rightarrow$ K^+ has a majority valence quark

For K^-: $p \to p\,K^+ K^-$ $\Rightarrow$ uud $\to$ ($s\,\bar{u}$) $\Rightarrow$ K^- has no valence quarks

For K^0: $p \to \Sigma^+ K^0$ $\Rightarrow$ uud $\to$ ($d\,\bar{s}$) $\Rightarrow$ K^0 has minority valence quark

h	Exclusive reaction	$\bar{M}_X$ (GeV c^{-2})	$\sqrt{s_t}$ (GeV)	E_t (GeV)	T_t (GeV)
π^+	$pn\pi^+$	1.878	2.018	1.233	0.295
π^-	$pp\pi^+\pi^-$	2.016	2.156	1.540	0.602
π^0	$pp\pi^0$	1.876	2.011	1.218	0.280
κ^+	$\Lambda^0 p\kappa^+$	2.053	2.547	2.520	1.582
κ^-	$pp\kappa^+\kappa^-$	2.370	2.864	3.434	2.496
K^0	$p\Sigma^+ K^0$	2.130	2.628	2.743	1.805



Aleshin Data
Allaby Data
Dekkers Data
Lundy Data
Marmer Data
Vorontsov Data
Abbott Data
MiniBooNE MC: K+ with ν in acceptance
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
pT (GeV/c) vs. xF

Cross Section Parameterizations

Various scaling variables on the market:

$$x_F = \frac{p_{\parallel}^{cm}}{p_{\parallel}^{cm\,\max}} \quad x_R = \frac{E_{cm}}{E_{cm}^{\max}} \quad x_T = \frac{x_R - x_{\min}}{1 - x_{\min}}$$

- Feynman Scaling
  - Invariant cross section is only a function of x_F and p_t (not p_{beam})

$$E\frac{d^3\sigma}{dp^3} = A\,F(x_F)\,G(p_t) \text{ for example } = A\left(1 - x_F\right)^a e^{-bp_t}$$

  - Claim that this is valid for E_{cm} > 10 GeV ($P_{beam} \approx$ 50 GeV)
- Sanford Wang Parameterization

$$\frac{d^2\sigma(p + Be \to K^+ + X)}{dp\,d\Omega} = c_{k,1}p^{c_{k,2}}\left(1 - \frac{p}{p_{beam} - c_{k,9}}\right)\exp\left[-c_{k,3}\frac{p^{c_{k,4}}}{p_{beam}^{c_{k,5}}} - c_{k,6}\vartheta\left(p - c_{k,7}p_{beam}\cos^{c_{k,8}}\vartheta\right)\right]$$

Secondary Particle	Sanford-Wang parameter								
	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9
K^+	12.53	1.654	0.314	1.038	0.174	4.658	0.106	10.53	2.635

Yan Liu S-W Fits

  - Original Wang paper says that coefficients are approximately given by: c_2 = 0.5, c_4=c_5=1.67, and cosθ term can be ignored mostly, then:

$Y = d^2\sigma/dp\,d\Omega$ and $X = P/P_i$, we can rewrite the formula as

$$Y = AP_i^{1/2}F(X)\exp(-CP_t)$$

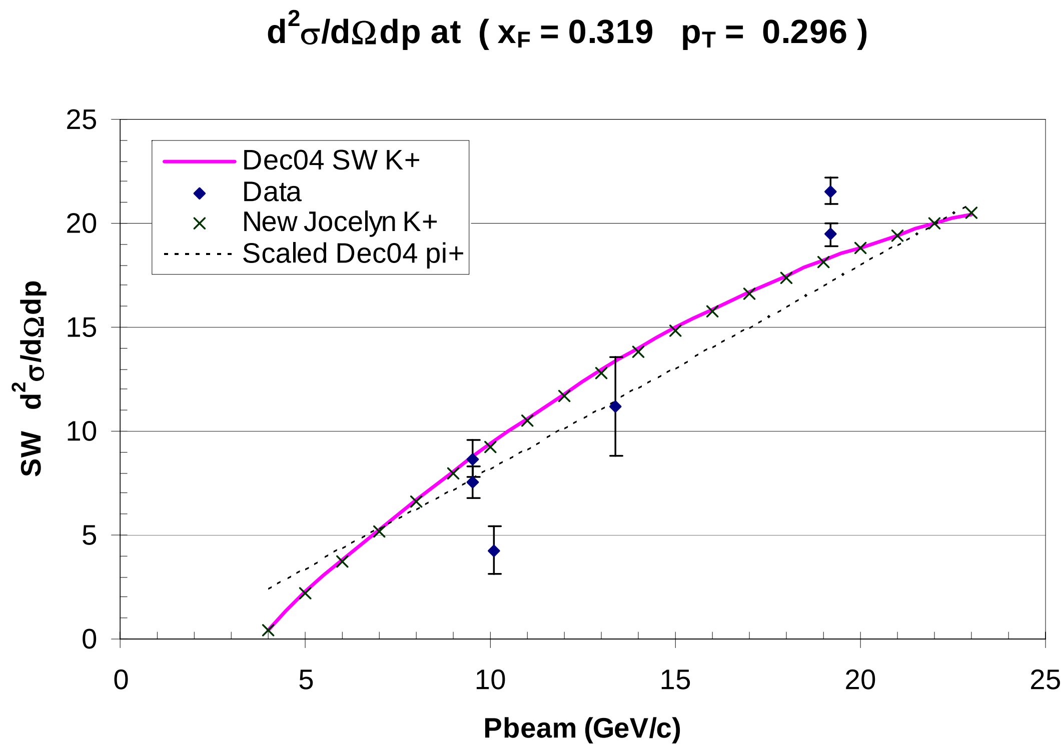
with

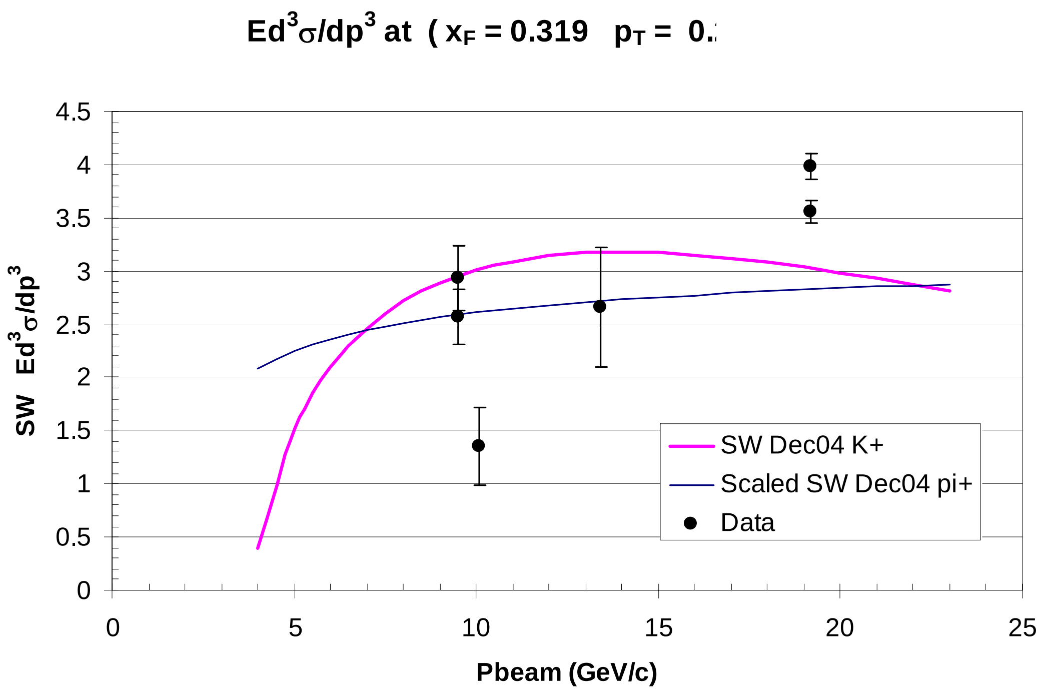
$$F(X) = X^{1/2}(1-X)\exp(-BX^{5/3}), \qquad (3)$$

This would imply a $\sqrt{P_{beam}}$ dependence for $d^2\sigma/d\Omega dp$
Which translates to $E\,d^3\sigma/dp^3$ constant
⇒ SW leads to x_F scaling
But our fits don't match the assumptions

Beam Energy Dependence of Our SW Fits

- Look at P_{Beam} dependence at the MiniBooNE "Sweet Spot"



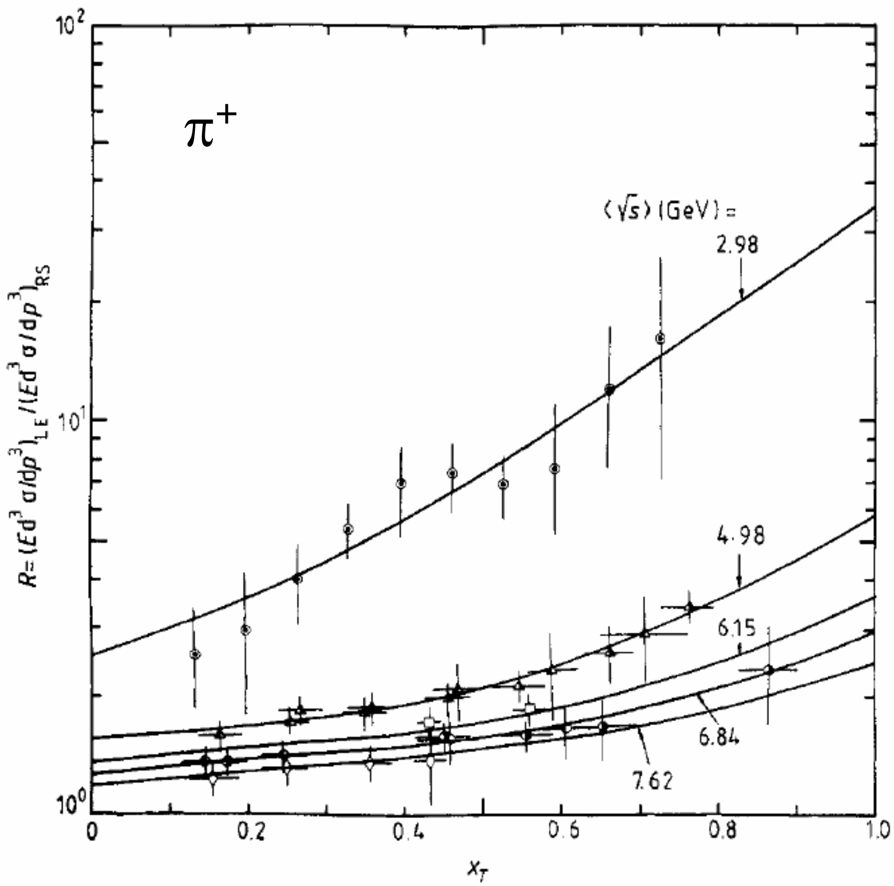


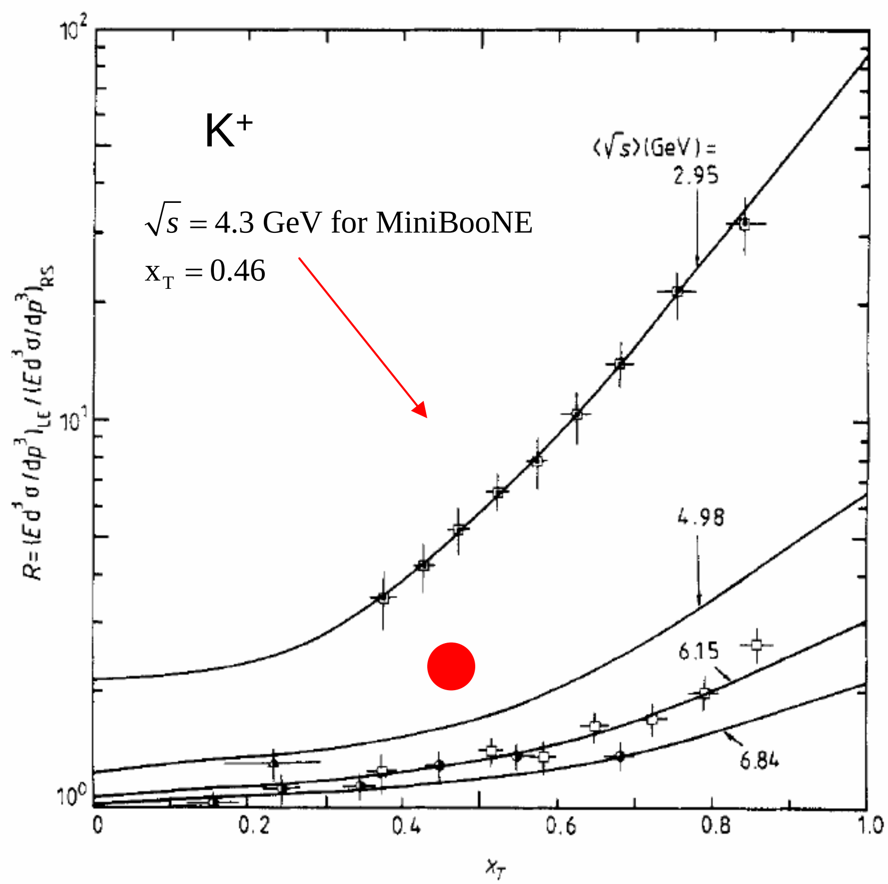
- Invariant cross section
  - For π^+: scaling at about the $\pm$20% level
  - For K^+: scaling violations become very large below P_{Beam} = 10 GeV
    $\Rightarrow$ **Is this correct?**

Other Parameterizations of Scaling Violations

- Tan and Ng (J.Phys.G 9 (1983) 1289) studies of pp particle prod.
  - Have investigated how the low enegy data deviates from "radial" scaling parameterization found from higher energy data
  - Developed a parameterization for: $R = d\sigma_{LE} / d\sigma_{RS}$

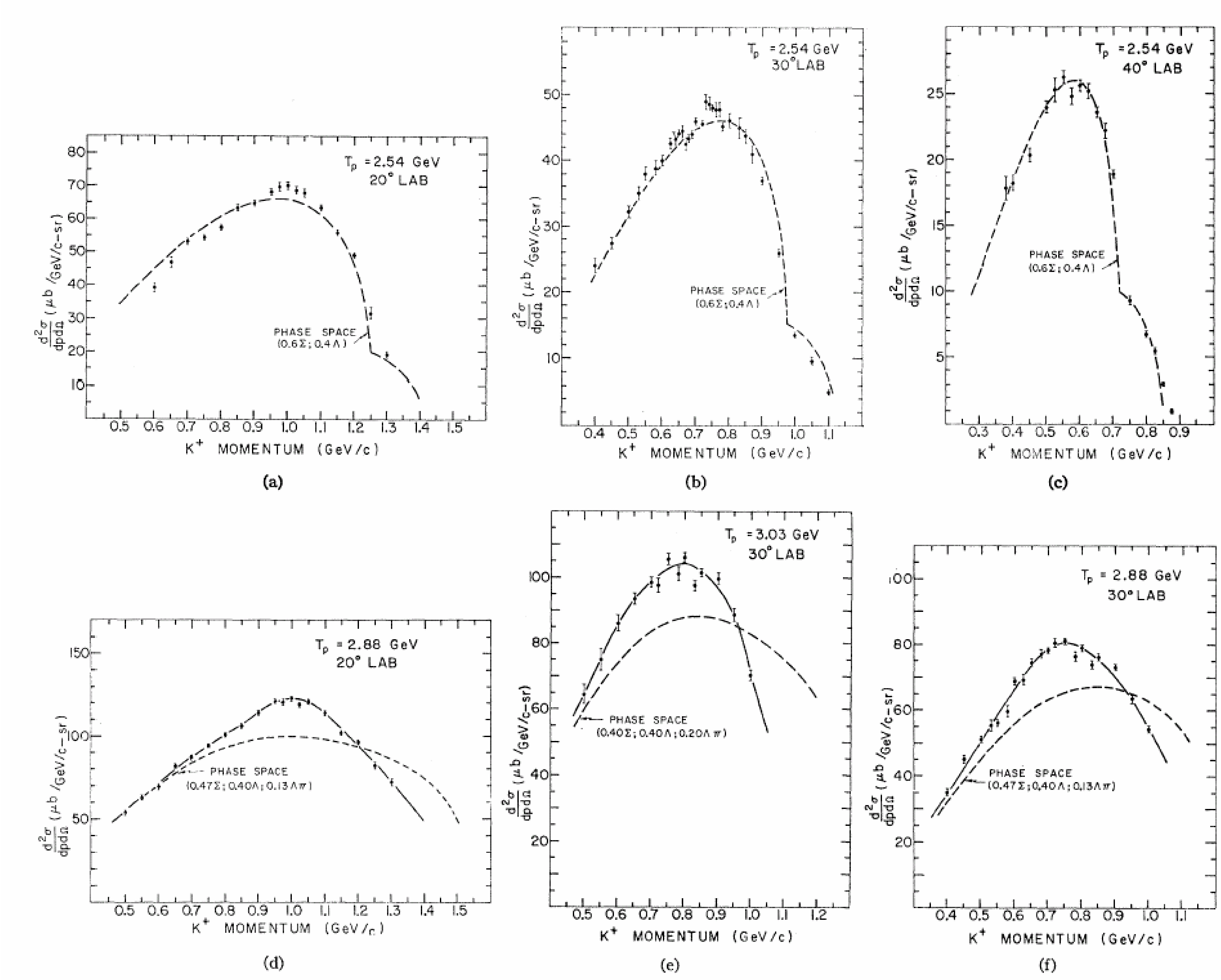
$$R^{-1} = 1 - \exp[-(1-\exp(-A(x_T)Q^{B(x_T)}))\exp(C(x_T)Q - D(x_T))]$$





Some Low Energy pp Kaon Data Available

- Hogan et al. Data P_{Beam} = 3.35 – 3.86 GeV
  - Pretty close to pure phase space calculation (40% $K^+\Lambda p$ + 60% $K^+\Sigma N$)



Conclusions / Plans

- Need to incorporate low energy data into the fits and try to constrain shape below 10 GeV
  - Can we use pp data and correct to p Be ??
- Try including Tan and Ng low-energy correction into SW parameterization
  - Maybe just use their correction without fitting; otherwise many parameters
- Best if we could get a kaon parameterization from these older data and then compare to HARP results
- K^0's
  - May also be able to use Tan and Ng correction since their study showed that it worked for π^+, π^-, and K^+
  - Main data is Abe et al. at 12 GeV