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SDC
SOLENOIDAL DETECTOR NOTES

ACCEPTANCE AND MASS RESOLUTION STUDIES FOR SDC MUON EOI SUBSYSTEM DESIGN

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Acceptance and Mass Resolution Studies for SDC Muon EoI SubSystem Design

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This note summarizes updated results of a repeat of previous SDC muon acceptance and off-line/on-line mass resolution studies done by Jim Wiss and myself using the ISAJET V6.24 Monte Carlo event generator, smearing the final state muon momenta with parametrizations of the muon momentum resolution for the central and intermediate region muon systems for the following SSC p-p /s = 40 TeV reactions:

A.) Z0 -> mu+mu-
B.) Z0' -> mu+mu- (Mz' = 200 GeV/c2)
C.) Z0' -> mu+mu- (Mz' = 500 GeV/c2)
D.) Z0' -> mu+mu- (Mz' = 0.5 - 4.0 TeV/c2) (Toy MC only)
E.) ZZ pairs -> 4 muons
F.) Higgs -> ZZ -> 4 muons (M_higgs = 400 GeV/c2)
G.) Higgs -> ZZ -> 4 muons (M_higgs = 800 GeV/c2)

In the present study, via use of his matrix mcs-weighted momentum resolution program, Jim has obtained parametrizations of the offline muon momentum resolution for the EoI muon system design for the barrel region, and the intermediate region, for both the EoI iron core toroid and EoI air core toroid designs. The previous parametrizations for the momentum resolutia in the intermediate region were slightly incorrect. The present results used parametrizations for the momentum resolutia for the iron and air core toroids which are correct.

For the barrel region, the off-line momentum resolution parametrization has been obtained for 3-d beam-constraint + SSD + CTC + barrel muon toroid system.

For the intermediate region with the iron core toroid, the off-line momentum resolution has been obtained for 3-d beam constraint + SSD + SSD outriggers + forward radial chambers + iron core toroid system.

For the intermediate region with the air core toroid, the off-line momentum resolution has been obtained for 3-d beam constraint + SSD + SSD outriggers + forward radial chambers + air core toroid system.

The momentum resolution curves obtained from the parametrizations of results from Jim's matrix program, which include the proper Pt and eta-dependences, agree with the momentum resolution curves obtained directly from the matrix program to the 5-10% level.

Operationally, the 4-vector information from the ISAJET data file for each reaction is input to another program; the muon momenta are smeared by the appropriate resolution for the portion of the SDC muon system they traverse. The smeared momenta, masses are compared with the initial momenta, masses to obtain information on momentum and mass resolution, etc. The subroutine which does the momentum smearing is FNALD::USR$ROOT34:[ERREDE.ISA]SMEARIT4.FOR. The main program from which the following results have been obtained is in the same area, and is called SSC_MUONS.FOR, see also SSC_MUONS.COM for the link file and other subroutines not discussed here in this note.

The eta-independent Pt-acceptance is not unity for high-mass states due to the forward (high-momentum/low-Pt) component of the angular distribution for these reactions.

Sigma_Mz, Sigma_Mzz, Sigma_Mhiggs, % Mass Resolution are obtained without reference to intrinsic widths of physical particle states - i.e. these quantities are associated only with finite detector resolution.

The following tables also contain information on acceptances for e.g. central-central vs. central - intermediate vs. intermediate - intermediate Z0 -> mu+mu-, etc. where the various eta-regions are defined as:

Central	=	C:	|Eta_mu| < 1.5
Intermediate	=	I: 1.5 <	|Eta_mu| < 2.5
Forward	=	F: 2.5 <	|Eta_mu|

The mass resolution in the intermediate region for the ICT is a factor of approximately 2x worse than that for the ACT for most of the physics reactions above. The difference in the mass resolution for a 500 GeV/c2 Z' -> mu+mu- from ISAJET vs. that obtained with the Toy MC is due to the finite Z' Pt in the ISAJET case vs. the 0 Pt (back-to-back) opening angle in the Toy MC.

In general, for the reactions with ZZ pairs -> 4 muons, inspection of the various angular regions reveals that there are some rather striking angular correlation effects on the mass resolution associated with the parent state, e.g. Higgs -> ZZ -> 4 muons.

```
      Momentum Smearing Code - Barrel Toroid Muons:  |eta_mu| < 1.5
      ==============================================================

      XK     = 1.00/PT
c
      XX     = PT/500.0
      AA     = 0.0940
      BB     = 0.2340
      CC     = 0.2180
c
      IF (XX.LT.1.0) THEN
        REL  = AA*XX*(1.0 -  XX*BB*(1.0 + CC*ETA**2))
      ELSE
        REL  = AA*BB*(1.0 + CC*ETA**2) +
     &         AA*XX*(1.0 - 2.0*BB*(1.0 + CC*ETA**2))
      ENDIF
c
      XKSM   = XK + (XK*REL*GSS)              ! GSS = random gaussian smear
      PTSM   = 1.0/XKSM

      Momentum Smearing Code - ICT/Intermediate Muons:  1.5 < |eta_mu| < 2.5
      ======================================================================

      XK     = 1.00/PT
c
      RELHLP = 5.20E-5*PT/TNTH**2
c
      AA     = 0.1180*SQRT(ABS(CSTH))
      BB     = 9.42E-5*CSTH**2/TNTH
      RELTOR = SQRT(AA**2 + (BB*PT)**2)
c
      REL    = 1./SQRT(1./RELHLP**2 + 1./RELTOR**2)
c
      XKSM   = XK + (XK*REL*GSS)              ! GSS = random gaussian smear
      PTSM   = 1.0/XKSM

      Momentum Smearing Code - ACT/Intermediate Muons:  1.5 < |eta_mu| < 2.5
      ======================================================================

      XK     = 1.00/PT
c
      RELHLP = 5.20E-5*PT/TNTH**2
c
      AA     = 0.0335*SQRT(ABS(SNTH))
      BB     = 2.07E-4*CSTH**2
      RELTOR = SQRT(AA**2 + (BB*PT)**2)
c
      REL    = 1./SQRT(1./RELHLP**2 + 1./RELTOR**2)
c
      XKSM   = XK + (XK*REL*GSS)              ! GSS = random gaussian smear
      PTSM   = 1.0/XKSM
```

A.) Z0 -> mu+mu- (1000 Events)

Sigma*B(Z0 -> mu+mu-) = 3.3 nb => 3.3 Hz @ L = 10**33 cm-2 s-1
=> 0.3*10**8 events for L*dt = 10**40.

Eta-Independent Pt-Acceptance for (Pt_mu1 .OR. Pt_mu2) > 20 GeV/c: 81.0%

Eta Region	Eta-Acceptance (after Pt_mu Cut)	Sigma_Mz (GeV/c2)		Mass Resolution (Per-Cent)	
C-C	22.8%	0.56		0.61%	
C-I	17.8%	0.73	1.38	0.80%	1.50%
I-I	6.4%	1.18	3.01	1.29%	3.28%
	47.0%	(ACT)	(ICT)	(ACT)	(ICT)
X-F	53.0%				

B.) Z0' -> mu+mu- (Mz' = 200 GeV/c2) (1000 Events)

NB: Mz' > 380 GeV/c2 @ 95% CL for SM couplings from CDF DY/Z e+e- data.

Sigma*B(Z0' -> mu+mu-) = 143.7 pb => 0.14 Hz @ L = 10**33 cm-2 s-1
=> 1.4*10**6 events for L*dt = 10**40.

Eta-Independent Pt-Acceptance for (Pt_mu1 .OR. Pt_mu2) > 20 GeV/c: 96.1%

Eta Region	Eta-Acceptance (after Pt_mu Cut)	Sigma_Mz (GeV/c2)		Mass Resolution (Per-Cent)	
C-C	21.8%	2.45		1.22%	
C-I	20.0%	2.48	4.92	1.24%	2.46%
I-I	6.2%	2.81	7.48	1.41%	3.74%
	48.0%	(ACT)	(ICT)	(ACT)	(ICT)
X-F	52.0%				

C.) Z0' -> mu+mu- (Mz' = 500 GeV/c2) (1000 Events)

Sigma*B(Z0' -> mu+mu-) = 0.7 pb => 7.0*10**-4 Hz @ L = 10**33 cm-2 s-1
=> 7000 events for L*dt = 10**40.

Eta-Independent Pt-Acceptance for (Pt_mu1 .OR. Pt_mu2) > 20 GeV/c: 98.6%

Eta Region	Eta-Acceptance (after Pt_mu Cut)	Sigma_Mz (GeV/c2)		Mass Resolution (Per-Cent)	
C-C	29.9%	14.98		3.00%	
C-I	25.3%	14.04	20.14	2.81%	4.03%
I-I	5.8%	16.05	24.11	3.21%	4.82%
	61.0%	(ACT)	(ICT)	(ACT)	(ICT)
X-F	39.0%				

NB: X-F = C-F + I-F + F-F

D.) Z0′ -> mu+mu- (Mz′ = 0.5 - 6.0 TeV/c2) (10000 Events)

Micro-Toy MC:

Assume Pt_Z′ = Plong_Z′ = 0.0
Random Isotropic Angular Distribution (==> no C-F dimuon pairs)

Eta-Independent Pt-Acceptance for (Pt_mu1 .OR. Pt_mu2) > 20 GeV/c:

Z′ Mass (TeV/c2)	Pt-Acceptance
0.5	98.6%
1.0	99.9%
> 2.0	100.0%

Eta-Acceptance (after Pt_mu Cut):

C-C = 90.3%
I-I = 8.6%
F-F = 1.1%

Central - Central Z0′ -> mu+mu-

Z′ Mass (TeV/c2)	dMz′_shft (of <Mz′>)	%dMz′_shft (of <Mz′>)	Sigma_Mz′ (GeV/c2)	Mass Resolution (Per-Cent)
0.5	0.29	0.1%	12.74	2.55%
1.0	2.31	0.2%	45.10	4.51%
2.0	14.49	0.7%	153.20	7.66%
3.0	49.92	1.7%	331.10	11.04%
4.0	93.71	2.3%	568.20	14.21%

Intermediate - Intermediate Z0′ -> mu+mu-

Z′ Mass (TeV/c2)	dMz′_shft (of <Mz′>)		%dMz′_shft (of <Mz′>)		Sigma_Mz′ (GeV/c2)		Mass Resolution (Per-Cent)	
	(ACT)	(ICT)	(ACT)	(ICT)	(ACT)	(ICT)	(ACT)	(ICT)
0.5	0.12	0.43	0.0%	0.1%	6.67	13.61	1.33%	2.72%
1.0	0.65	2.87	0.1%	0.3%	21.36	46.97	2.14%	4.70%
2.0	4.82	15.20	0.2%	0.8%	77.18	148.80	3.86%	7.44%
3.0	14.50	40.39	0.5%	1.3%	171.80	297.40	5.73%	9.91%
4.0	35.79	85.47	0.9%	2.1%	307.70	408.10	7.69%	10.20%

E.) ZZ Pairs -> 2(mu+mu-) (1000 Events)

Sigma*B(ZZ -> 2(mu+mu-)) = 25 fb => 25*10**-6 Hz @ L=10**33 cm-2 s-1
=> 250 events for L*dt = 10**40.

Eta-Independent Pt-Acceptance:

2 or more muons w/ Pt_mu > 20 GeV/c: 99.3%

Eta Region	Eta-Acceptance (after Pt_mu Cut)	Sigma_Mz (GeV/c2)		Mass Resolution (Per-Cent)	
C-C + C-C	9.1%	0.75		0.82%	
C-C + C-I	14.6%	0.77	1.11	0.85%	1.22%
C-I + C-I	4.6%	1.07	2.54	1.17%	2.79%
C-C + I-I	2.3%	0.91	2.02	1.00%	2.22%
C-I + I-I	1.4%	1.04	2.80	1.14%	3.07%
I-I + I-I	0.2%	1.09	2.92	1.20%	3.20%
	32.2%	(ACT)	(ICT)	(ACT)	(ICT)
X-Y + X-F	67.8%				

Eta Region	Sigma_Mzz (GeV/c2)		Mass Resolution (Per-Cent)	
C-C + C-C	2.44		0.99%	
C-C + C-I	2.38	3.98	0.88%	1.47%
C-I + C-I	3.94	9.99	1.46%	3.70%
C-C + I-I	6.28	10.86	2.33%	4.02%
C-I + I-I	2.82	6.84	1.04%	2.53%
I-I + I-I	2.50	8.00	0.93%	2.96%
	(ACT)	(ICT)	(ACT)	(ICT)

<Mzz> ~ 270 GeV/c2

NB: X-Y = C-C + C-I + C-F + I-I + I-F + F-F
X-F = C-F + I-F + F-F

There are 21 = {6 + (36-6)/2} unique combinations of X-Y + X-Y:

	C-C	C-I	C-F	I-I	I-F	F-F
C-C	X	X	X	X	X	X
C-I	O	X	X	X	X	X
C-F	O	O	X	X	X	X
I-I	O	O	O	X	X	X
I-F	O	O	O	O	X	X
F-F	O	O	O	O	O	X

F.) Higgs -> ZZ Pairs -> 2(mu+mu-) (M_Higgs = 400 GeV/c2) (1000 Events)

Sigma*B(Higgs->ZZ-> 4mu) = 8.8 fb => 8.8*10**-6 Hz @ L=10**33 cm-2 s-1
=> 88 events for L*dt = 10**40.

Eta-Independent Pt-Acceptance:

2 or more muons w/ Pt_mu > 20 GeV/c: 99.6%

Eta Region	Eta-Acceptance (after Pt_mu Cut)	Sigma_Mz (GeV/c2)		Mass Resolution (Per-Cent)	
C-C + C-C	17.7%	1.19		1.30%	
C-C + C-I	17.4%	1.20	1.65	1.32%	1.80%
C-I + C-I	5.7%	1.18	2.03	1.29%	2.23%
C-C + I-I	5.5%	1.17	2.38	1.28%	2.61%
C-I + I-I	2.5%	1.58	2.82	1.73%	3.09%
I-I + I-I	0.4%	1.64	3.53	1.80%	3.87%
	49.2%	(ACT)	(ICT)	(ACT)	(ICT)
X-Y + X-F	50.8%				

Eta Region	Sigma_Mhiggs (GeV/c2)		Mass Resolution (Per-Cent)	
C-C + C-C	5.43		1.36%	
C-C + C-I	4.47	6.57	1.12%	1.64%
C-I + C-I	4.23	7.66	1.06%	1.92%
C-C + I-I	6.98	13.16	1.75%	3.29%
C-I + I-I	5.06	10.52	1.26%	2.63%
I-I + I-I	9.43	18.02	2.36%	4.51%
	(ACT)	(ICT)	(ACT)	(ICT)

NB: X-Y = C-C + C-I + C-F + I-I + I-F + F-F
X-F = C-F + I-F + F-F

G.) Higgs -> ZZ Pairs -> 2(mu+mu-) (M_Higgs = 800 GeV/c2) (1000 Events)

Sigma*B(Higgs->ZZ-> 4mu) = 1.5 fb => 1.5*10**-6 Hz @ L=10**33 cm-2 s-1
=> 15 events for L*dt = 10**40.

Eta-Independent Pt-Acceptance:

2 or more muons w/ Pt_mu > 20 GeV/c: 98.9%

Eta Region	Eta-Acceptance (after Pt_mu Cut)	Sigma_Mz (GeV/c2)		Mass Resolution (Per-Cent)	
C-C + C-C	29.7%	2.81		3.08%	
C-C + C-I	19.9%	2.53	3.28	2.78%	3.59%
C-I + C-I	3.2%	2.66	3.98	2.94%	4.36%
C-C + I-I	8.6%	2.69	4.96	2.95%	5.44%
C-I + I-I	3.2%	2.49	5.80	2.73%	6.36%
I-I + I-I	1.6%	3.87	9.08	4.24%	9.96%
	66.3%	(ACT)	(ICT)	(ACT)	(ICT)
X-Y + X-F	33.7%				

Eta Region	Sigma_Mhiggs (GeV/c2)		Mass Resolution (Per-Cent)	
C-C + C-C	20.82		2.60%	
C-C + C-I	17.58	20.25	2.20%	2.53%
C-I + C-I	12.81	19.10	1.60%	2.39%
C-C + I-I	20.93	30.79	2.62%	3.85%
C-I + I-I	15.04	29.53	1.88%	3.69%
I-I + I-I	23.68	37.65	2.96%	4.71%
	(ACT)	(ICT)	(ACT)	(ICT)

NB: X-Y = C-C + C-I + C-F + I-I + I-F + F-F
X-F = C-F + I-F + F-F