Azimuthal Asymmetries in Drell-Yan Lepto-Production in Early Stages at FAIR

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for the PANDA Collaboration

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The Nucleon Structure

Torino (Italy)
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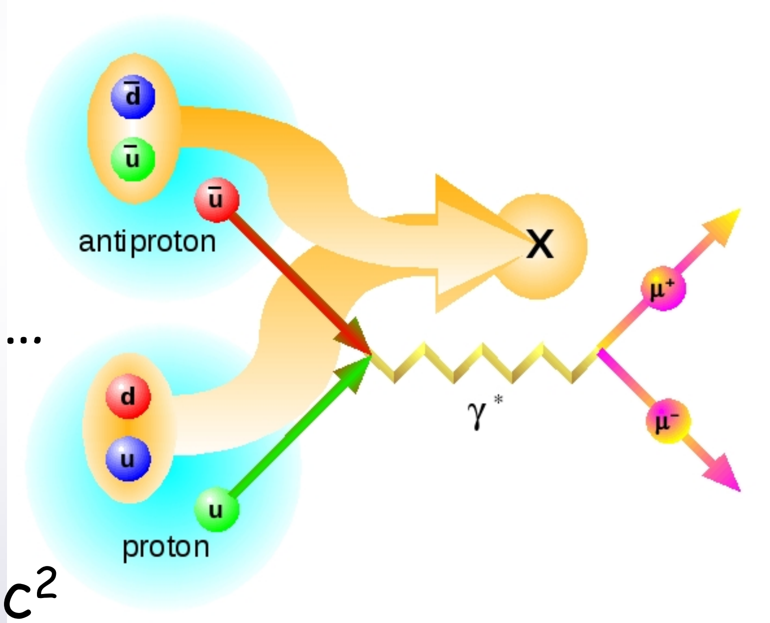
Overview

- Motivation
- Drell-Yan process and background
    - A. Bianconi Drell-Yan generator
    - Cut studies
- Investigation of Drell-Yan asymmetries
- Summary

Drell-Yan Process and Background

- Drell-Yan: $\bar{p}p \rightarrow \mu^+\mu^- X$

  cross section $\sigma \sim 1$ nb @ $s = 30$ GeV^2



- Background: $\bar{p}p \rightarrow \pi^+\pi^- X$, $2\pi^+2\pi^- X$,……

  cross section $\sigma \sim 20\text{-}30$ μb

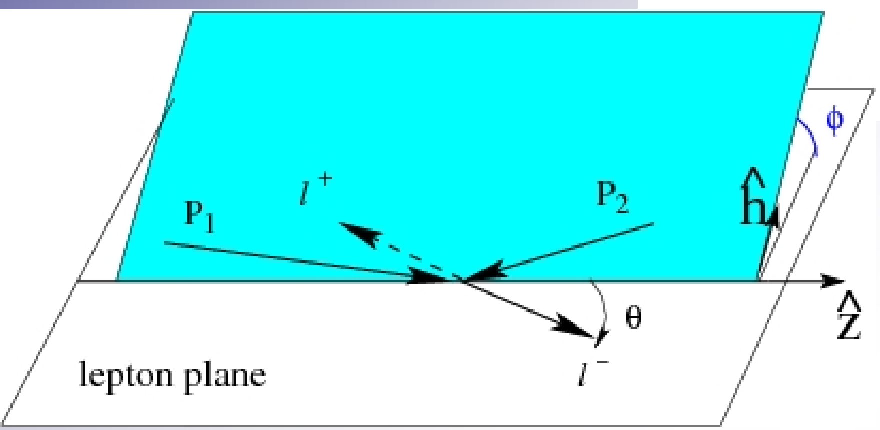
  $m_\mu = 105$ MeV/c^2; m_π 145 MeV/c^2

  average primary pion pairs: ~ 1.5

- Background studies: needed rejection factor of 10^7

Drell-Yan Asymmetries

Collins-Soper frame



UNPOLARISED

$$\frac{d\sigma^o}{d\Omega\, dx_1\, dx_2\, d\mathbf{q}_T} = \frac{\alpha^2}{12Q^2}\sum_f e_f^2 \Big\{ (1+\cos^2\theta)\,\mathcal{F}\left[\bar{f}_1^f\, f_1^f\right] + f\,\sin^2\theta\,\cos 2\phi\,\mathcal{F}\left[\left(2\hat{\mathbf{h}}\cdot\mathbf{p}_{1T}\,\hat{\mathbf{h}}\cdot\mathbf{p}_{2T} - \mathbf{p}_{1T}\cdot\mathbf{p}_{2T}\right)\frac{\bar{h}_1^{\perp f}\, h_1^{\perp f}}{M_1 M_2}\right]\Big\}$$

SINGLE-POLARISED

$$\frac{d\sigma}{d\Omega\, dx_1\, dx_2\, d\mathbf{q}_T} = \frac{d\sigma^o}{d\Omega\, dx_1\, dx_2\, d\mathbf{q}_T} + \frac{d\Delta\sigma^\uparrow}{d\Omega\, dx_1\, dx_2\, d\mathbf{q}_T}$$

$$\frac{d\Delta\sigma^\uparrow}{d\Omega\, dx_1\, dx_2\, d\mathbf{q}_T} = \frac{\alpha^2}{12sQ^2}\sum_f e_f^2\,|\mathbf{S}_{2T}|\Big\{ (1+\cos^2\theta)\,\sin(\phi-\phi_{S_2})\,\mathcal{F}\left[\hat{\mathbf{h}}\cdot\mathbf{p}_{2T}\,\frac{\bar{f}_1^f\, f_{1T}^{\perp f}}{M_2}\right] - \sin^2\theta\,\sin(\phi+\phi_{S_2})\,\mathcal{F}\left[\hat{\mathbf{h}}\cdot\mathbf{p}_{1T}\,\frac{\bar{h}_1^{\perp f}\, h_{1T}^f}{M_1}\right] - \sin^2\theta\,\sin(3\phi-\phi_{S_2})\,\mathcal{F}\left[\left(4\hat{\mathbf{h}}\cdot\mathbf{p}_{1T}\,(\hat{\mathbf{h}}\cdot\mathbf{p}_{2T})^2 - 2\hat{\mathbf{h}}\cdot\mathbf{p}_{2T}\,\mathbf{p}_{1T}\cdot\mathbf{p}_{2T} - \hat{\mathbf{h}}\cdot\mathbf{p}_{1T}\,\mathbf{p}_{2T}^2\right)\frac{\bar{h}_1^{\perp f}\, h_{1T}^{\perp f}}{2M_1 M_2^2}\right]\Big\}$$

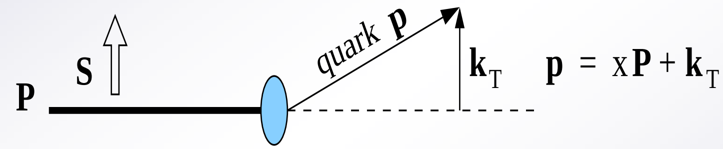
$U = N(\cos 2\varphi > 0)$

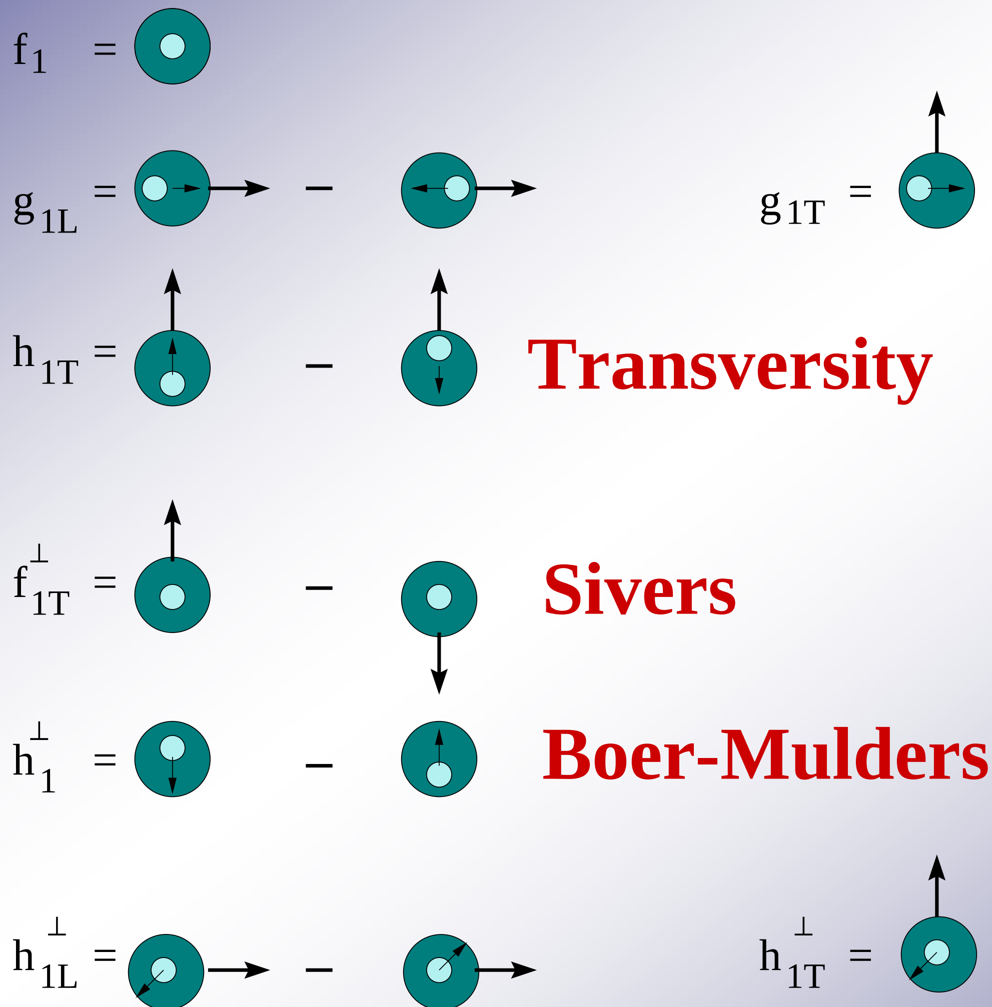
$D = N(\cos 2\varphi < 0)$

Asymmetry $A = \frac{U-D}{U+D}$

TMD: K_T-dependent Parton Distributions

Twist-2 PDFs $f_1(x) = \int d^2k_T\, f_1(x, k_T)$

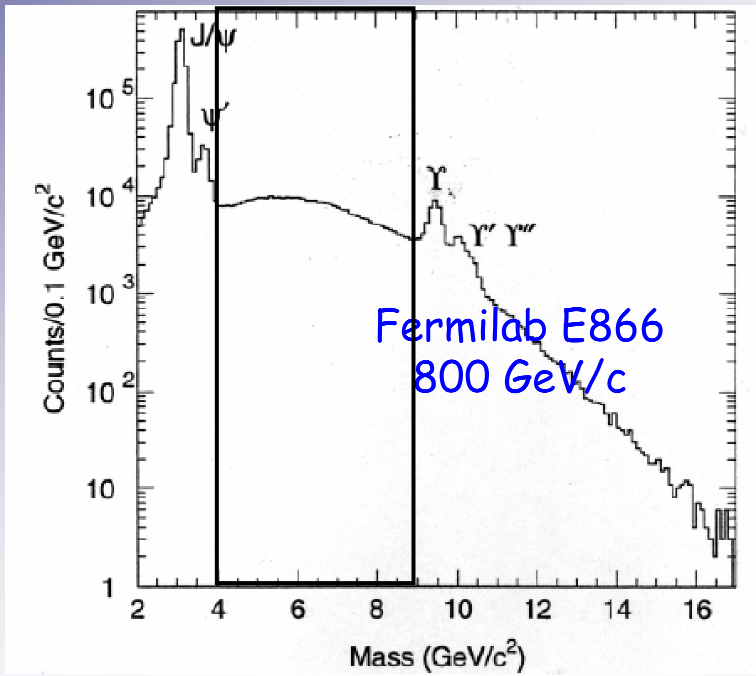


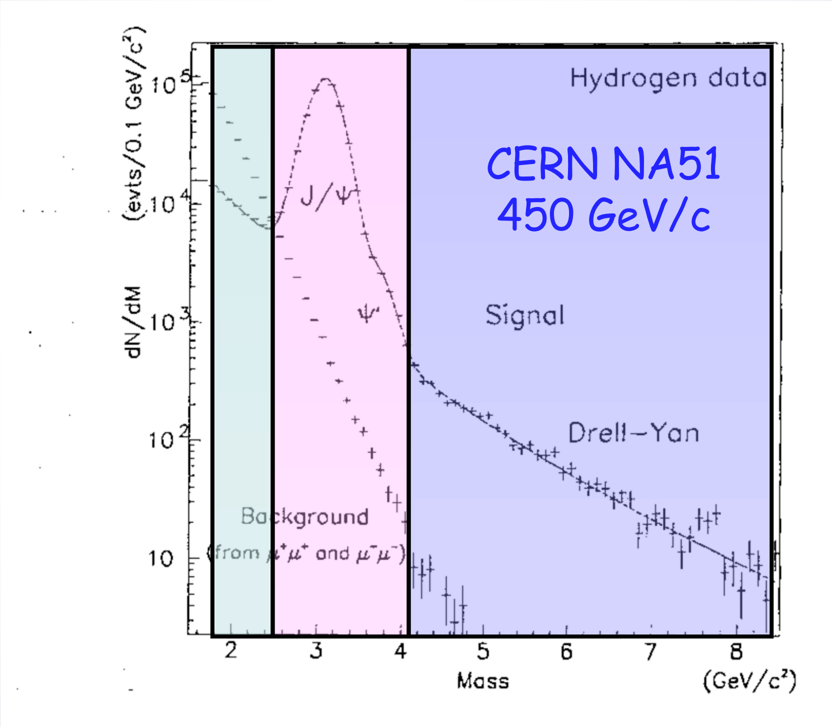


Distribution functions		Chirality even	Chirality odd
Twist-2	U	f_1	$h_1^{\perp}$
	L	g_1	$h_{1L}^{\perp}$
	T	$f_{1T}^{\perp}, g_{1T}$	$h_1, h_{1T}^{\perp}$

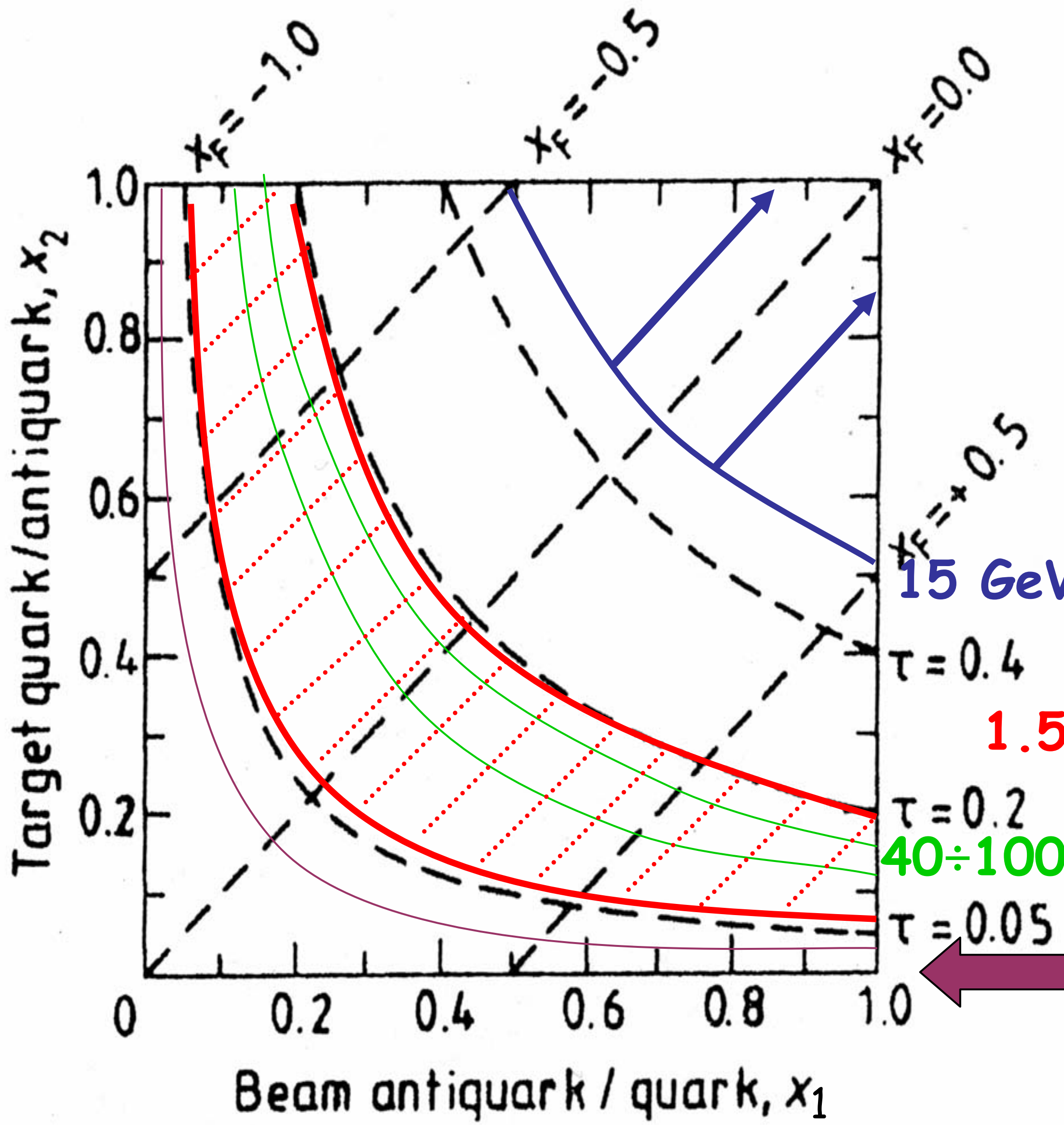
Di-Lepton Production

$\bar{p}p \to l^+l^-X$





Phase space for Drell-Yan processes



$x_{1,2}$ = mom fraction of parton$_{1,2}$

$\tau = x_1 \cdot x_2$

$x_F = x_1 - x_2$

τ = const: hyperbolae

x_F = const: diagonal

15 GeV/c ← PANDA/PAXfix

$1.5 \text{ GeV/c}^2 \leq M_{\mu\mu} \leq 2.5 \text{ GeV/c}^2$

40÷100 GeV/c ← PAX @ HESR

← symmetric HESR collider

A. Bianconi Drell-Yan Generator for $\bar{p}p$

- Antiproton beam
- Polarized/Unpolarized beam and target
- Drell-Yan cross section from experimental data
- Selects event depending on the variables:

  $x_1, x_2, P_T, \vartheta, \varphi, \varphi_S$

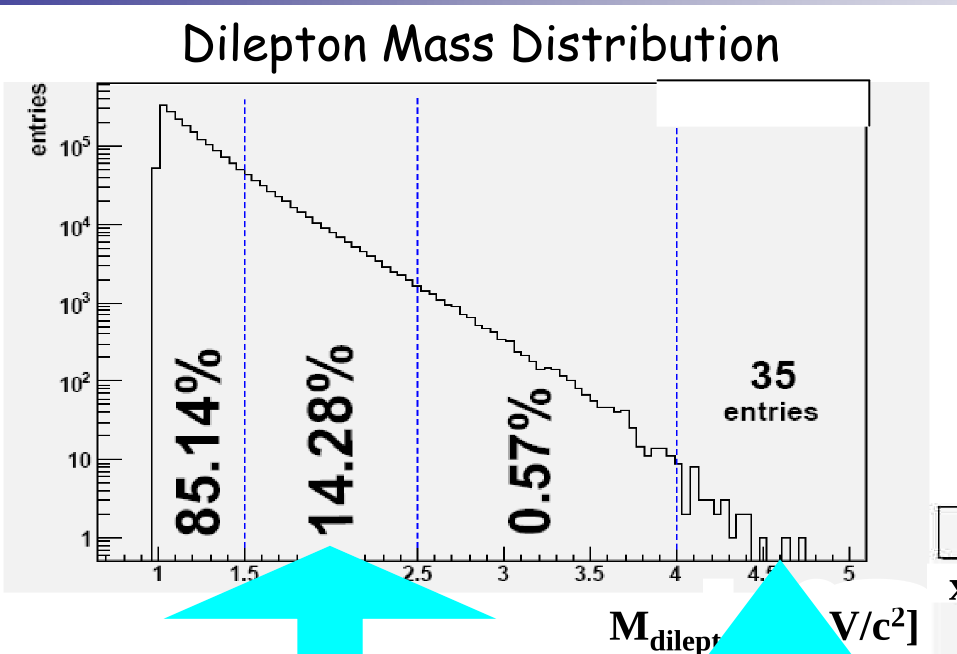
  from a flat distribution
- Cross section: $$\frac{d\sigma}{dx_1 dx_2 dP_T d\Omega} = \frac{K}{S} \cdot S(x_1, x_2) \cdot S'(P_T) \cdot A(\vartheta, \varphi, \varphi_S)$$

A. Bianconi, *Monte Carlo Event Generator DY_AB4 for Drell-Yan Events with Dimuon Production in Antiproton and Negative Pion Collisions with Molecular Targets, internal note (PANDA collaboration)*

A. Bianconi, M. Radici, *Phys. Rev.* **D71**, 074014 (2005) & **D72**, 074013 (2005)

DY @ 15 GeV/c — $\bar{p}p \to \mu^+\mu^- X$

$\sqrt{s} = 5.5$ GeV



A. Bianconi Drell-Yan Generator [1]

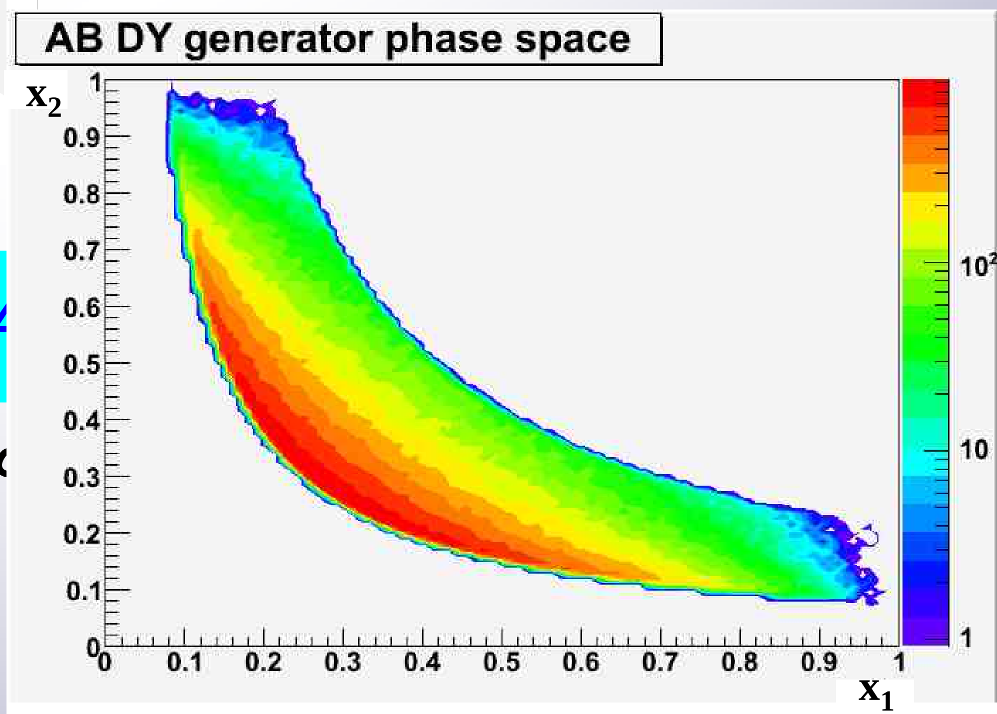
- layout studies for muon id with ABDYG (1.5 MEv)

Focus o… one

$\sigma^0_{4\leq M\leq 9} \sim 0.4$…

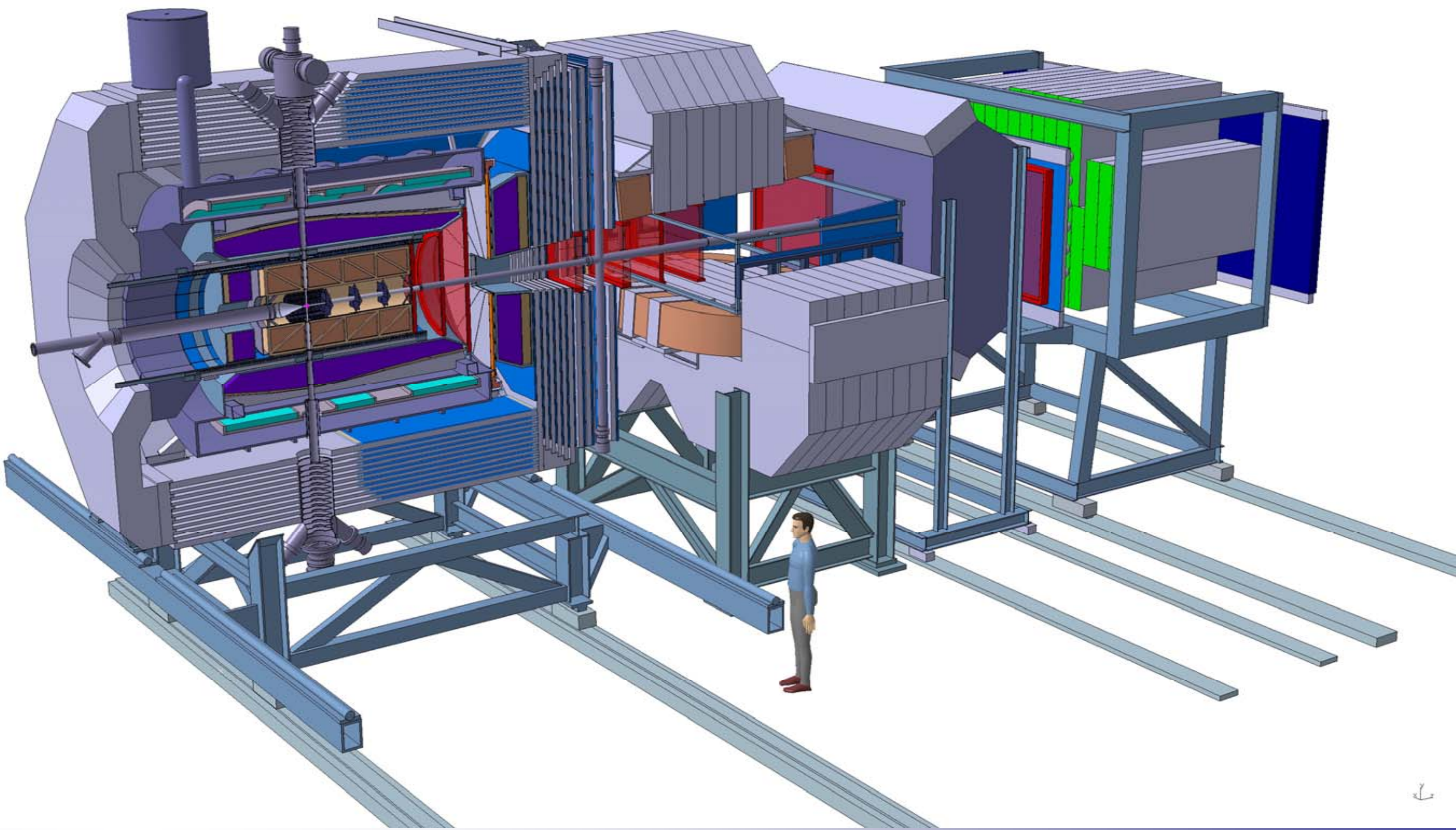
1.5 MEv i… .5 < M < 2.5 (GeV/c…

$\sigma^0_{1.5\leq M\leq 2.5} \sim 0.8$ nb

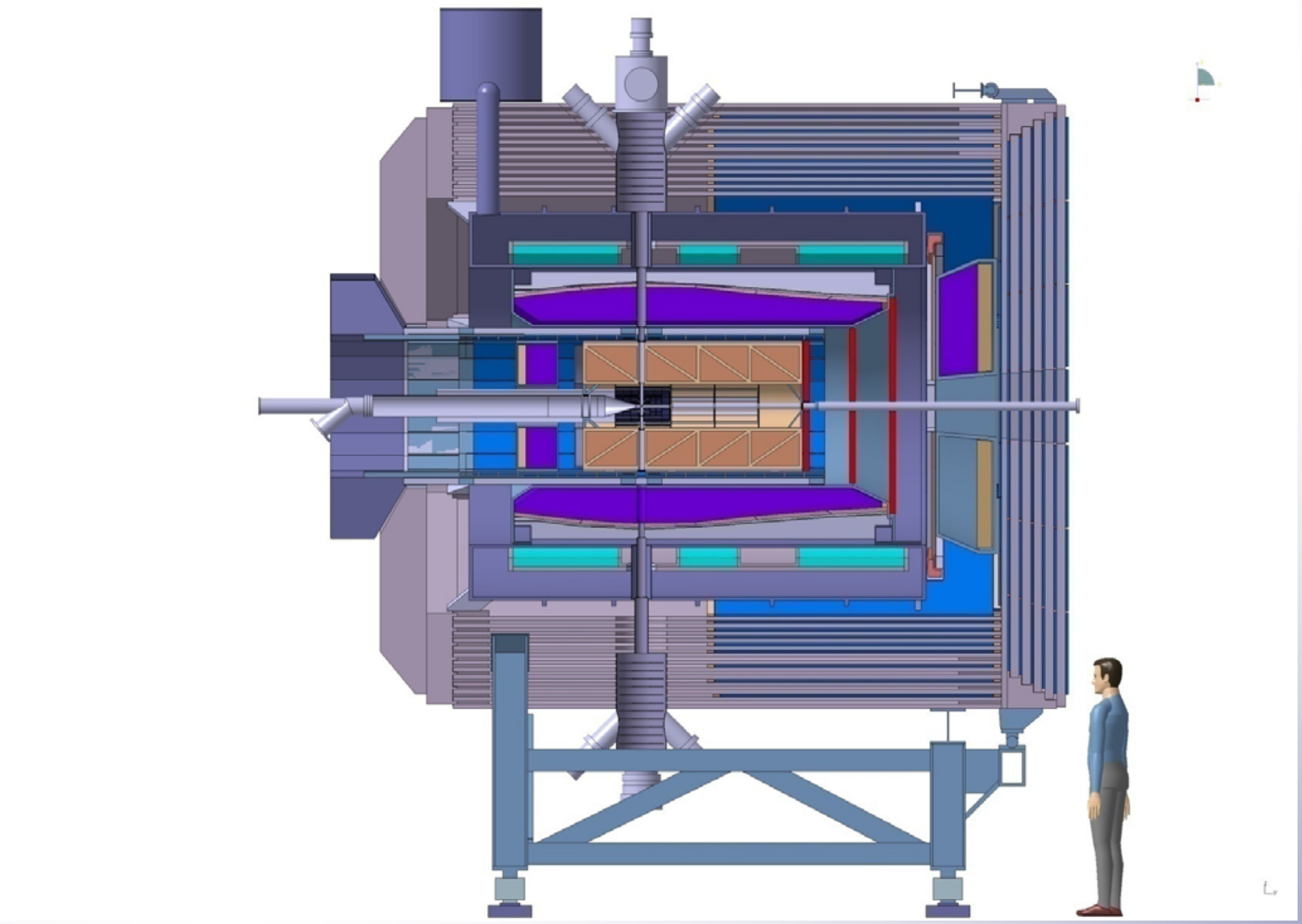


[1]A. Bianconi and M. Radici, Phys. Rev. D71 (2005) 074014

PANDA Detector Setup Design



PANDA Detector Setup Design



Signal: A. Bianconi Drell-Yan generator

Background: PYTHIA8 generator

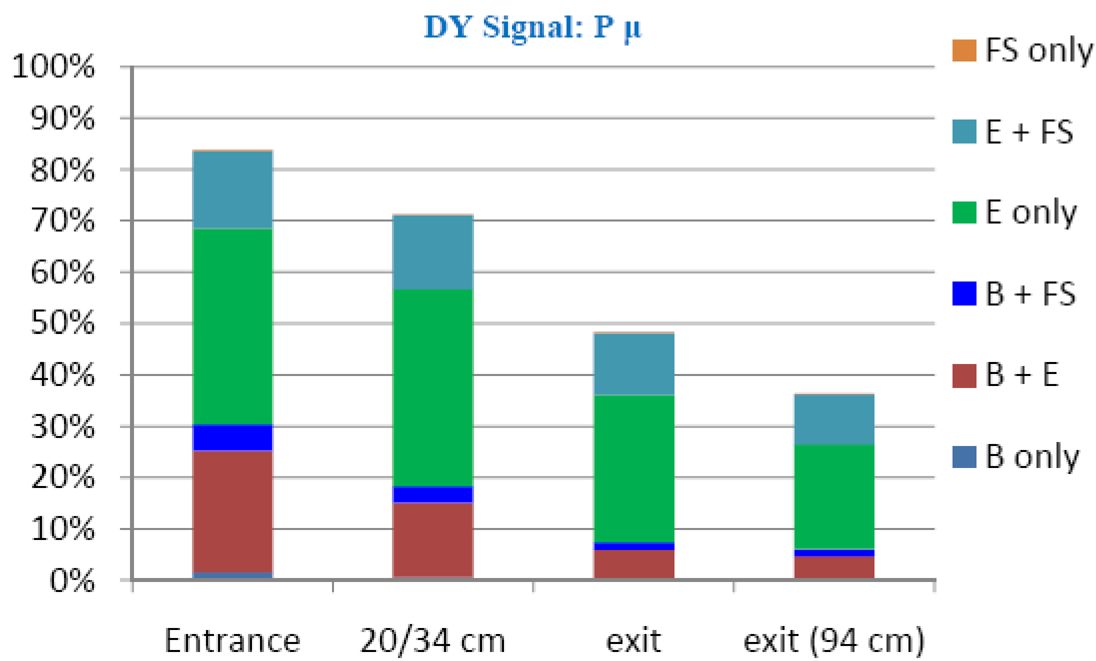
Framework: Muon Independent Simulation Software (MISS)

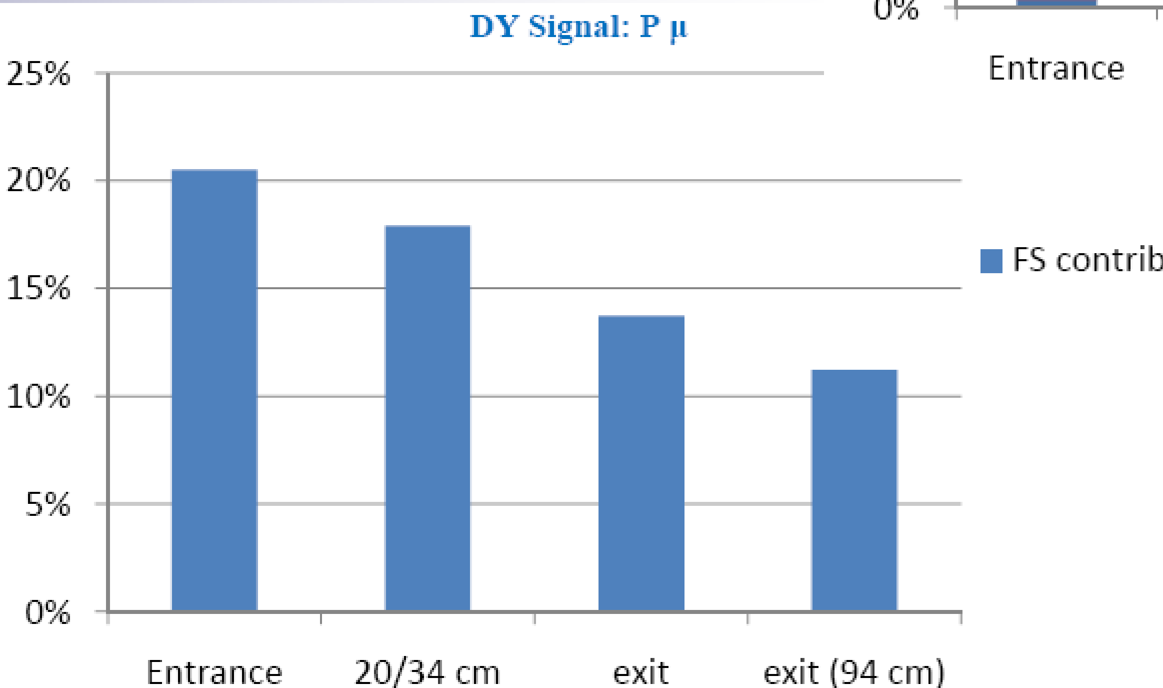
Next step: complete the work in PANDAROOT

ABDYG Signal Distribution

Most of the signal composed of two muons in the ENDCAP

Smaller contribution from B+E couples





Contributions from the FS region are not negligible

Background and Cuts

Sources of background

- Primary background: Primary π & Secondary μ from Primary π
- Secondary background: Secondary π & Secondary μ from Secondary π

Cuts and their effect on signal

Rejection factor of 10^7

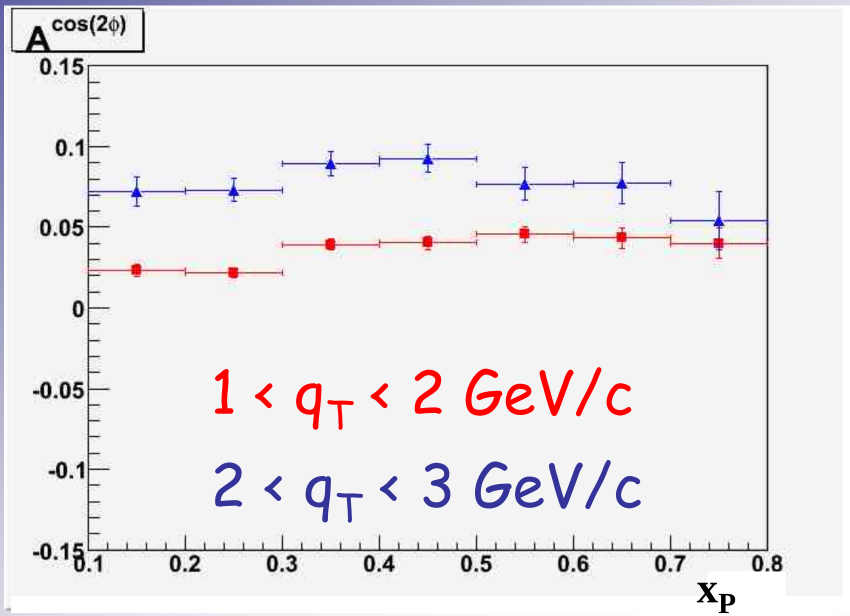
	Iron	At least 1 hit in the first 2 layers	$q_T > 0.75$ GeV/c
Signal	Linear rejection	Reject 30% of ... al	~ 35% of the signal is reconstructed
Primary Background		$\approx 10^3$	Rejection $\approx 10^4$
Secondary Background	Almost no effect	Rejection $\approx 10^4$	Rejection $>5 \cdot 10^6$

Next Step:

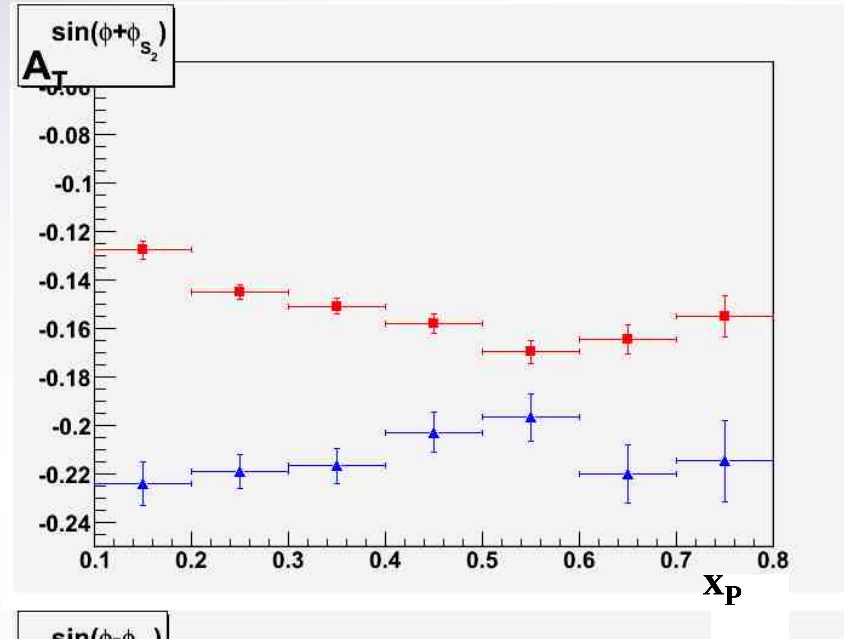
Kinematic refit

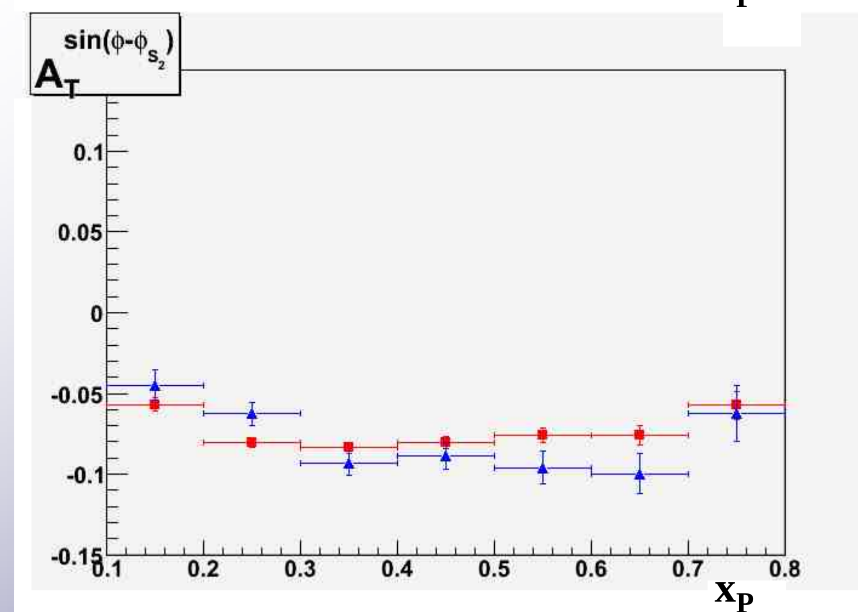
DY Asymmetries @ Vertex

UNPOLARISED



SINGLE-POLARISED



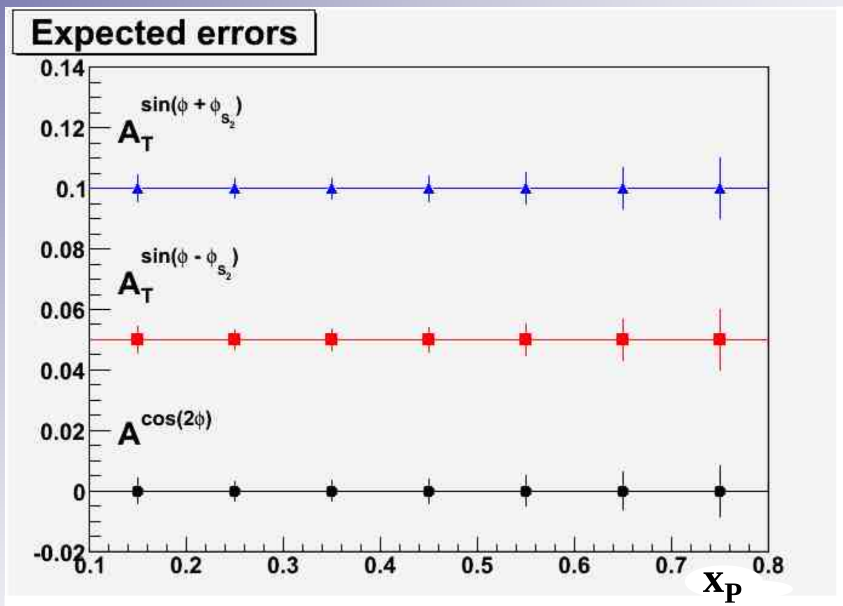


500KEv included in asymmetries

Acceptance corrections crucial!

DY Asymmetries @ B(20cm)-E(34cm)

Statistical errors for 500KEv generated

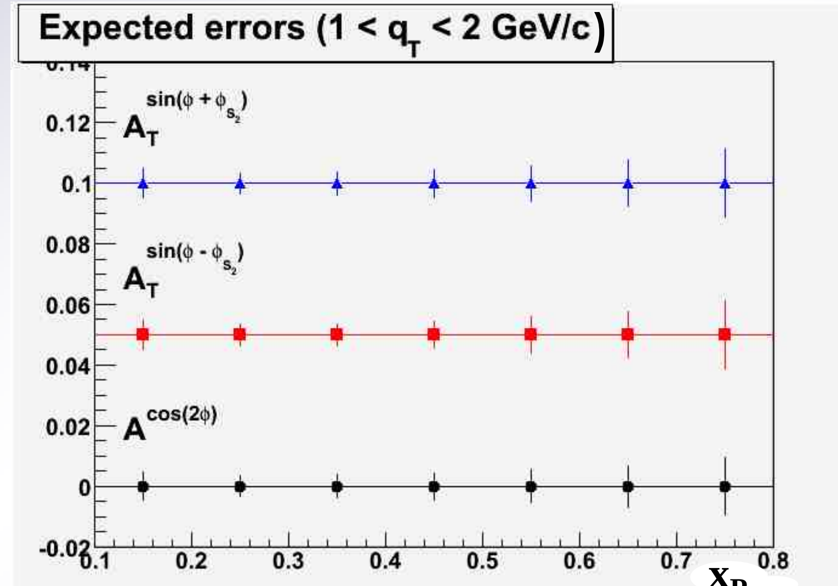


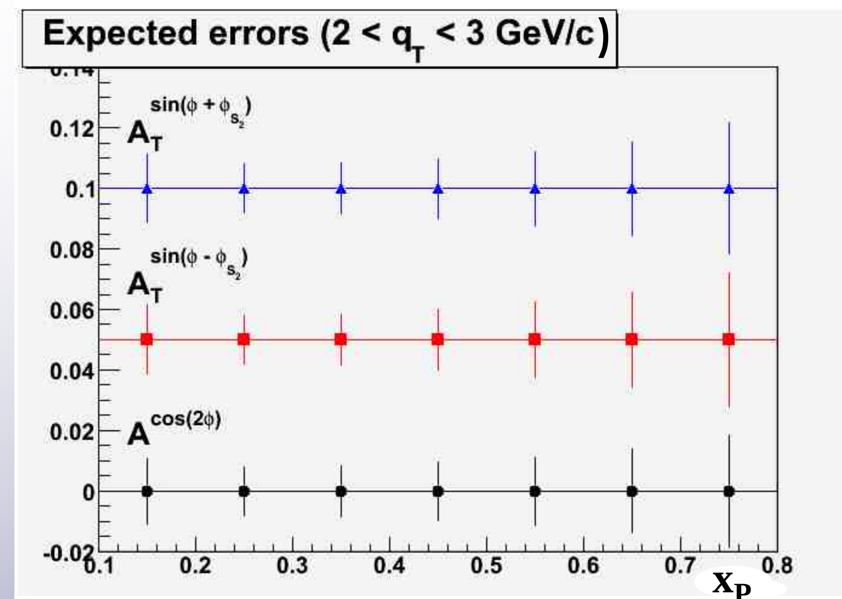
$R = L \cdot \sigma \cdot \varepsilon$

$= 2 \cdot 10^{32} cm^{-2} s^{-1} \times$

$\times\ 0.8 \cdot 10^{-33} cm^{2} \times 0.33$

$= 0.05\ s^{-1}$ ~ 130 Kev/month





Summary

- Interest on Drell-Yan studies
  - $1.5 < M_{\mu\mu} < 2.5$ GeV/c^2
  - Cuts for background rejection

Rejection factor achieved for secondary background: $> 5\ 10^6$

Kinematically constrained refit still to be investigated

- Few months of data taking are enough to:
  - ➢ evaluate unpolarised and single-spin asymmetries with good accuracy ⇒ investigate their dependence on $q_{T,\mu\mu}$

- Extensive simulations needed on the GRID ($\sim 10^8$ Ev) with PANDAROOT in order to:
  - check rejection factor
  - set kinematic cuts

Summary

- $B_{20cm\ Fe} \times E_{34cm\ Fe}$ rejection factors with
  - $q_{T,\mu\mu} > 0.75$ GeV/c
  - reaction vertex in the target region
  - $1.5 < M_{\mu\mu} < 2.5$ GeV/c^2
  - kinematically constrained refit still to be investigated

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  - check rejection factor
  - set kinematic cuts

MISS

(credits G.C. Serbanut)

Muon Independent Simulation Software

- Pure GEANT4 simulation

  ROOT used for storage and plots

- Geometry:

  magnet design: nov-dec 2007 release

  magnetic field: Genova design

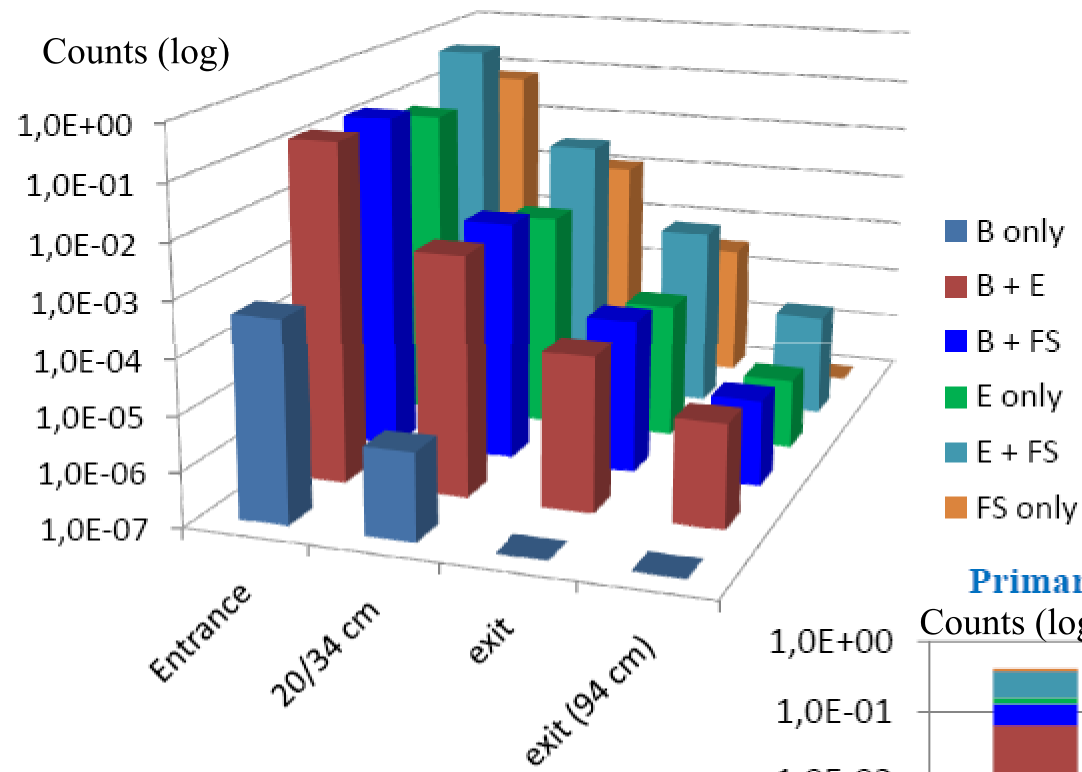
- Muon Detector: 1 layer each 2cm of iron

  Sensible volumes filled with Ar+CO_2

- Results presented in the Physics Book

Hadronic Background Distribution

Primary Background Rejection: Pπ + Pπ→Sμ — Fe only

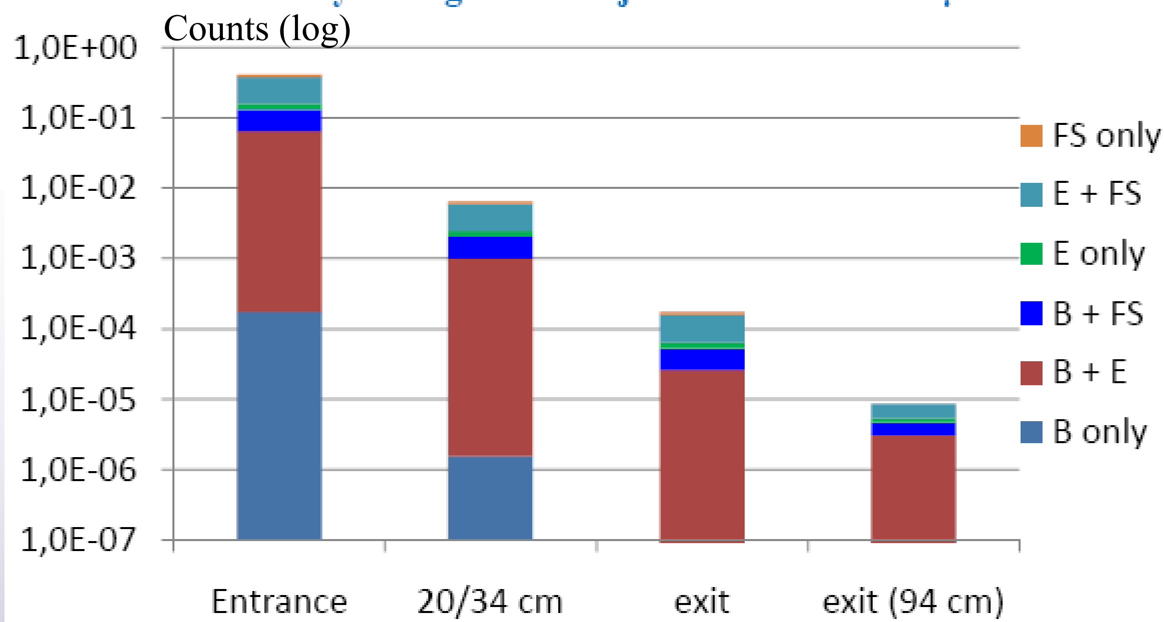


Primary Background

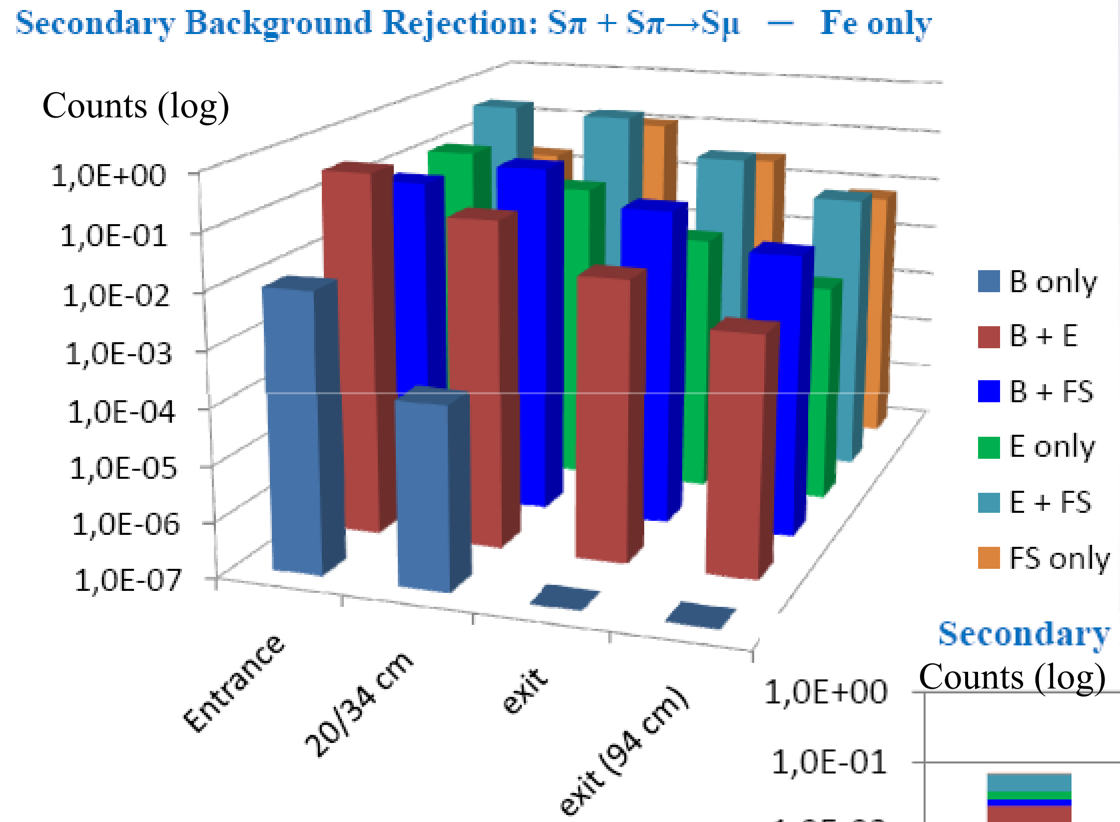
Regular rejection as expected

Rejection not sufficient

Primary Background Rejection: Pπ + Pπ→Sμ



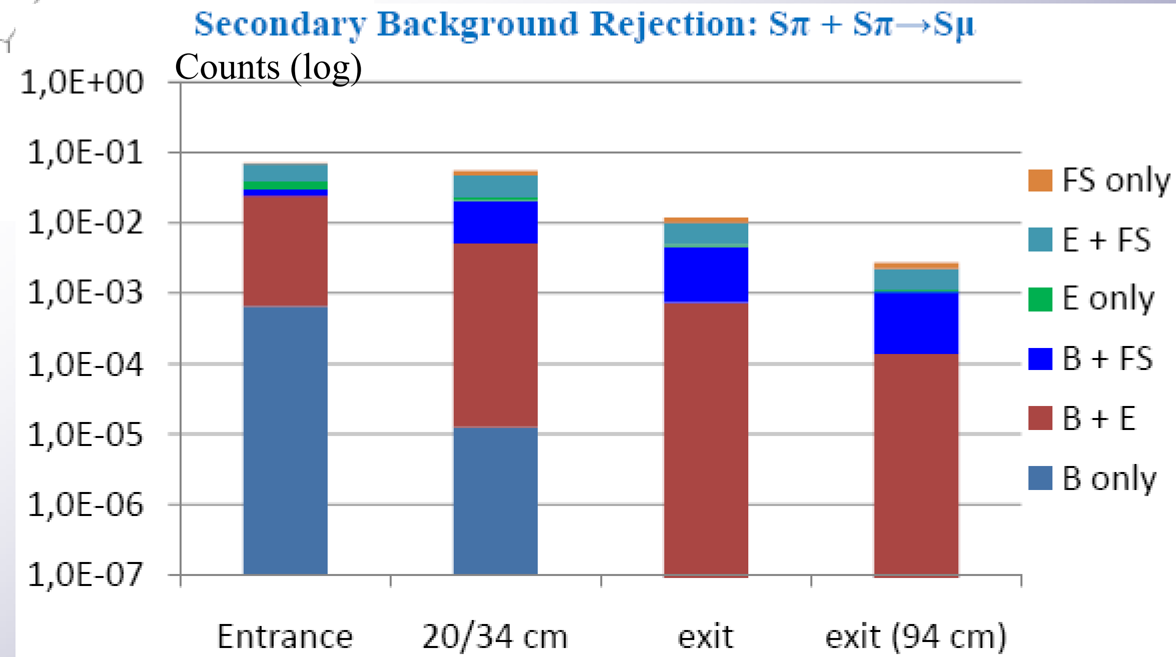
Hadronic Background Distribution



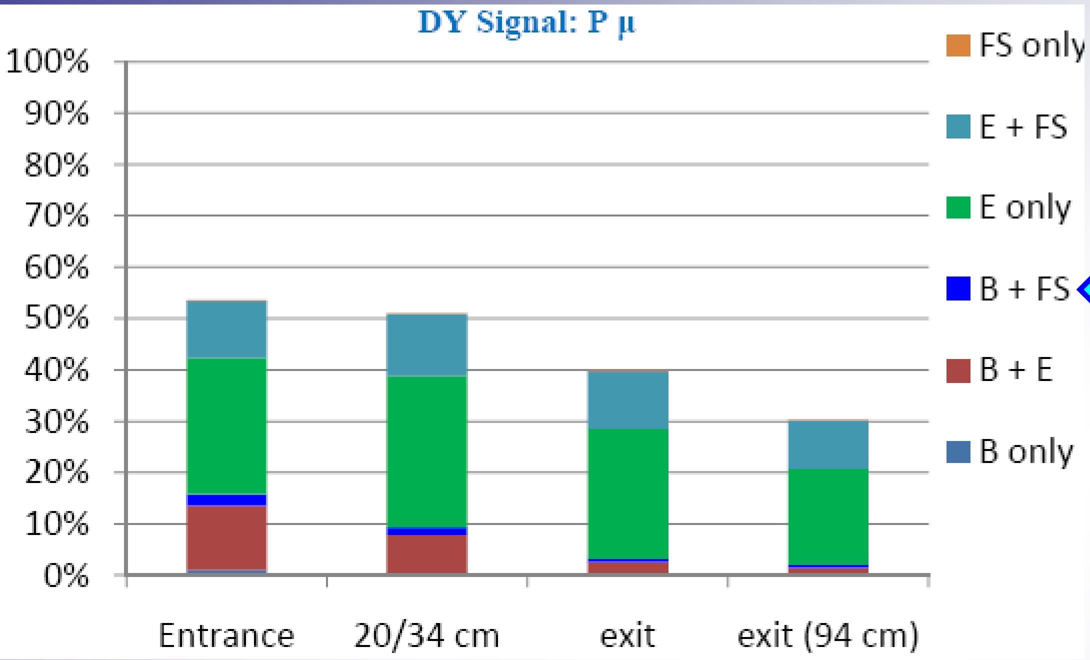
Secondary Background

Almost no effect

Almost no rejection



ABDYG Signal Distribution



$1.5 < M_{\mu\mu} < 2.5\ GeV/c^2$

Very tough requirements on track lenght

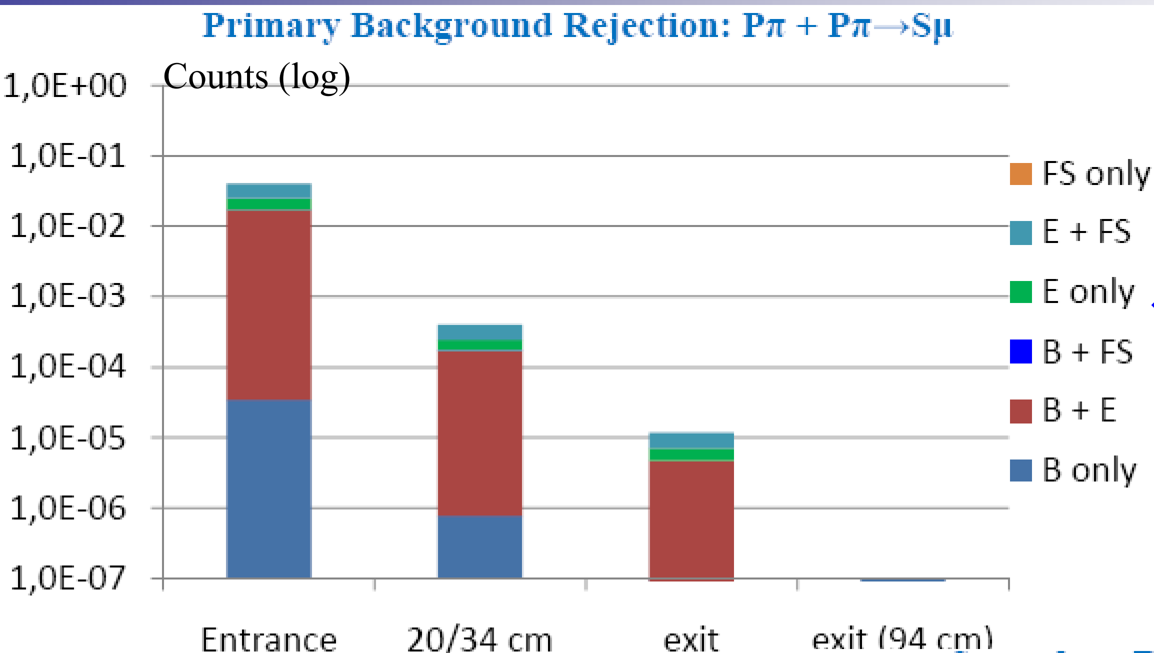
Kinematic cut:

At least 1 hit in the first 2 layers

↓

Cut of signal

Hadronic Background Distribution



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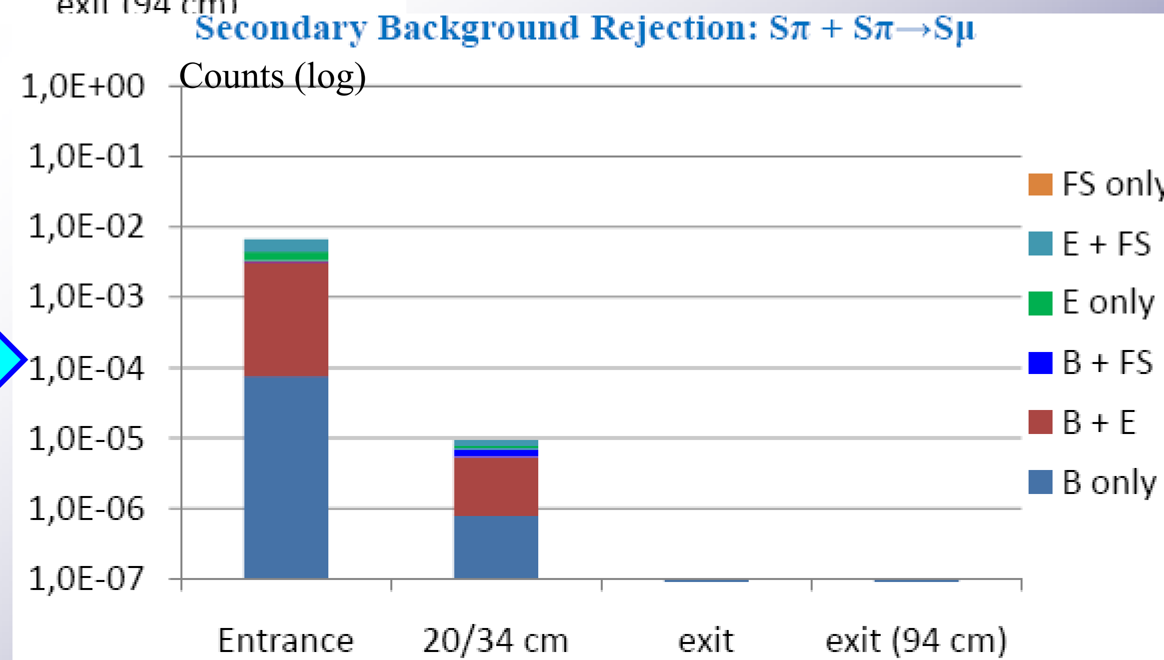
Very tough requirements on track lenght



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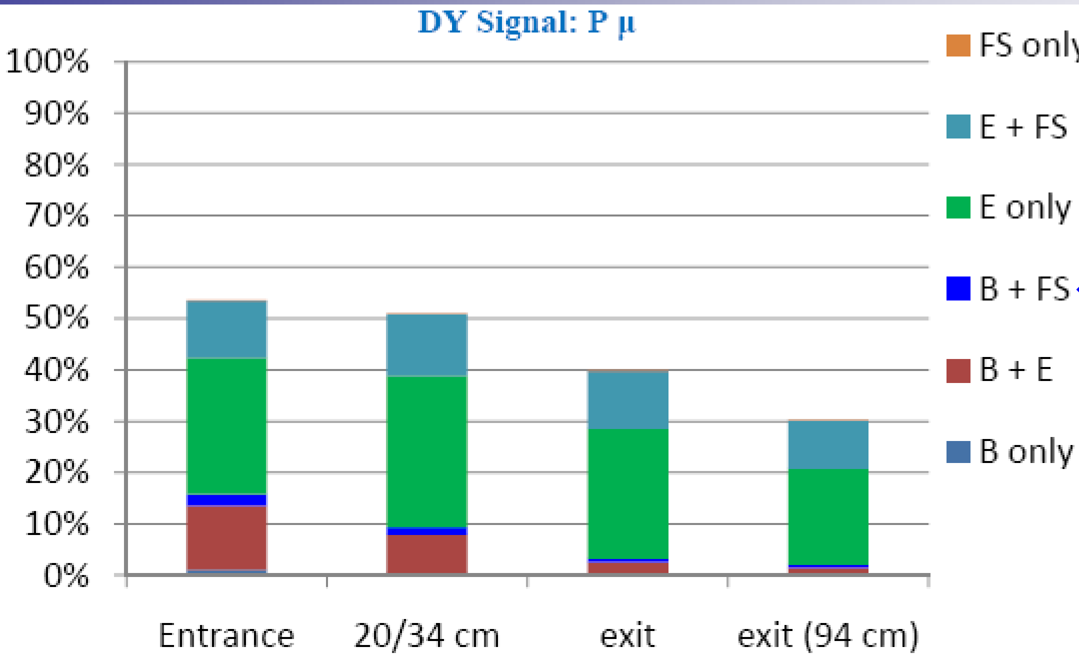
ABDYG Signal Distribution



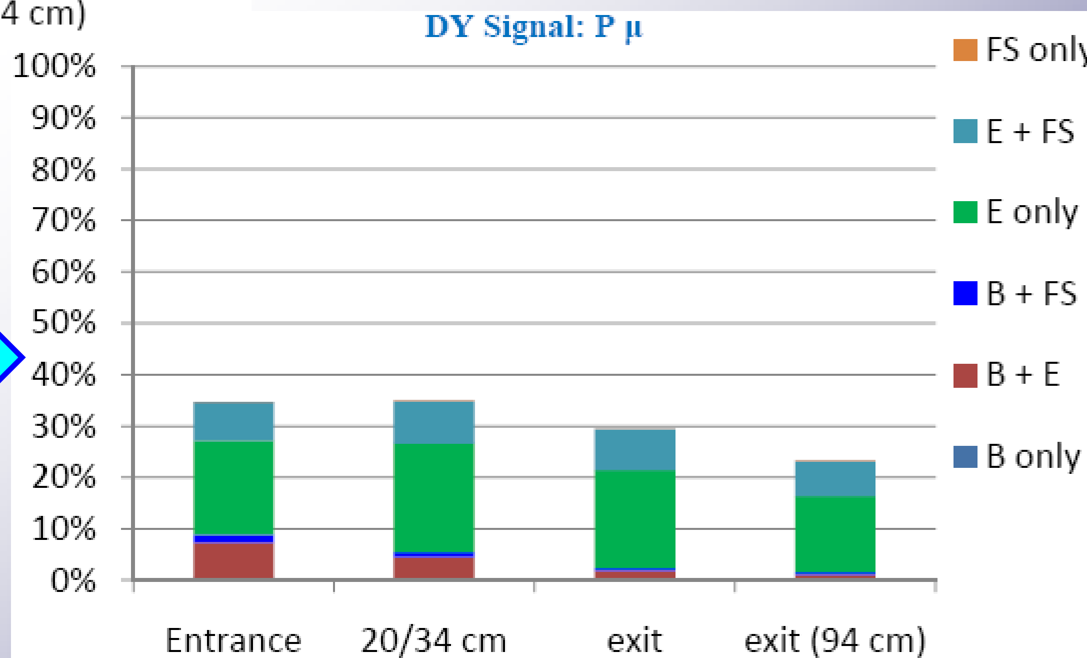
$1.5 < M_{\mu\mu} < 2.5$ GeV/c^2

Very tough requirements on track lenght

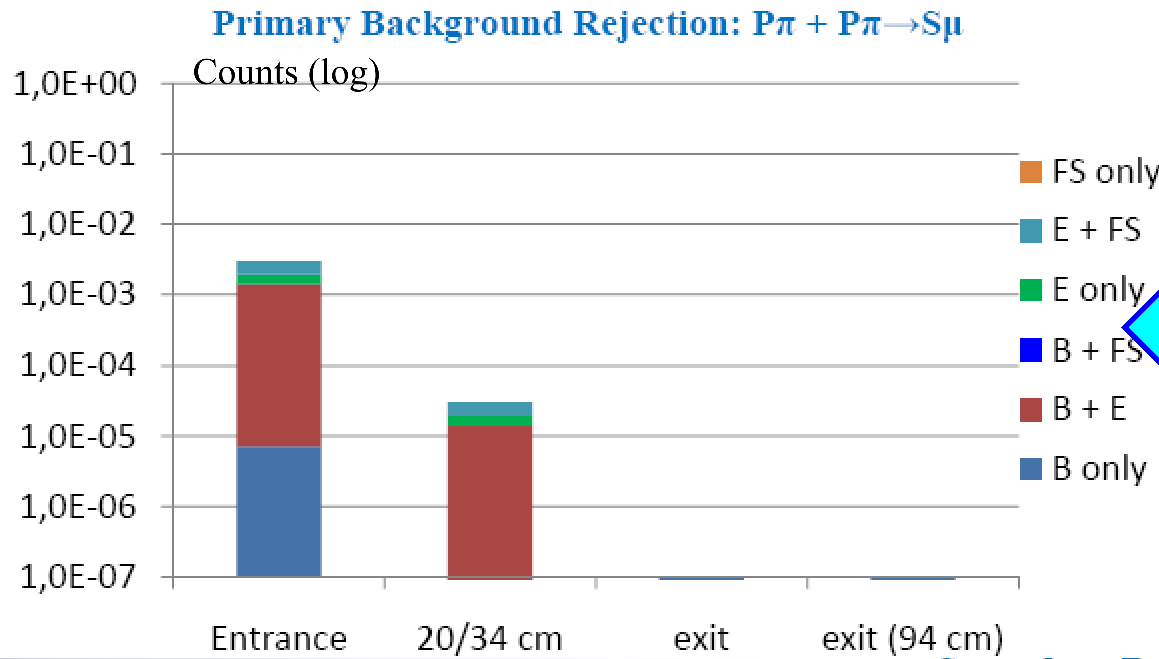
$1.5 < M_{\mu\mu} < 2.5$ GeV/c^2

Very tough requirements on track lenght

$q_{T,\mu\mu} > 0.75$ GeV/c



Hadronic Background Distribution



$1.5 < M_{\mu\mu} < 2.5$ GeV/c^2

Very crude requirements on track lenght

$p_{T,\mu\mu} > 0.75$ GeV/c

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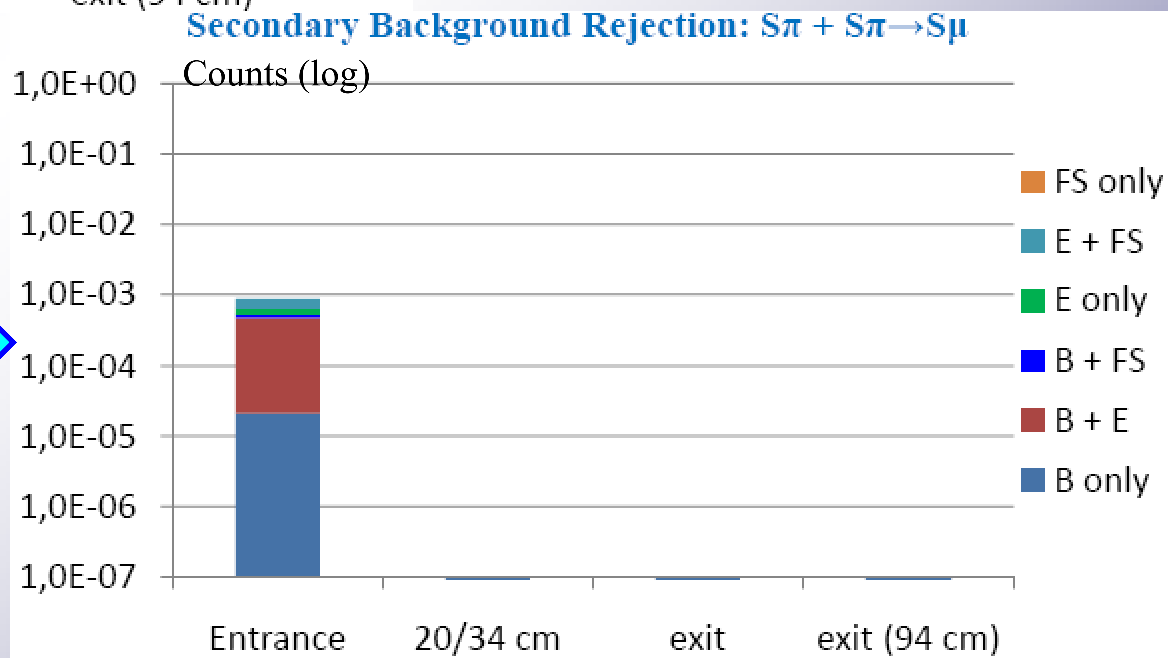
Very crude requirements on track lenght

$p_{T,\mu\mu} > 0.75$ GeV/c



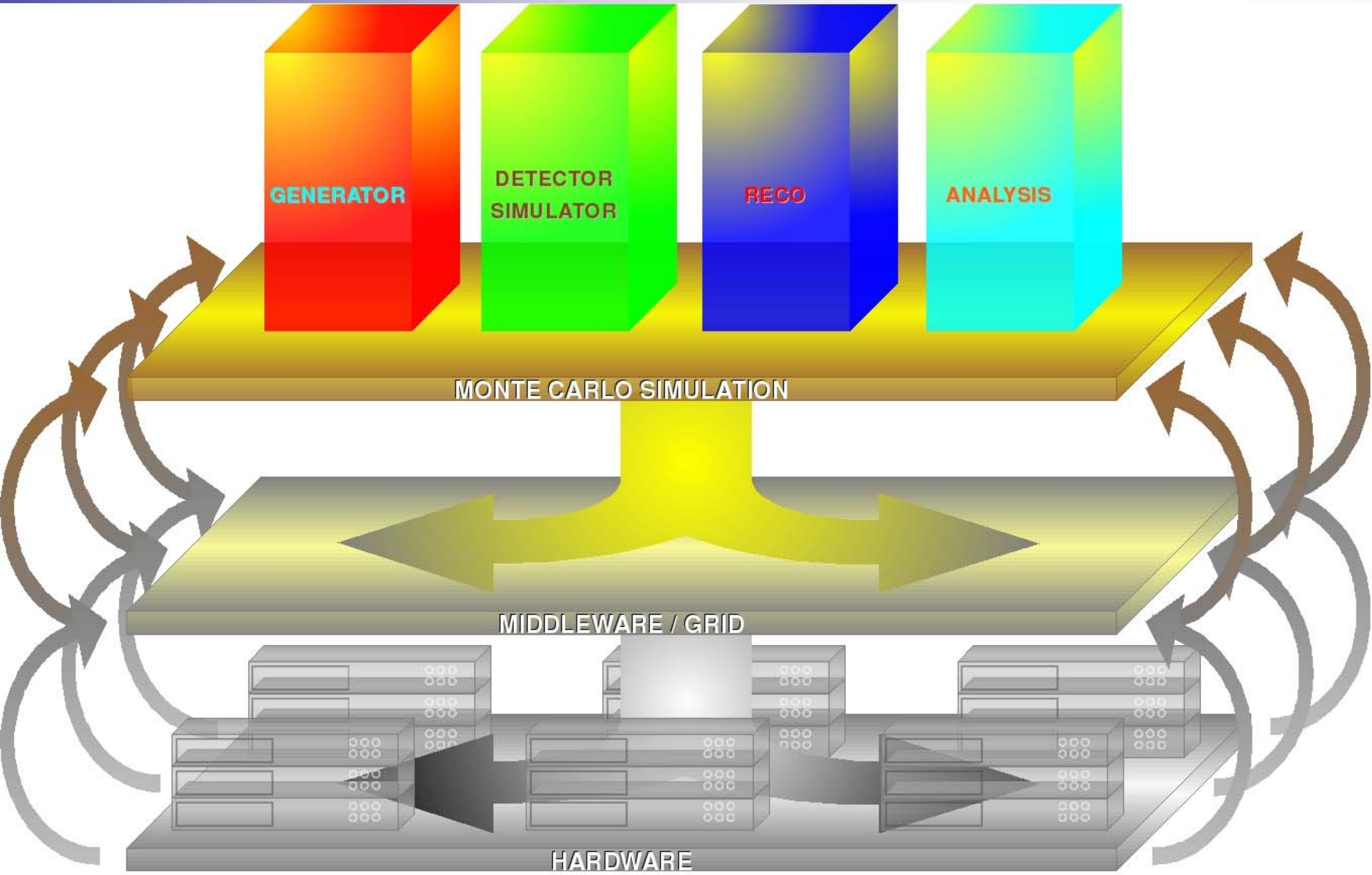
Computing Environments – INFN Grid

(credits G.C. Serbanut)

- Motivation
  - CPU time consumption
  - collect statistics
- Operational
- Nutshell with precompiled FairSoft, PandaRoot, gcc and system libraries
- Jobs:
  - Jobs are started with scripts (BASH+AWK)
  - Nutshell is moved to the local machine (~40s)
  - Environment variables set
  - Run process (40 min)
  - Output send to the database and saved (2min, 910MB)
  - Nutshell and output removed from the local machine (few s)
- Full automatization

10000 signal events

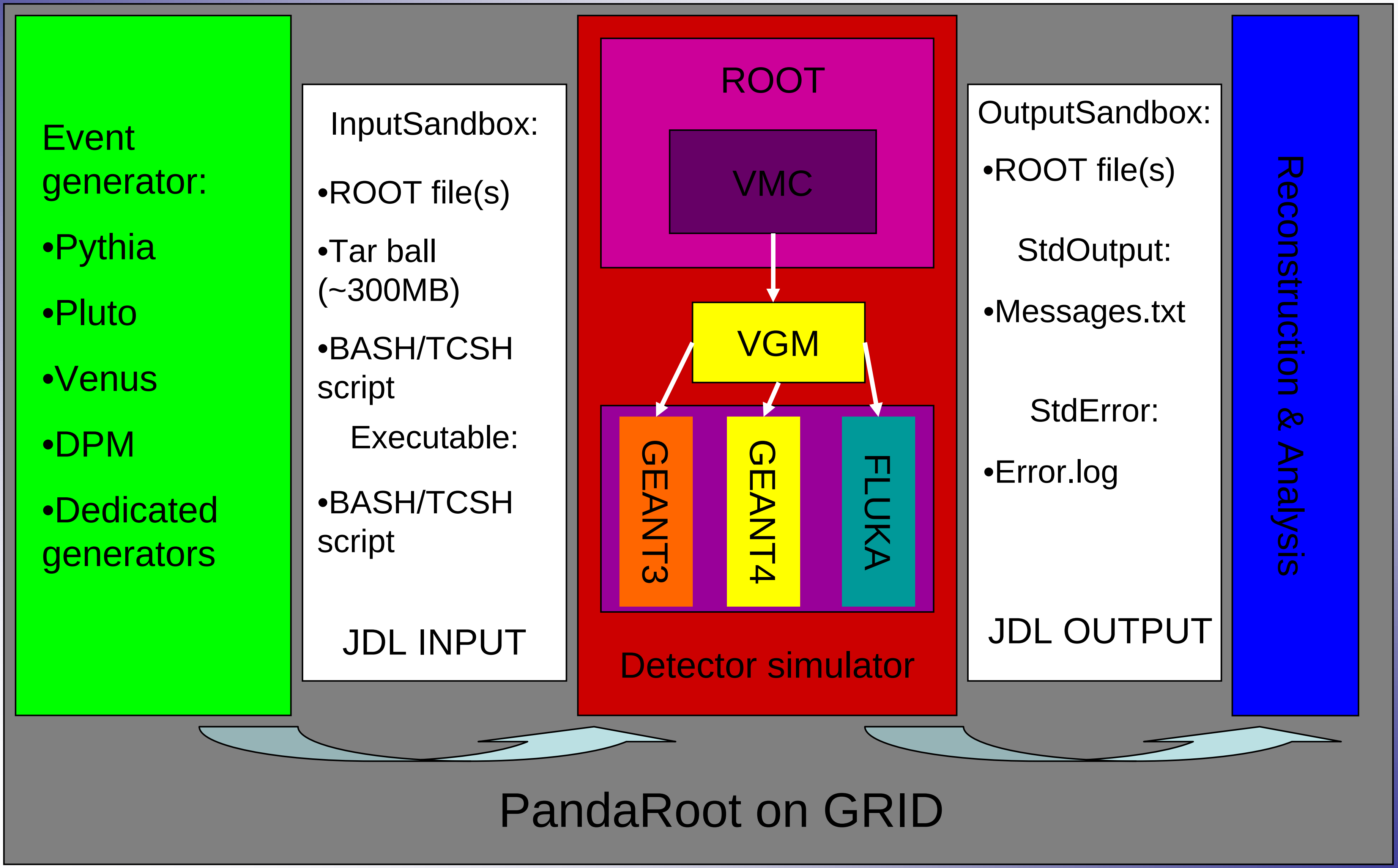
Computing Environments – INFN Grid



Computing Environments – INFN Grid

(credits G.C. Serbanut)

Schema of PandaRoot simulations on the INFN Grid



Computing Environments – Farm

(credits G.C. Serbanut)

- Operational
- Nutshell with precompiled FairSoft, PandaRoot, gcc and system libraries
- Jobs:

10000 signal events

- Jobs are started with scripts (BASH+AWK)

  Nutshell is created and then moved to the local machine (few s)

  Jobs are running locally (40 min)

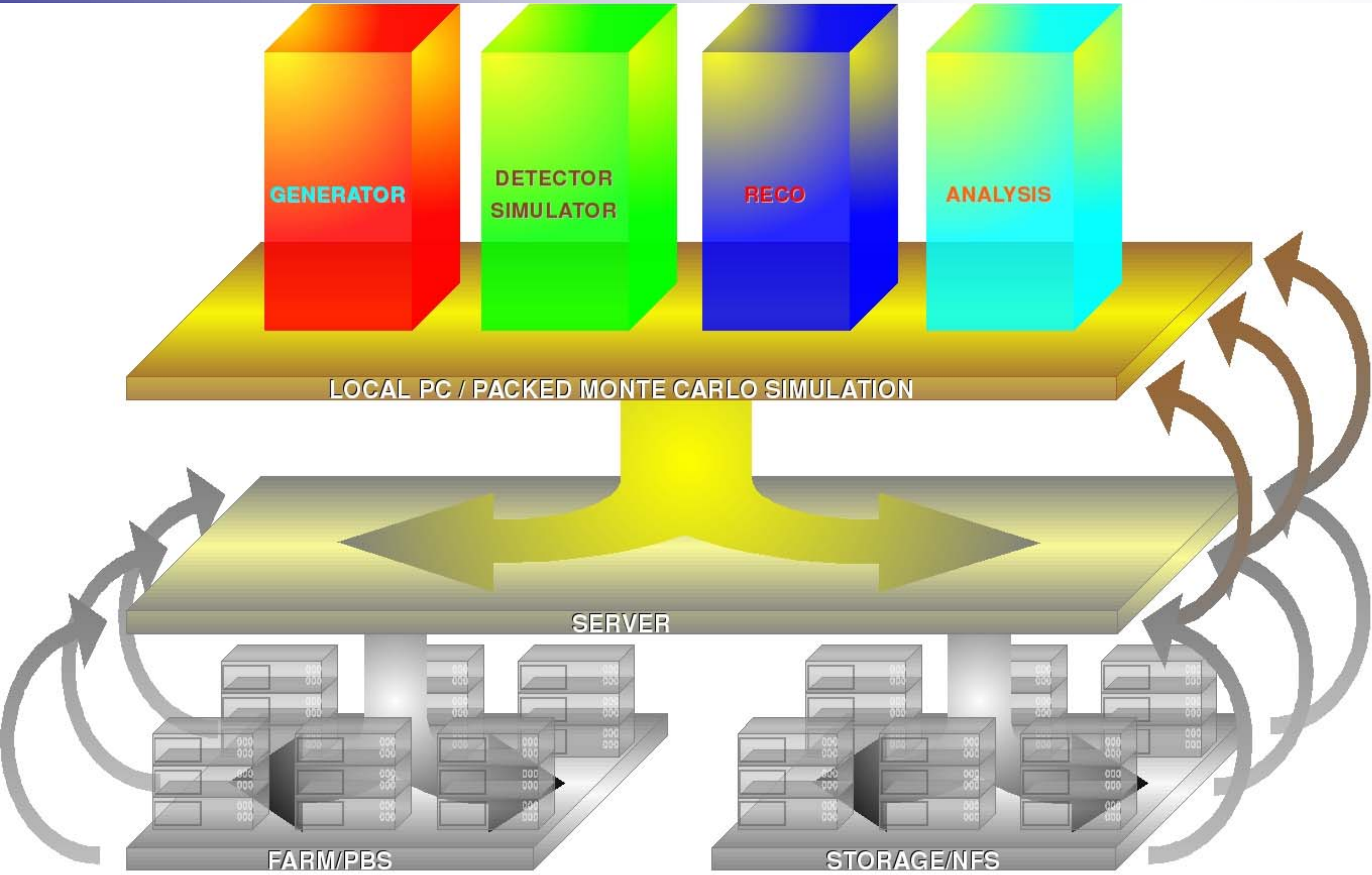
  Output moved to storage elements (2min, 910MB)

  Clean the computing element (few s)

- Check free space on disks

  Balance of the amount of data on storage elements

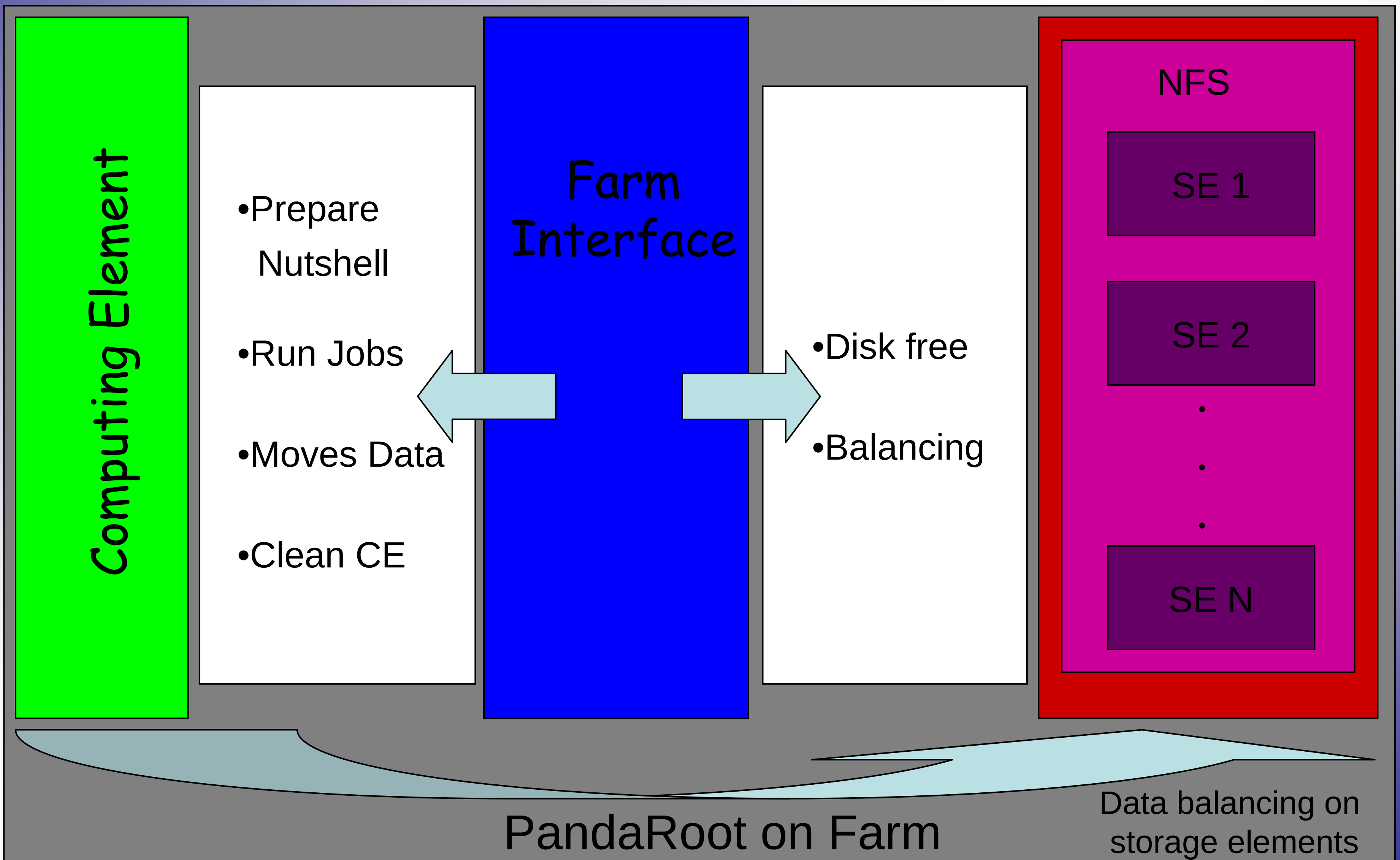
Computing Environments – Farm



Computing Environments – Farm

(credits G.C. Serbanut)

Schema of PandaRoot simulations on the Torino Farm



Computing Environments – Cluster

(credits G.C. Serbanut)

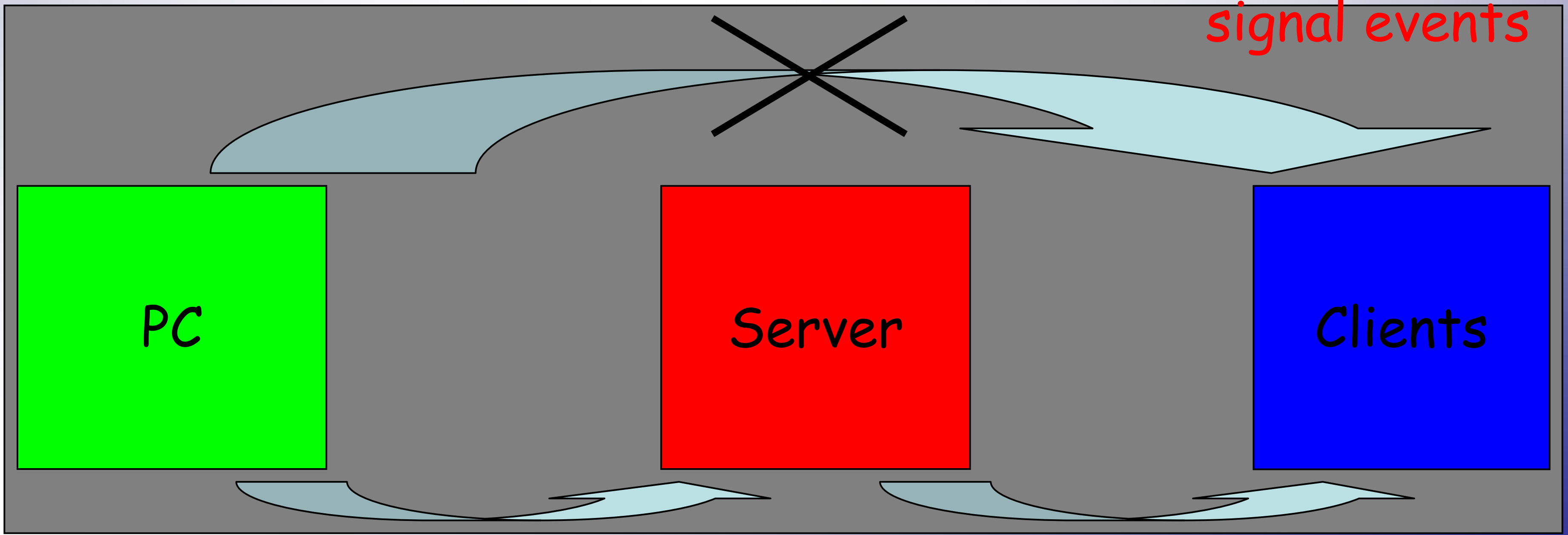
- 4 clients with 2 CPUs dual core -> 16 threads at once
- Jobs are started with scripts (BASH+AWK)
  - Passwordless ssh connection among all the machines (SSH v.2)
  - Clean input/output (few s)

  Copy locally input data (few s)

  Start and monitor the simulations (35 min)

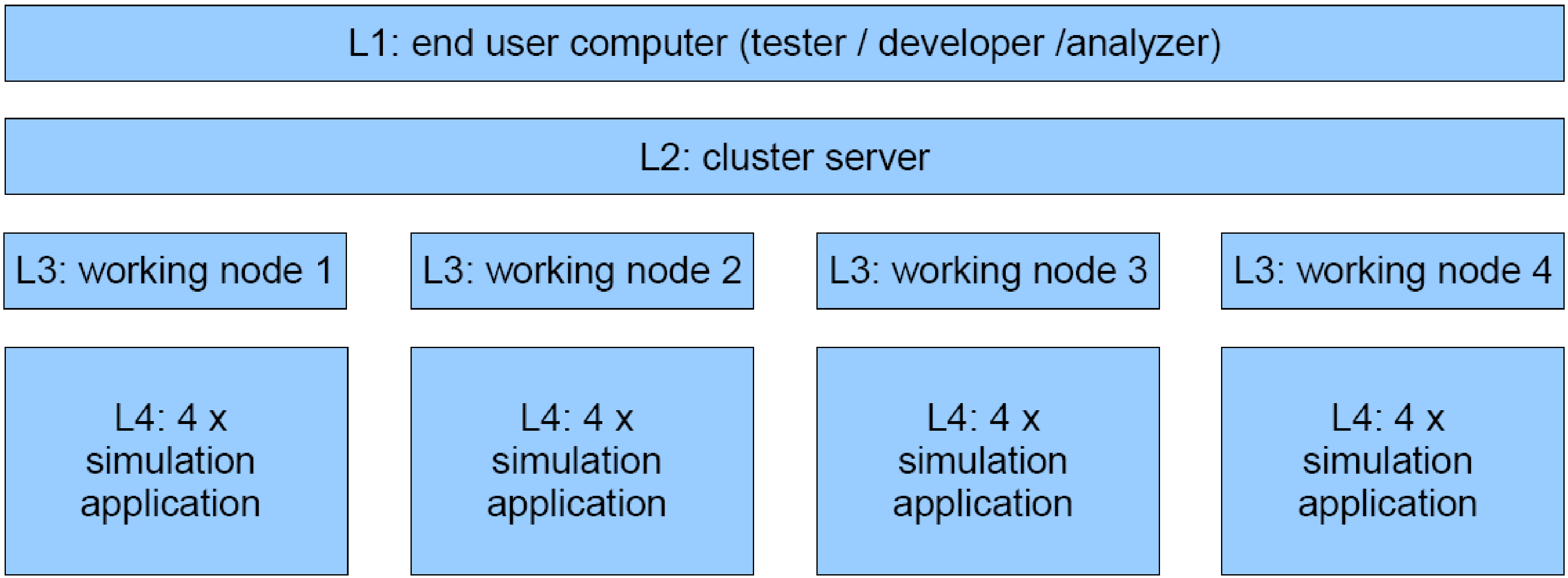
  Retrieving the data (2min, 910MB)

10000 signal events



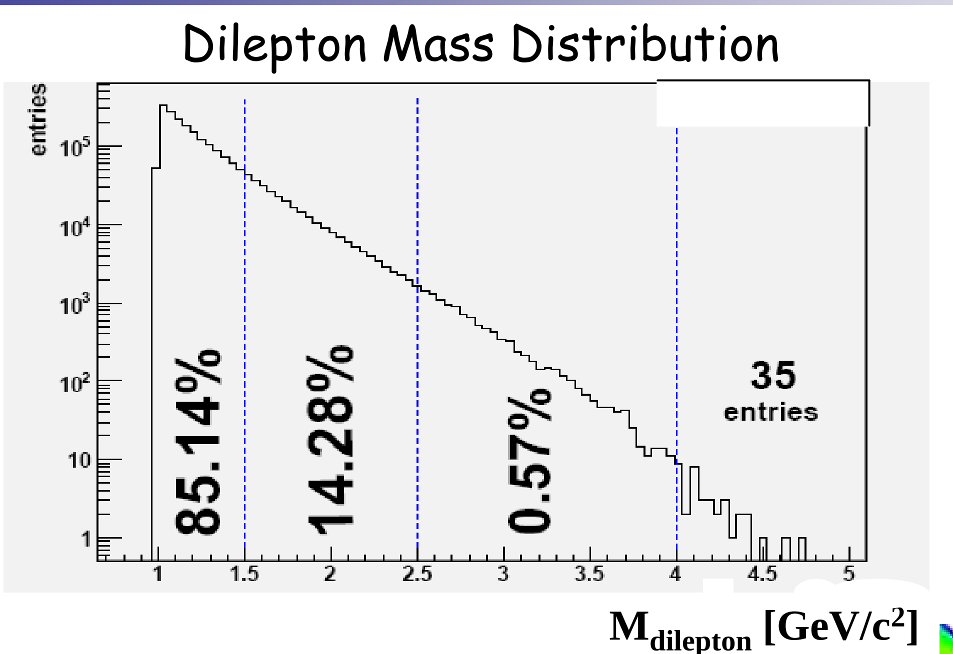
Computing Environments – Cluster

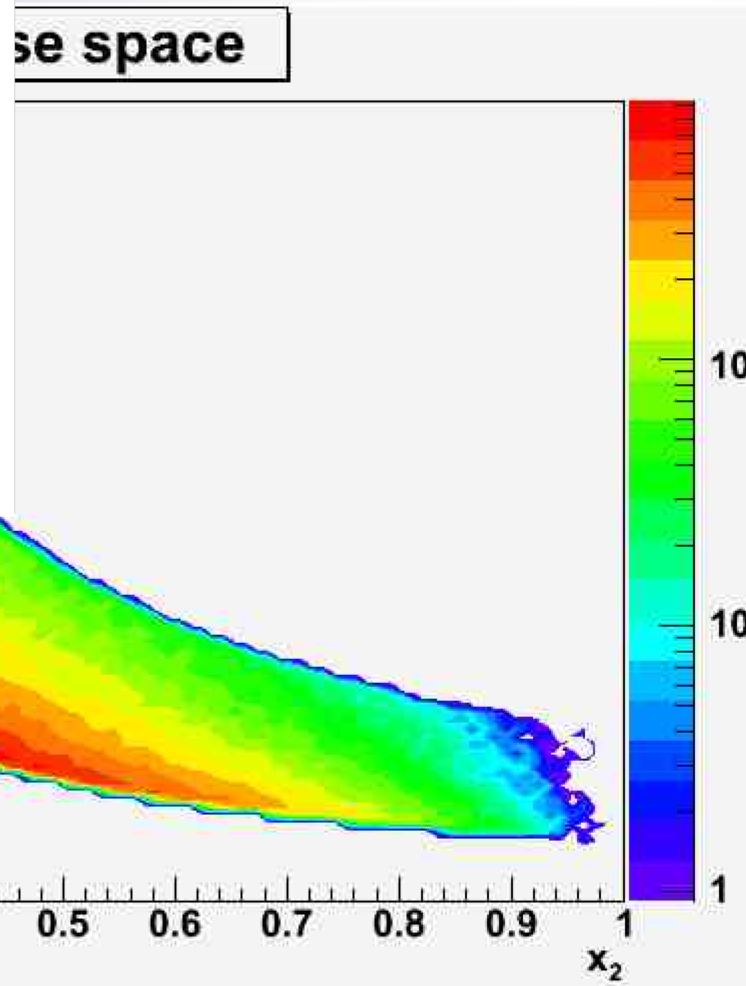
Automatization



DY @ 15 GeV/c — $\bar{p}p \rightarrow \mu^+\mu^- X$

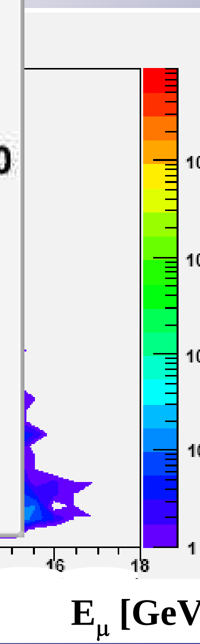
$\sqrt{s} = 5.5$ GeV





erator [1]

id



Focus o

1.5 MEv i

$\sigma^0_{1.5 \leq M \leq 2}$

[1]A. Bianconi and M. Radici, Phys. Rev. D71 (2005) 074014