An indirect SUSY search: $B_s^0 \to \mu^+\mu^-$

Fermilab Summer Intern Talks

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Introduction

BStntuple

Discriminating Variables for $B_s^0 \to \mu^+\mu^-$

Background Estimation

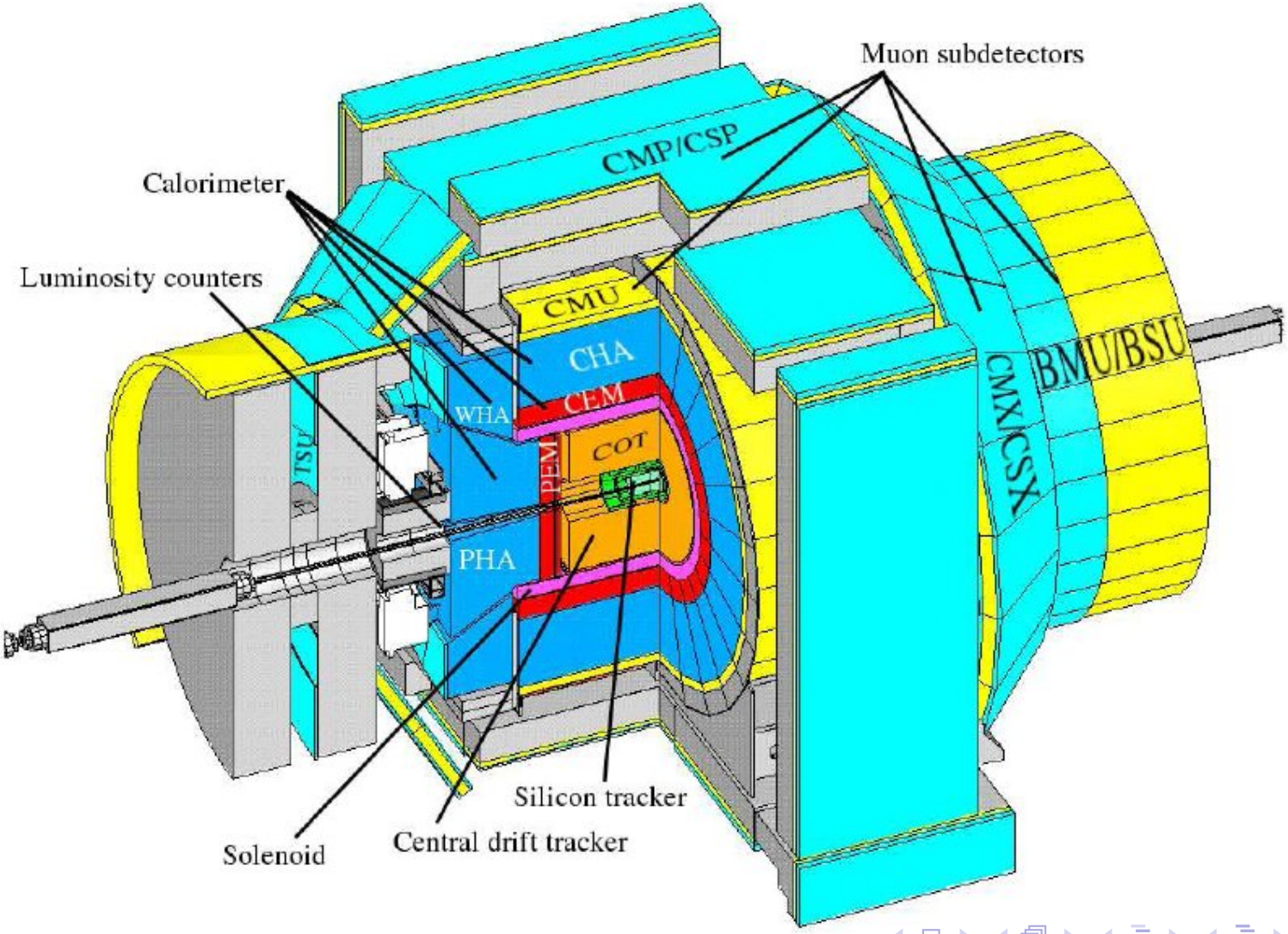
Conclusion

Why?

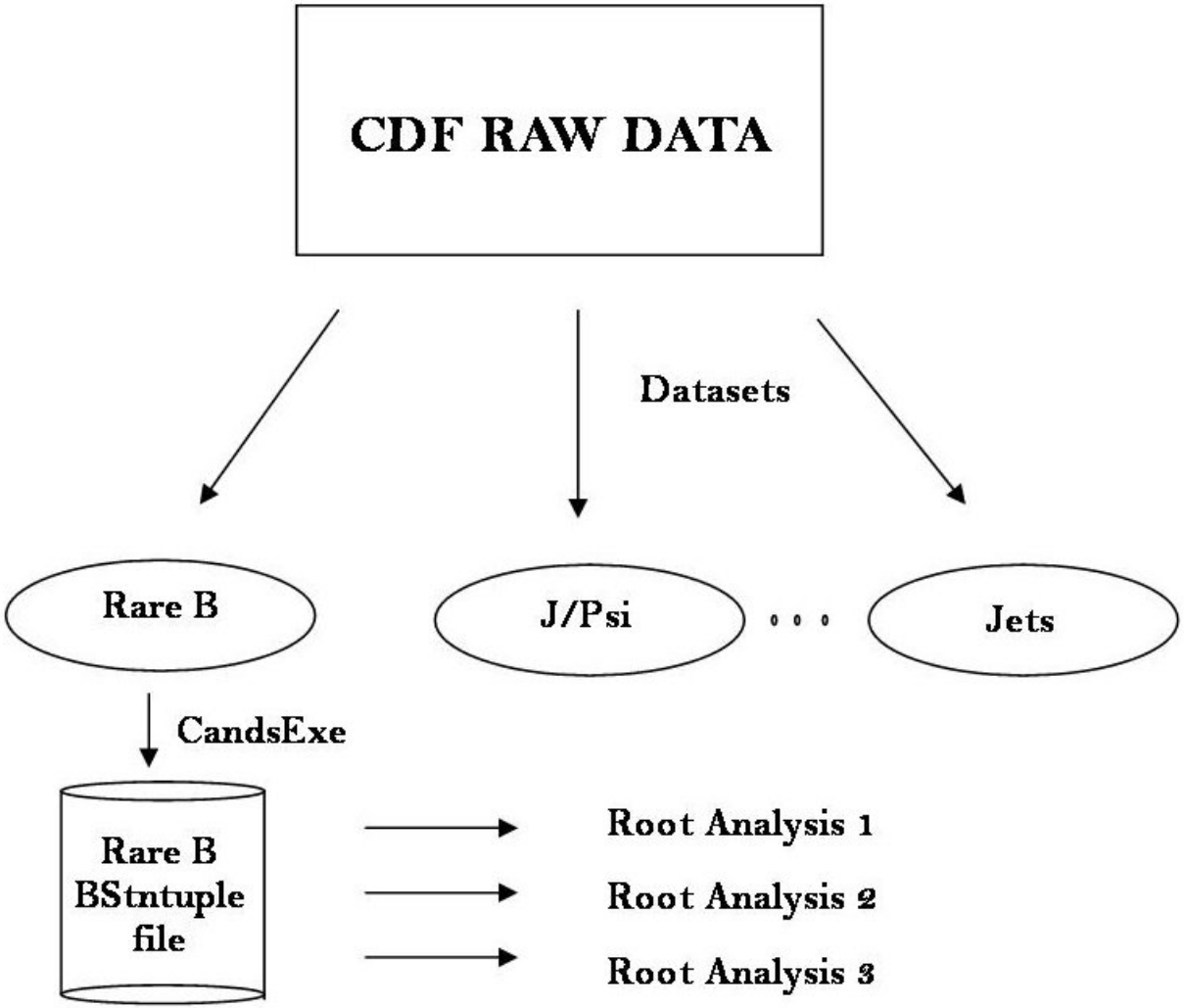
The SM was remarkebly successful over the last decades...
However: HIGGS, Dark Matter,... $\to$ New Physics beyond SM

- Flavor Changing Neutral Current (FCNC) decay $B_s^0 \to \mu^+\mu^-$ is highly suppressed in SM
- SM prediction $Br(B_s^0 \to \mu^+\mu^-) = (3.5 \pm 0.9) \times 10^{-9}$
- Branching Ratio significantly enhanced in many new physics models (e.g. SUSY)
- Observation of $B_s^0 \to \mu^+\mu^-$ @Tevatron would directly indicate new physics
- Pushing the limit $\to$ Constrain theorists

The CDF Detector



Concept


CDF RAW DATA
Datasets
Rare B
J/Psi
Jets
CandsExe
Rare B BStntuple file
Root Analysis 1
Root Analysis 2
Root Analysis 3

Rare B dataset

So far the B group has been using BStntuple for

- Hadronic dataset
- J/Ψ dataset

But we do not have the Rare B dataset processed...

- Using the exisisting J/Ψ `tcl` $\overset{created}{\longrightarrow}$ `rareB.tcl` file
- Validation of the Rare B dataset is still ongoing...

Decay Modes for Rare B dataset

These decay modes are included in the Rare B BStntuple:

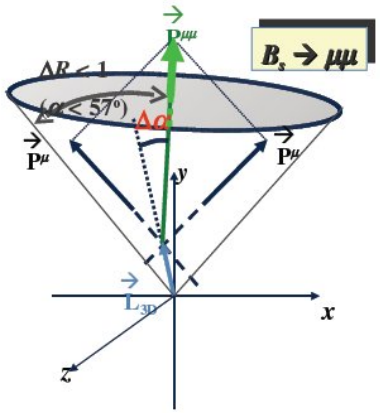
$J/\Psi \to \mu\mu$	$B^+ \to \mu\mu K$
$B^+ \to J/\Psi K^+$	$B^0 \to \mu\mu K^*$
$B^0 \to J/\Psi K^{*0}$	$B_s \to \mu\mu\Phi$
$B_s^0 \to J/\Psi\Phi$	$B_s \to \mu\mu$

Example of a decay mode in the *.tcl* file:

```
# B+ to Mu Mu K
module clone    D_SSS B-MMK
module enable   D_SSS-B-MMK
module talk     D_SSS-B-MMK
  source $env(ENV_TCL_DIR)/trigZero.tcl
  Cuts
    verbose     set 0
    reject      set 0
    massMin     set 3.0
    massMax     set 6.7
    chi2Max     set 50
    deltaZ0Max  set 5.0
    pvVersion   set $env(PRIMARY_VERTEX)
    pointType   set $env(POINTING_TYPE)
  exit
  D_SSS-B-MMK
    iS1CollDesc set Muons
    iS2CollDesc set Muons
    iS3CollDesc set All-Kaons
    oDCollDesc  set B-MMK
    pid         set 521
  exit
exit
```

$B_s^0 \to \mu^+\mu^-$ Signal vs Background Discrimination

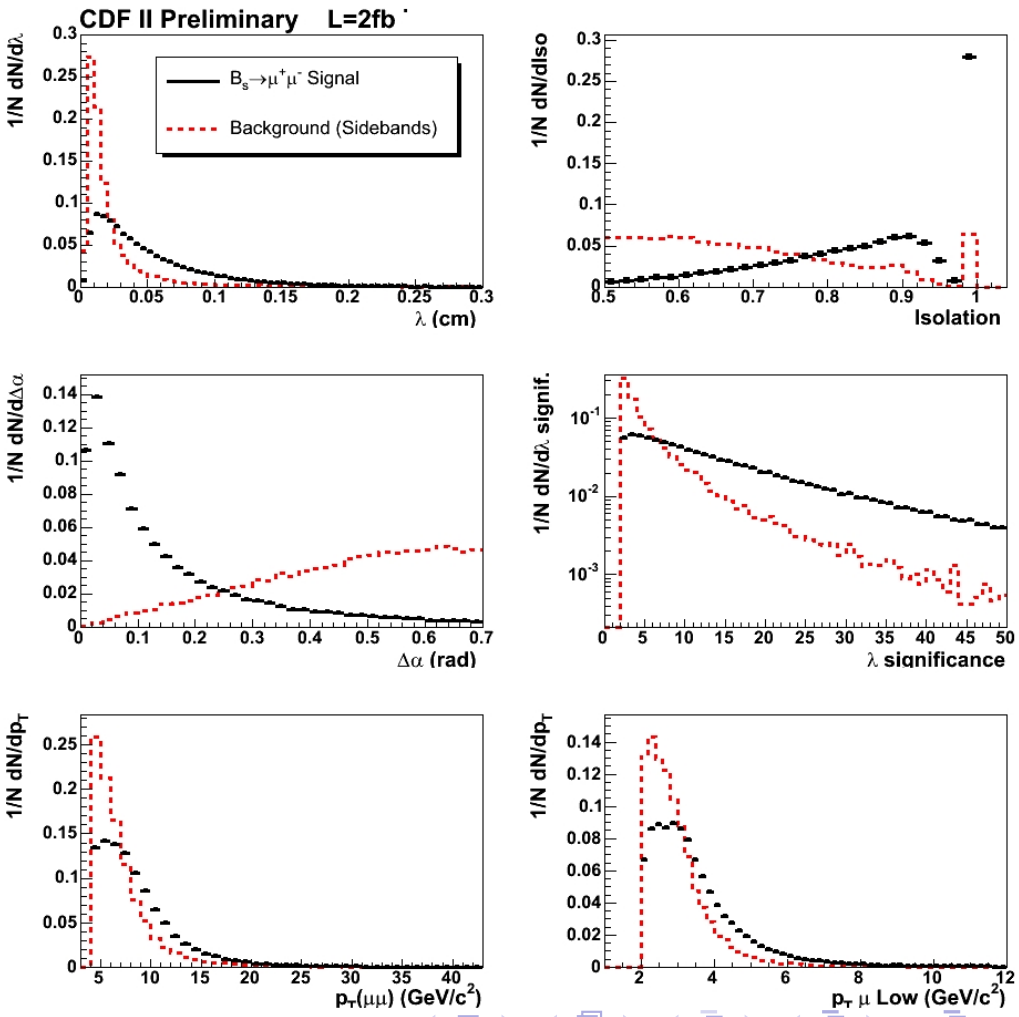
The Signal vs. Background Discrimination is done by a Neural Network based on 6 discriminating input variables:



1. λ - the proper decay length $\lambda = c\tau$
2. Isolation - Fraction of $p_T(B)$ in a cone of radius $\Delta R < 1.0$
3. Pointing $\Delta\alpha$ - angle between B_s mom. and decay axis
4. λ/σ_λ - λ significance
5. $p_T(\mu\mu)$ - transverse Momentum of B_s
6. $p_T^{low}(\mu)$ - low μ p_T

NN Input Distributions

- Signal from MonteCarlo
- Bkg from sidebands
- Good distinction Sign vs. Bkg

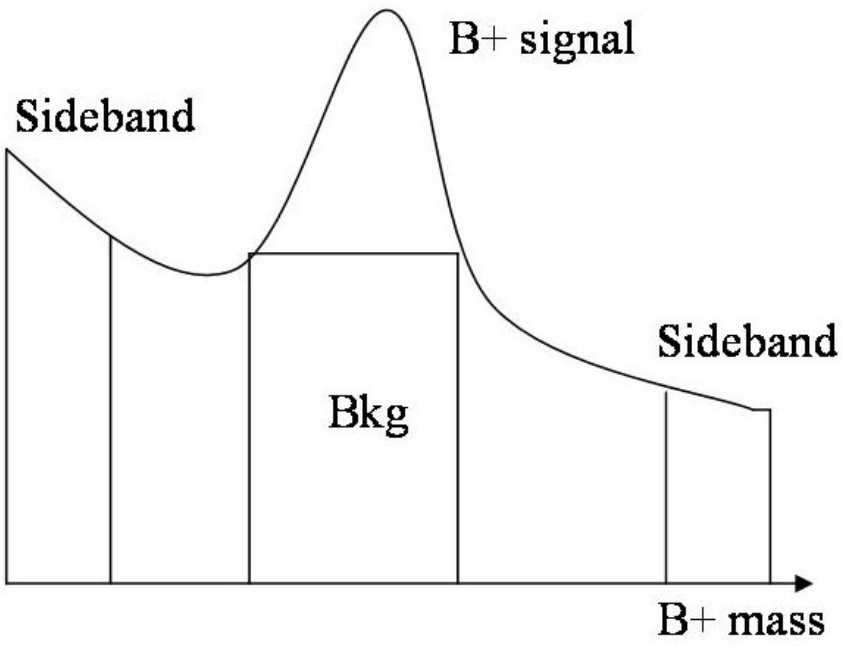


How well does Monte Carlo models Signal?

To check our B_s signal MC model we compare the NN distributions with a B^+ signal sample:

- Using $B^+ \to J/\Psi K^+$ as control sample
- B^+ signal window contains background

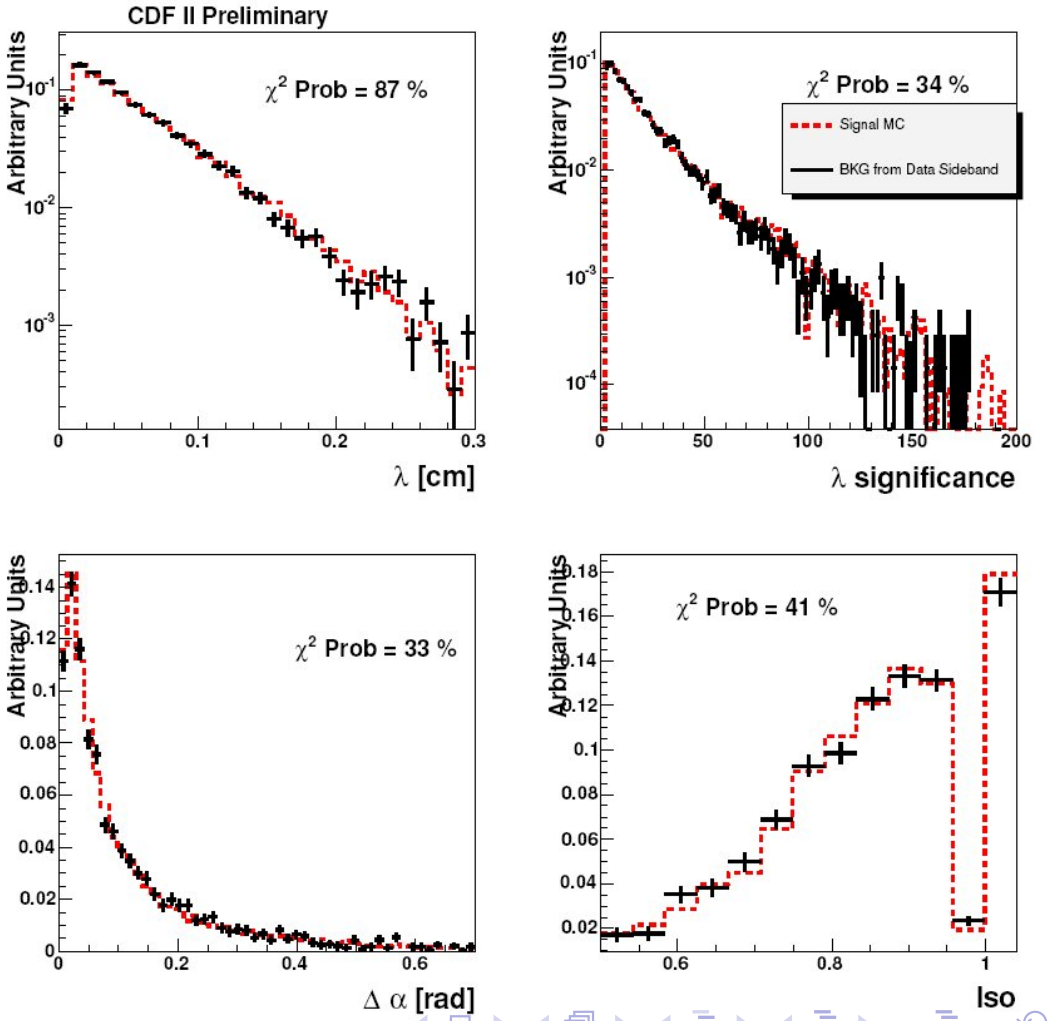
$\Rightarrow$ Use sideband subtraction method to obtain true signal distr.:



Crosscheck: Is the Monte Carlo correct?

To crosscheck our MC model:

- Compare B^+ signal MC with $B^+ \to J/\Psi K$ signal
- Good agreement!

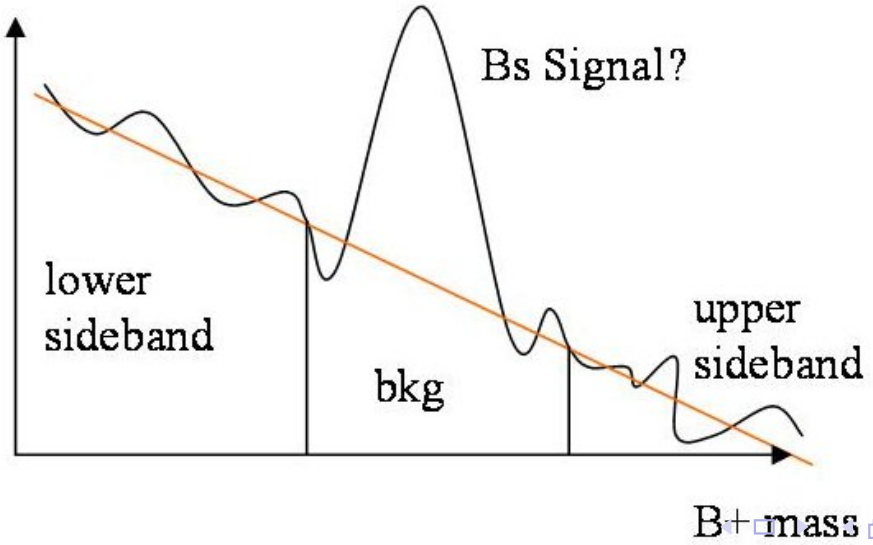


Background estimate for $B_s^0 \to \mu^+\mu^-$

Before looking into the signal region, we have to estimate the expected background events:

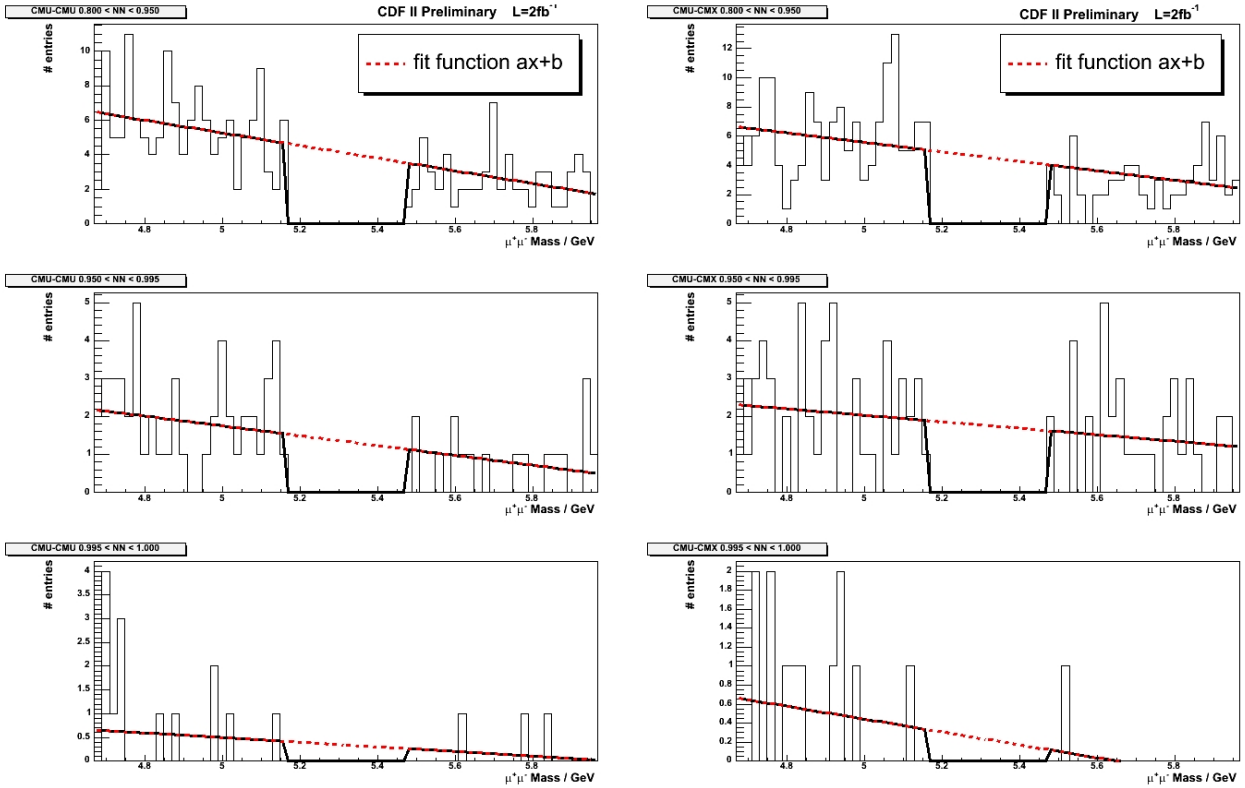
- We look at the $B_s^0 \to \mu^+\mu^-$ data excluding the signal region
- Perform polynomial fit (ax+b) over upper and lower sidebands
- Integration of the fit function over the signal region gives bkg events

Concept:



Background estimate & Systematical uncertainty study

- Divided each channel in 3 NN slices:
  $0.800 < NN_1 < 0.950 < NN_2 < 0.995 < NN_3 < 1.0$



The default for $0.995 < NN < 1.0$: flat line fit (low statistics)

Bkg Estimate Results

Integration of fit function ax+b gives us expected background events; listed for 5 mass bins in the signal window:

NNout/Massbins $[GeV]$:	$5.310 - 5.334$	$5.334 - 5.358$	$5.358 - 5.382$	$5.382 - 5.406$	$5.406 - 5.430$
$CMU : 0.800 - 0.950$	4.91 ± 0.34	4.80 ± 0.34	4.69 ± 0.33	4.59 ± 0.32	4.48 ± 0.32
$CMU : 0.950 - 0.995$	1.60 ± 0.19	1.57 ± 0.18	1.52 ± 0.18	1.49 ± 0.19	1.45 ± 0.18
$CMU : 0.995 - 1.000$	0.41 ± 0.10	0.39 ± 0.10	0.38 ± 0.09	0.36 ± 0.09	0.35 ± 0.09
$CMX : 0.800 - 0.950$	5.44 ± 0.36	5.34 ± 0.35	5.25 ± 0.35	5.16 ± 0.35	5.06 ± 0.34
$CMX : 0.950 - 0.995$	2.11 ± 0.22	2.08 ± 0.22	2.06 ± 0.22	2.04 ± 0.22	2.01 ± 0.22
$CMX : 0.995 - 1.000$	0.27 ± 0.09	0.25 ± 0.09	0.23 ± 0.09	0.21 ± 0.09	0.19 ± 0.09

In the $0.995 < NN < 1.0$ we expect:

≈ 1.9 events in the CMU-CMU channel and
≈ 1.2 events in the CMU-CMX channel!

3 months at Fermilab

- Broad overview over lab life and recent & future HEP activities
- Introduction into Accelerator-, Detectorphysics, Data Analysis
- Got to know a lot of interesting people from all over the globe

$\Rightarrow$ Thanks Cheng-Ju, thanks to Fermilab for making this possible