The x_s Reach of BTeV

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Workshop on B Physics at Run II
and Beyond

Fermilab
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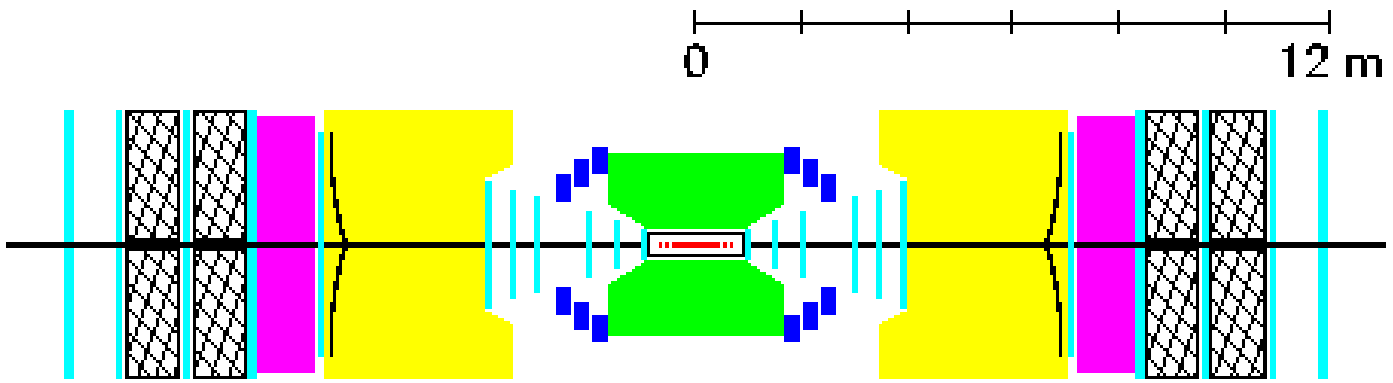
- The Evolving Baseline Detector
- Decay Modes
- Method
- Results (still using PTDR detector)
- Future Plans
- Summary and Conclusions

http://home.fnal.gov/~kutschke/BTeV/talks/000224_wg3.ps

BTeV: Horizontal Section at y=0

- Pixel Detector
  31 Stations of (yxy)
  Inside beam vacuum
- Wire Chambers
  Aperature tanθ=0.3
- Dipole Magnet Steel
  Field Integral: 2.6 T–m
  Vertical Bend
  SM3 from E605
- RICH. (C_4F_{10}/C_5F_{12})
  Meaningful K/π separation
  for 3.0<p<70 GeV/c
  Option: areogel preradiator
- Magnet Coils
- EM Cal
  Options: Pb–Scint,
  Pb–liq A, liq Kr, CsI
- Beam Pipe Vacuum
- μ Absorber and Toroid
  μ trigger



Changes to the Baseline Detector since PTDR

- Pixel planes now doublets, not triplets.
  - Motivation: much less material.
    conversions; pair production;
    cost; complexity; . . .
  - Trigger algorithm now demonstrated with doublets. See Erik Gottshalk's talk in WG1.
- Forward tracking system has Si strips at small radii, straws at larger radii.
  - Motivation: occupancy.
- $PbWO_4$ is the plan for the EMCal.
  - Motivation: rad hard.

Decay Modes Considered

$$B_s \rightarrow D_s^- \pi^+$$
$$\hookrightarrow \phi\pi^-$$
$$\hookrightarrow K^+K^-$$
$$\hookrightarrow K^{*0}K^-$$
$$\hookrightarrow K^+\pi^-$$

- Large product BR.
- Narrow intermediate States.
- $D_s \rightarrow KK\pi$ Dalitz plot cut.

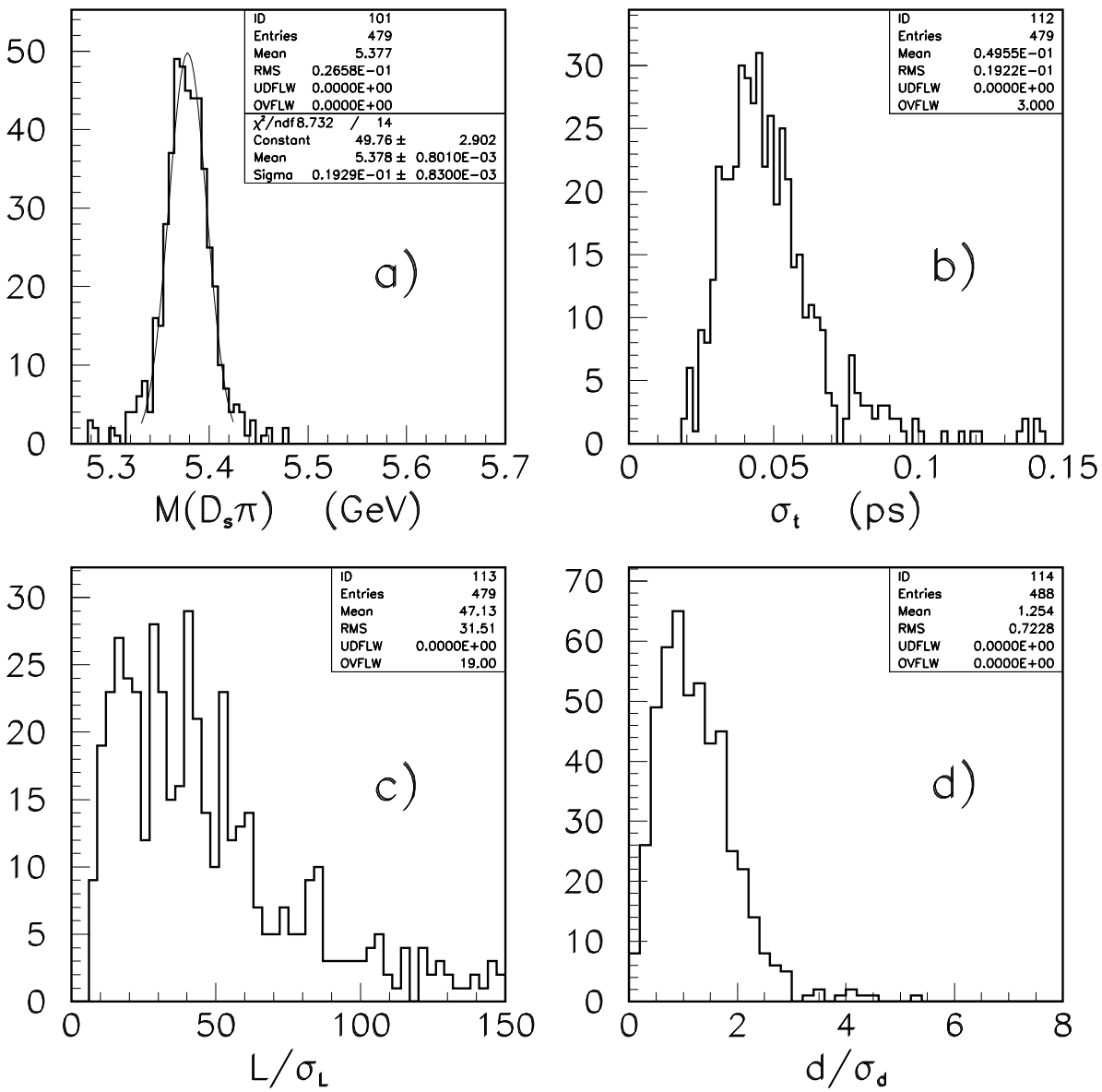
$$B_s \rightarrow J/\psi\ \bar{K}^{*0}$$
$$\hookrightarrow K^-\pi^+$$
$$\hookrightarrow \mu^+\mu^-$$

- Redundant trigger.
- 4 prong vertex.
- These partially overcome low product BR (Cabbibo suppressed).

Analysis Plan

- Simulations with MCFast
  - Signal Channels
    - Efficiency (including trigger).
    - Mass resolution (σ_m).
    - Proper decay time resolution. (σ_t).
  - High stats simulation of BG
    - S/B; feedback to analysis cuts.
    - $B \to \Psi X$ or $B \to D_s X$.
    - Generic B.
  - Tagging ϵD^2 from a separate study.
  - Details of cuts can be found in Preliminary TDR on our web site.
- Standalone Calculations
  - Ensemble of Mini Monte Carlo runs.
  - "Analytic" *á la* McDonald. Princeton-HEP 92-04.

Simulation Results for $B_s \to D_s^- \pi^+$



$\sigma_m = 19 \pm 1 \mathrm{MeV}/c^2$ $\qquad$ $\sigma_t = 50 \pm \mathrm{fs}$

Simulation Results for $B_s \to D_s^- \pi^+$

Quantity	Value	Yield (Events/year)
Luminosity:	2×10^{32} cm^{-2}s^{-1}	
One Year:	10^7 s	
$\sigma_{b\bar{b}}$:	100 μb	
$\mathcal{B}(B_s \to D_s^- \pi^+)$:	3.0×10^{-3}	
$\mathcal{B}(D_s^- \to \phi\pi^-)$:	0.030	
$\mathcal{B}(D_s^- \to K^{*0}K^-)$:	0.036	
$\mathcal{B}(\phi \to K^+K^-)$:	0.49	
$\mathcal{B}(K^{*0} \to K^+\pi^-)$:	0.67	
$\mathcal{B}(\bar{b} \to B_s)$	0.13	6,210,000
ϵ(Geometric)	0.08	
ϵ(Analysis cuts : $\phi\pi^-$)	0.40	
ϵ(Analysis cuts : $K^{*0}K^-$)	0.33	
ϵ(Trigger)	0.60	108,000
ϵ(Tag)†	0.15	16,100
Mistag fraction†	0.25	
$\epsilon_{\rm tag} D^{2\dagger}$	0.04	
S/B	3:1	
σ(Proper Decay time)	50 fs	

† Uses only highest quality tags, leptons and kaons! Highly conservative.

Numbers in red used in Mini Monte-Carlo.

Simulation Results for $B_s \to J/\psi\ \bar{K}^{*0}$

Quantity	Value	Yield (Events/year)
Luminosity:	2×10^{32} cm^{-2}s^{-1}	
One Year:	10^7 s	
$\sigma_{b\bar{b}}$:	100 μb	
$\mathcal{B}(B_s \to \psi \bar{K}^{*0})$:	8.5×10^{-5}	
$\mathcal{B}(\psi \to \mu^+\mu^-)$:	0.061	
$\mathcal{B}(\bar{K}^{*0} \to K^-\pi^+)$:	0.667	
$\mathcal{B}(\bar{b} \to B_s)$	0.13	180000
ϵ(Geometric)	0.18	
ϵ(Analysis cuts)	0.17	5508
ϵ(Trigger) Tracking only	0.60	
ϵ(Trigger) Total	0.85	4680
ϵ(Tag)†	0.15	700
Include $\psi \to e^+e^-$		1030
Mistag fraction†	0.25	
$\epsilon_{\rm tag} D^{2\dagger}$	0.04	
S/B	2:1	
σ(Proper Decay time)	38 fs	

† Uses only highest quality tags, leptons and kaons! Highly conservative.

Numbers in red used in Mini Monte-Carlo.

The Mini Monte-Carlo

- Assume that BG has same lifetime as B_s.
- Assume gaussian smearing with fixed σ, $N(0, \sigma; t)$.
- Assume step function efficiency.
- Mixed and unmixed lifetime distributions are:

$$F^0_{\pm}(t) = \frac{N}{2}[1 \pm D(1-b)\cos(xt)]\exp(-t).$$

$D =$ tagging dilution. $b=$ background fraction.

Include smearing and efficiency:

$$F_{\pm}(t) = \epsilon(t) \int F^0_{\pm}(t')\ N(0, \sigma; t-t')dt',$$

- Must be careful to normalize $F_{\pm}(t)$ such that the area under $F_{\pm}(t)$ is independent of x_s.
- Also define the fraction and number of mixed and unmixed events, $f_{\pm}$, $n_{\pm}$.

...The Mini Monte-Carlo

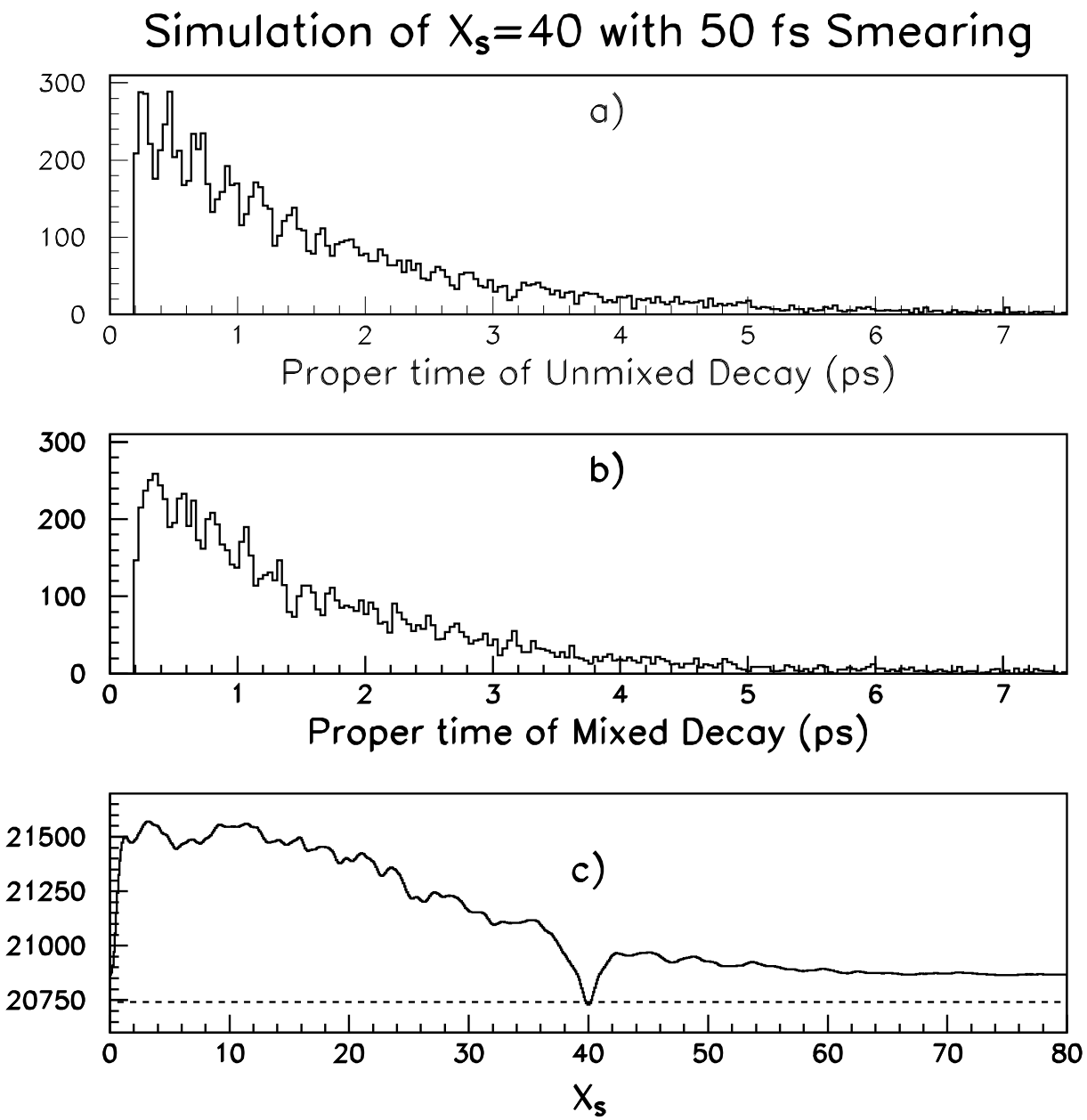
- Generate N "events" according to the two distributions $F_{\pm}(t)$.
- Define unbinned likelihood function:

$$\mathcal{L}(x) = \prod_i n_+ \; F_+(t_i) \; \prod_j n_- \; F_-(t_j)$$

$$-\ln(\mathcal{L}(x)) = -\sum_i \ln(n_+ F_+(t_i)) \; - \; \sum_j \ln(n_- F_-(t_j))$$

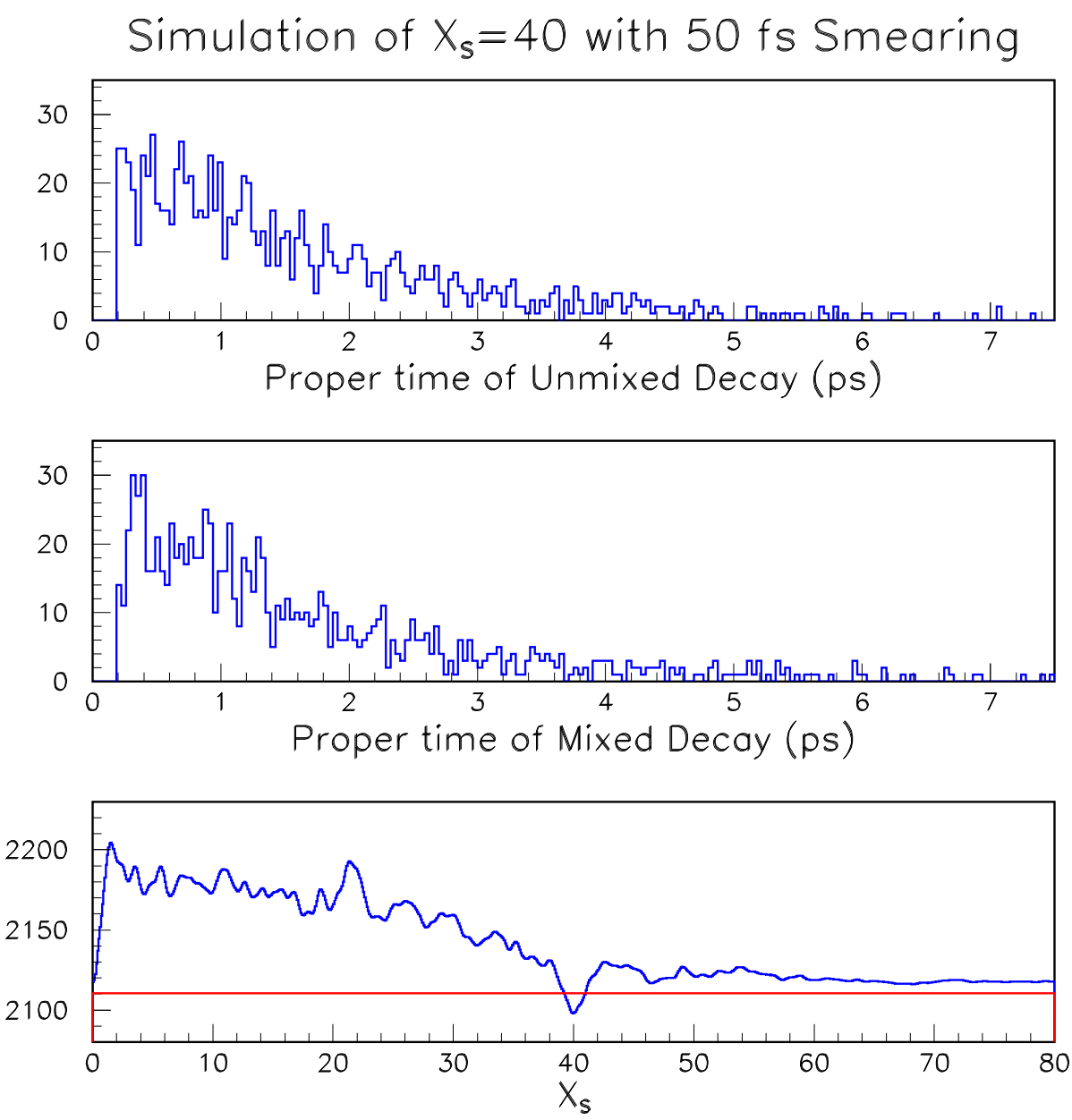
- i runs over unmixed events
- j runs over mixed events.
- The 1σ confidence interval is given by $\Delta(-\ln(\mathcal{L})) = 0.5$.

Mini-MC for 1 Year of $B_s \to D_s^- \pi^+$



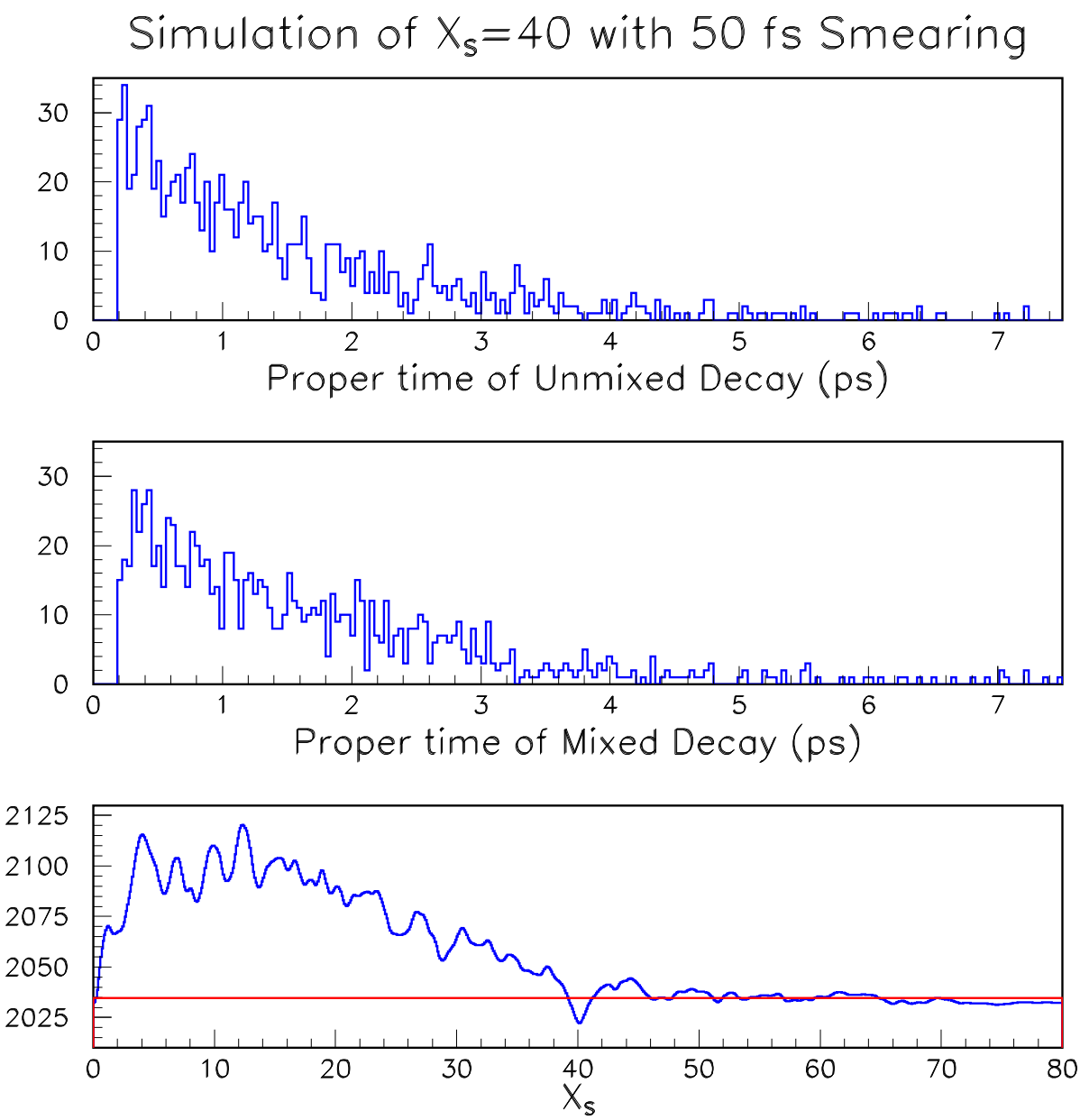
- The dashed line shows 5σ above the minimum.

Mini-MC for 1 Month of $B_s \to D_s^- \pi^+$



- The red line shows 5σ above the minimum.

Mini-MC for 1 Month of $B_s \to D_s^- \pi^+$



- The dashed line shows 5σ above the minimum.

Lessons Learned from Mini-MC

- x_s reach is limited by likelihood function having large secondary minima.
- At the statistical limit of observing a signal, the error on x_s is about ± 0.2.
- This error is approximately independent of x_s for all interesting values of x_s.
- Error is consistent with Craemer-Rao minimum error bound.
- Errors returned by the fit correctly describe the dispersion of values "measured" in an ensemble of Mini-MC runs.

The "Analytic" Calculation

Likelihood function was,

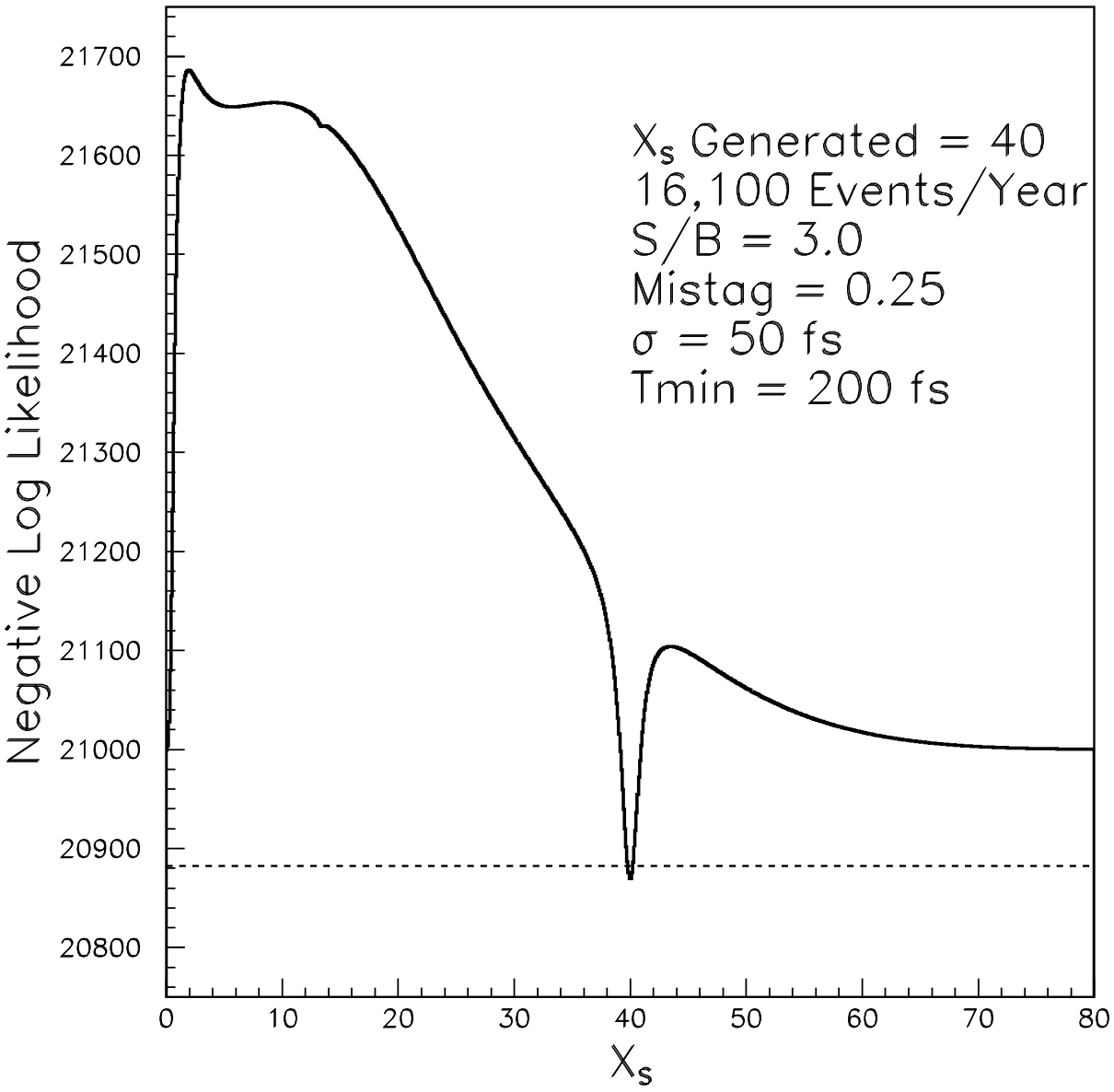
$$-\ln(\mathcal{L}(x)) = -\sum_i \ln(n_+ F_+(t_i)) - \sum_j \ln(n_- F_-(t_j))$$

To smooth out fluctuations, replace sums with an integral over the parent distribution:

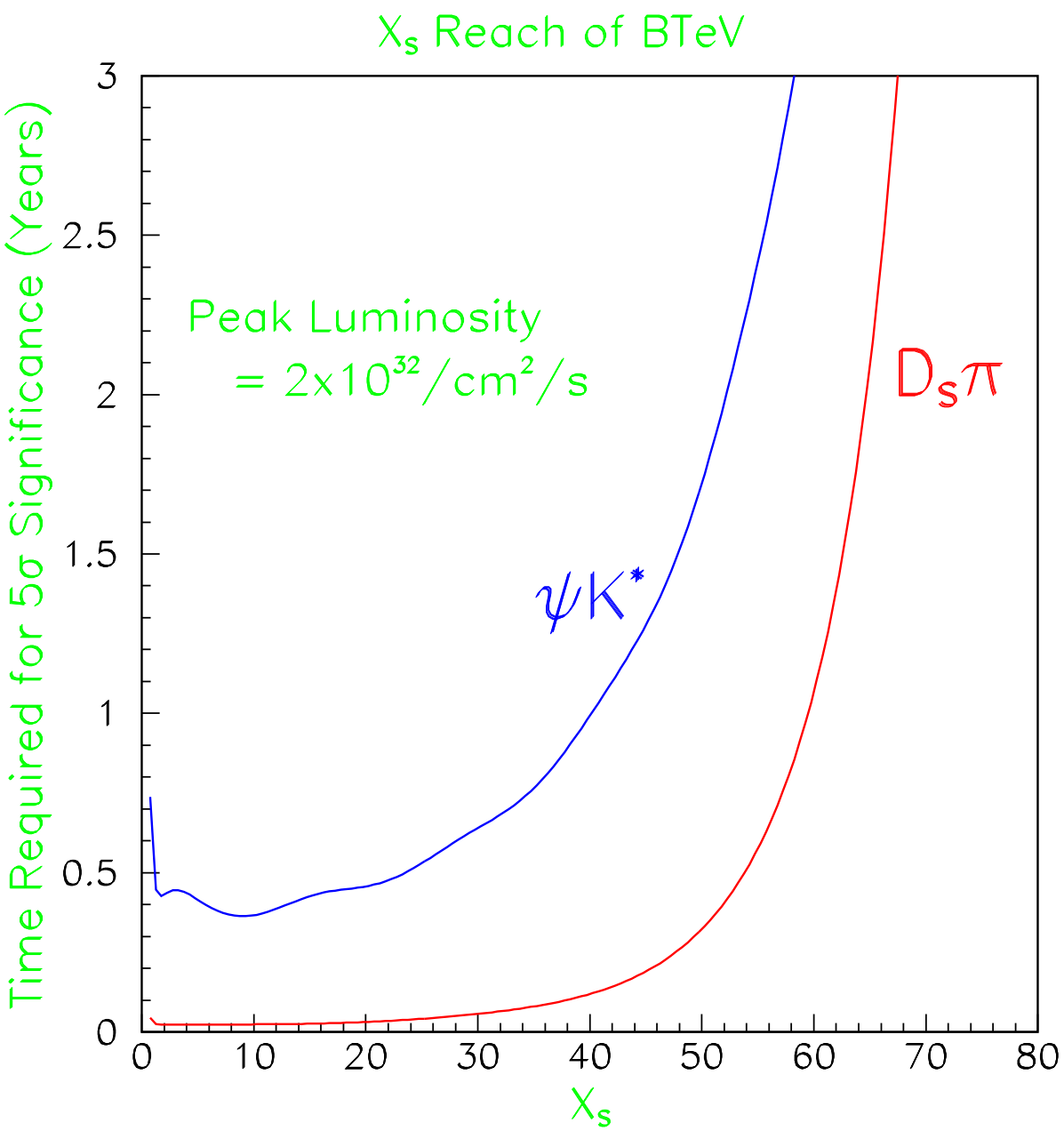
$$-\ln(\mathcal{L}(x)) \simeq -N \left\{ f_+ \int_{t_0}^{\infty} F_+(t;x_0) \ln(F_+(t;x)) dt - f_- \int_{t_0}^{\infty} F_-(t;x_0) \ln(F_-(t;x)) dt \right\}$$

- x_0 is the generated value of x.

"Analytic" Computation of the Likelihood Function



- Define a signficant observation when (asymptote-minimum)=(25.+6.25)/2.


X_s Reach of BTeV
Time Required for 5σ Significance (Years)
Peak Luminosity
= 2x10^{32}/cm^2/s
ψK^*
$D_s\pi$
X_s
0
0.5
1
1.5
2
2.5
3
0
10
20
30
40
50
60
70
80

Future Plans

- Use all of the tagging power.
- For Mini-MC incorporate a distribution of resolutions.

Will Not Have time Before $\simeq$May

- Improve S/B studies: more statistics and dirtier MC.
- Add $B_s \to D_s^- \pi^+ \pi^+ \pi^-$.
- Re-verify reach with ensemble of Mini-MC "experiments"?

Conclusions

- BTeV has an x_s reach of about 60 for one year of running.
- This comfortably covers the expected range.
- Lots of headroom remains.