Event generation in C++ for LHC and LC

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Contents :

- Why C++ ?
- Matrix elements for multi particle final states
- Connection to the parton shower
- Summary

Why C++ ?

Simple answer : new solutions for new problems :

1. Experiments switch to C++
2. Large scale codes ($>$ 30000 lines) difficult to handle in Fortran:
   - Control over data-flow non–trivial (common blocks !)
   - Maintenance & development (at best) difficult
   - User "add–ons" & interfaces nearly impossible
3. Efforts for Pythia7 and Herwig++ : but common kernel

   $\Longrightarrow$ common errors & prejudices ?

   $\Longrightarrow$ Maybe want some **really** independent checks ?
4. Some new physics features ?

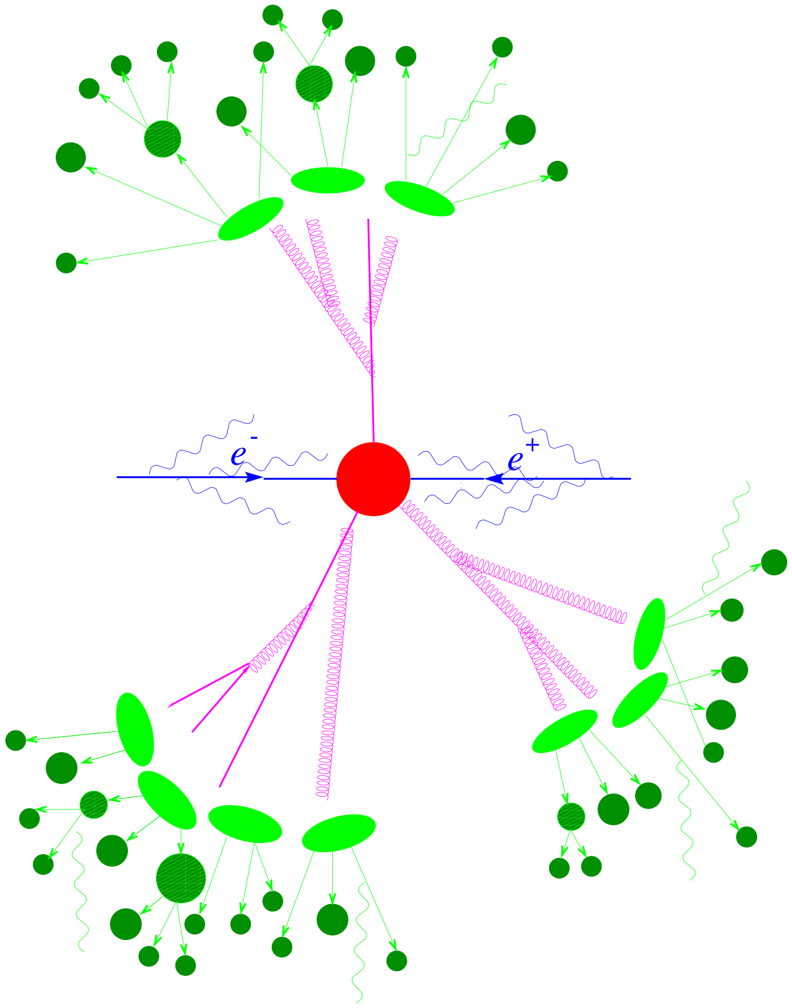
Demands on a modern Monte Carlo

Physics

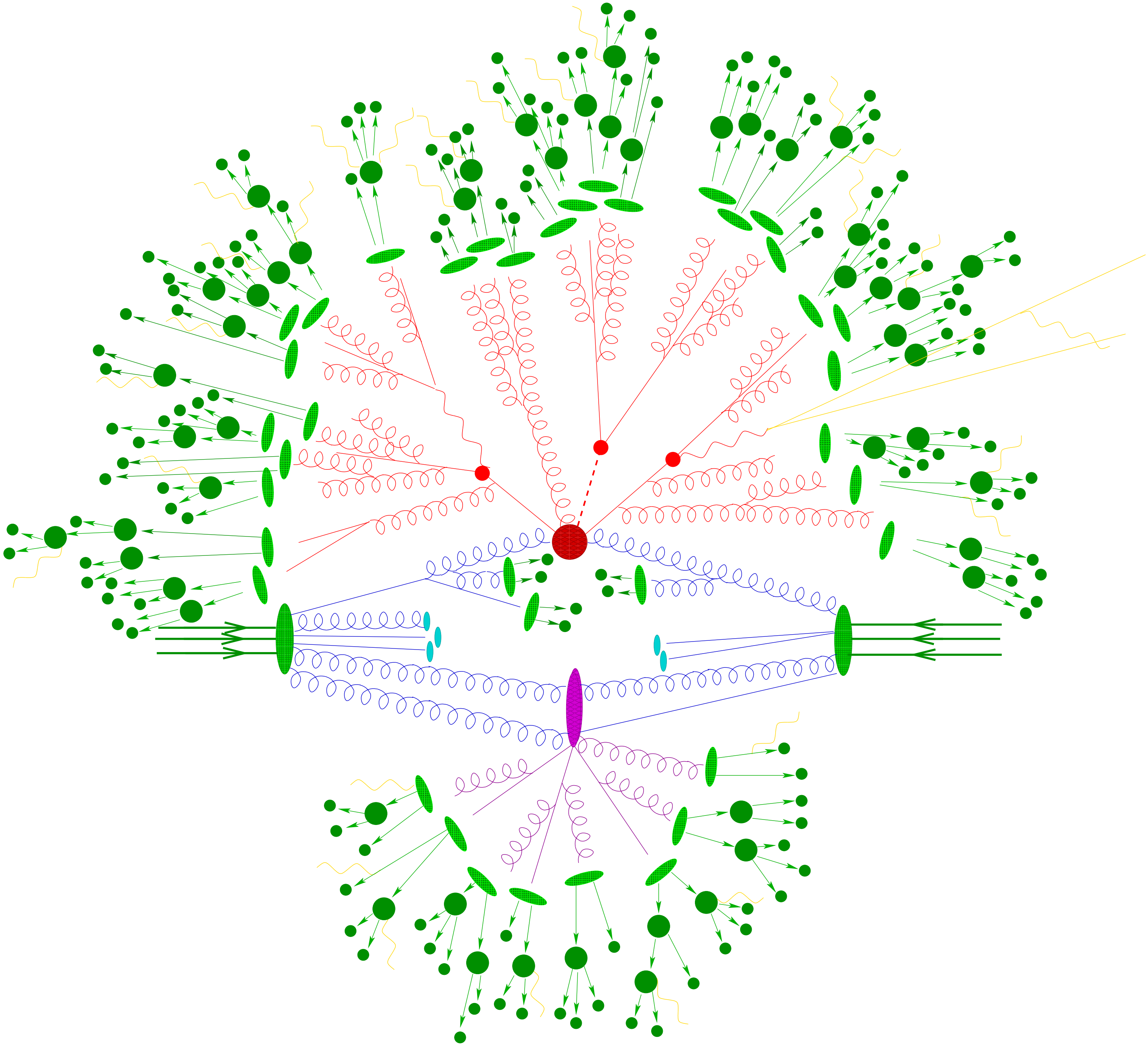
- Signals for new physics
- SM, MSSM, NMSSM,
  extra dimensions ...
- Good treatment of backgrounds
- Different ME's, PDF's etc.
- Different fragmentation schemes
- Hadron decays a la PDG

Computing

- Transparency (Maintenance)
- Modularity (Checks, replacements)
- Extensions possible
- Fast
- Object–oriented language
- $\Longrightarrow$C++



e^-
e^+



Hard events

"Signals & backgrounds for cool new physics"

Standard :

- Full matrix elements (ME) take full account of all interferences: relative angles (w.r.t. the beam or other particles) etc.
- In Standard event generators: long lists of $2 \to 2$ processes, additional particles via decays or emission of secondaries

Possible improvements :

- More loops (improving on total normalization)
- more legs (improving on multi-jet topologies)

$\Longrightarrow$ In both cases : How to match with parton shower (PS) ?

How to build state-of-the-art ME generators:

(The keyword is automation !!!)

The idea: Construct a "ME-generator-generator" (e.g. AMEGIC++):

- Generate amplitude to be squared
  (via Feynman diagrams or generating functional)
- Use helicity amplitudes or similar
  (no completeness relation, leads to proliferation of terms)
- Generate process-specific multi-channel integrator
  (with Feynman amplitudes all singularities are known)
- Create library files for everything !!!
  (leads to : run, compile & link, run again and enjoy)

$\Longrightarrow$ Still: number of outgoing particles ≤ 10, need for PS

("10" to be extra optimistic !!!)

AMEGIC++

(Authors : R. Kuhn, S. Schumann, T. Gleisberg, F.K.)

Automatic :

- generation of tree–level Feynman diagrams,
- translation into helicity amplitudes,
- creation of integrators (diagramwise),
- storage of amplitudes and channels in library.
- ≈ 30000 lines of code $\rightarrow \mathcal{O}(500000)$ lines of library

Current status :

- Standard Model successfully tested in:
  1. $e^+e^- \longrightarrow 5$ massive or massless jets
  2. $e^+e^- \longrightarrow 4f\gamma$ (massive or massless fermions)
  3. $t \longrightarrow Wb + \{\leq 3g, \leq 2\gamma\}$
  4. $q\bar{q} \longrightarrow$ 3jets
  5. Simple SUSY stuff (incl. polarizations)
- Manual for (β-) version 1.0 published
- MSSM currently implemented & tested
- Output to be improved (LateX, plots, graphs, ...)
- Code and manual for version 2.0 coming soon

Trivial tests : $e^+e^- \to 4f$

1. Comparison with RacoonWW (A. Denner *et al.*) :

Parameters:

α	=	1/128.07	α_s	=	0.12	$\sin\theta_W$	=	0.231031
M_W	=	80.23 GeV	Γ_W	=	2.0337 GeV			
M_Z	=	91.1888 GeV	Γ_Z	=	2.4974 GeV			

Cuts:

$\theta(l,\mathrm{beam})$	>	10°	$\theta(l,l')$	>	5°	$\theta(l,q)$	>	5°
$m(q,q')$	>	5 GeV	E_l	>	1 GeV	E_q	>	3 GeV

2. Comparison with F.Jegerlehner *et al.* :

Parameters:

α	=	1/132.50	α_s	=	0.1185	$\sin\theta_W$	=	0.222250
M_W	=	80.419 GeV	Γ_W	=	2.12 GeV			
M_Z	=	91.1882 GeV	Γ_Z	=	2.4952 GeV			
M_H	=	115.0 GeV	Γ_H	=	0.0049716 GeV			
M_e	=	0.510998902 MeV	M_μ	=	105.658357 MeV	M_τ	=	1777.03 MeV
M_u	=	5 MeV	M_d	=	9 MeV	M_s	=	150 MeV
M_c	=	1.3 GeV	M_b	=	4.5 GeV			
M_t	=	174.3 GeV	Γ_t	=	1.5 GeV			

Cuts:

$\cos\theta(l,\mathrm{beam})$	$\leq$	0.985	E_l	>	5 GeV	$m(q,q')$	>	10 GeV

Results after $1 \cdot 10^7$ Monte Carlo points.

	AMEGIC++	RacoonWW
final state	σ_{EW} [fb]	σ_{EW} [fb]
Leptonic modes		
$\nu_e\ \bar{\nu}_e\ e^-\ e^+$	256.7(4)	257.1(7)
$\nu_\mu\ \mu^+\ e^-\ \bar{\nu}_e$	227.3(1)	227.5(1)
$\nu_\mu\ \bar{\nu}_\mu\ \mu^-\ \mu^+$	228.8(1)	228.8(1)
$\nu_\mu\ \mu^+\ \tau^-\ \bar{\nu}_\tau$	218.49(9)	218.57(9)
$e^-\ e^+\ e^-\ e^+$	109.3(5)	109.4(3)
$e^-\ e^+\ \mu^-\ \mu^+$	116.2(4)	116.4(3)
$\mu^-\ \mu^+\ \mu^-\ \mu^+$	5.470(5)	5.478(5)
$\mu^+\ \mu^-\ \tau^-\ \tau^+$	11.02(2)	11.02(1)
$e^-\ e^+\ \nu_\mu\ \bar{\nu}_\mu$	14.137(9)	14.150(9)
$\nu_e\ \bar{\nu}_e\ \mu^+\ \mu^-$	17.79(3)	17.73(6)
$\nu_\tau\ \bar{\nu}_\tau\ \mu^+\ \mu^-$	10.100(6)	10.103(8)
$\nu_e\ \bar{\nu}_e\ \nu_e\ \bar{\nu}_e$	4.084(1)	4.082(1)
$\nu_e\ \bar{\nu}_e\ \nu_\mu\ \bar{\nu}_\mu$	8.321(2)	8.337(2)
$\nu_\mu\ \bar{\nu}_\mu\ \nu_\mu\ \bar{\nu}_\mu$	4.058(1)	4.057(1)
$\nu_\mu\ \bar{\nu}_\mu\ \nu_\tau\ \bar{\nu}_\tau$	8.220(2)	8.218(2)
Semi-leptonic modes		
$u\ \bar{d}\ e^-\ \bar{\nu}_e$	692.8(4)	693.6(3)
$u\ \bar{d}\ \mu^-\ \bar{\nu}_\mu$	666.5(3)	666.7(3)
$u\ \bar{u}\ e^-\ e^+$	86.81(7)	86.82(9)
$d\ \bar{d}\ e^-\ e^+$	42.92(4)	42.95(4)
$u\ \bar{u}\ \mu^-\ \mu^+$	24.68(2)	24.69(2)
$d\ \bar{d}\ \mu^-\ \mu^+$	23.71(1)	23.73(1)
$u\ \bar{u}\ \nu_e\ \bar{\nu}_e$	23.88(1)	23.95(2)
$d\ \bar{d}\ \nu_e\ \bar{\nu}_e$	20.63(2)	20.62(1)
$u\ \bar{u}\ \nu_\mu\ \bar{\nu}_\mu$	21.051(6)	21.050(5)
$d\ \bar{d}\ \nu_\mu\ \bar{\nu}_\mu$	19.826(5)	19.817(5)

	AMEGIC++	RacoonWW
final state	σ_{EW} [fb]	σ_{EW} [fb]
Hadronic modes, no QCD		
$u\ \bar{u}\ d\ \bar{d}$	2065.0(9)	2064.3(9)
$u\ \bar{d}\ s\ \bar{c}$	2016.0(9)	2015.3(8)
$u\ \bar{u}\ u\ \bar{u}$	25.732(9)	25.721(7)
$d\ \bar{d}\ d\ \bar{d}$	23.454(6)	23.448(6)
$u\ \bar{u}\ c\ \bar{c}$	51.59(2)	51.57(1)
$u\ \bar{u}\ s\ \bar{s}$	49.63(1)	49.62(1)
$d\ \bar{d}\ s\ \bar{s}$	47.04(1)	47.02(1)
Hadronic modes, with QCD		
$u\ \bar{u}\ d\ \bar{d}$	2142(1)	2141(1)
$u\ \bar{u}\ u\ \bar{u}$	71.33(4)	71.30(4)
$d\ \bar{d}\ d\ \bar{d}$	51.34(4)	51.32(3)
$u\ \bar{u}\ c\ \bar{c}$	144.73(9)	144.75(9)
$u\ \bar{u}\ s\ \bar{s}$	126.52(7)	126.52(8)
$d\ \bar{d}\ s\ \bar{s}$	104.81(6)	104.74(6)

	$\sqrt{s}$ = 200 GeV		$\sqrt{s}$ = 500 GeV	
final state	AMEGIC++	F.J.	AMEGIC++	F.J.
W-pair channels				
$u\,\bar{d}\,\mu^-\,\bar{\nu}_\mu$	630.96(29)	630.65(31)	211.50(20)	211.11(13)
$u\,\bar{d}\,\tau^-\,\bar{\nu}_\tau$	630.50(29)	630.18(31)	211.32(20)	210.95(13)
$c\,\bar{s}\,\mu^-\,\bar{\nu}_\mu$	630.71(28)	630.40(31)	211.39(19)	211.03(13)
$c\,\bar{s}\,\tau^-\,\bar{\nu}_\tau$	630.25(29)	629.93(31)	211.20(19)	210.87(13)
$t\,\bar{b}\,\mu^-\,\bar{\nu}_\mu$	–	–	59.06(1)	58.88(30)
$t\,\bar{b}\,\tau^-\,\bar{\nu}_\tau$	–	–	58.77(1)	58.80(29)
$c\,\bar{s}\,d\,\bar{u}$	1839.3(9)	1838.6(1.4)	749.33(69)	749.07(50)
$t\,\bar{b}\,d\,\bar{u}$	–	–	179.47(4)	177.8(1.9)
$t\,\bar{b}\,s\,\bar{c}$	–	–	179.29(4)	177.4(1.9)
$\nu_\tau\,\tau^+\,\mu^-\,\bar{\nu}_\mu$	205.83(10)	205.88(15)	60.781(55)	60.762(62)
$u\,\bar{u}\,d\,\bar{d}$	1922.6(9)	1921.4(7)	780.79(71)	780.66(25)
$c\,\bar{c}\,s\,\bar{s}$	1928.1(9)	1925.7(8)	782.84(70)	782.62(28)
$t\,\bar{t}\,b\,\bar{b}$	–	–	???	0.85519(56)
$\mu^+\,\mu^-\,\nu_\mu\,\bar{\nu}_\mu$	218.97(10)	218.91(19)	63.885(60)	63.933(70)
$\tau^+\,\tau^-\,\nu_\tau\,\bar{\nu}_\tau$	215.06(10)	214.94(20)	63.496(56)	63.468(74)
single-W channels				
$u\,\bar{d}\,e^-\,\bar{\nu}_e$	662.10(31)	661.68(40)	353.95(36)	354.06(27)
$c\,\bar{s}\,e^-\,\bar{\nu}_e$	661.79(31)	661.42(40)	353.82(36)	353.91(27)
$t\,\bar{b}\,e^-\,\bar{\nu}_e$	–	–	59.13(1)	58.54(65)
$\nu_\mu\,\mu^+\,e^-\,\bar{\nu}_e$	216.27(10)	216.29(21)	107.30(10)	107.34(14)
$\nu_\tau\,\tau^+\,e^-\,\bar{\nu}_e$	215.97(6)	216.13(21)	107.01(11)	107.25(13)
neutral leptonic channels				
$\mu^+\,\mu^-\,\tau^+\,\tau^-$	10.249(4)	10.267(14)	2.5066(11)	2.5117(44)
$\mu^+\,\mu^-\,\nu_\tau\,\bar{\nu}_\tau$	12.737(4)	12.729(10)	3.0344(20)	3.0336(31)
$\tau^+\,\tau^-\,\bar{\nu}_\mu\,\nu_\mu$	9.1570(21)	9.1659(59)	2.7215(12)	2.7174(27)
$\nu_\mu\,\bar{\nu}_\mu\,\nu_\tau\,\bar{\nu}_\tau$	10.612(4)	10.608(6)	4.0781(45)	3.9179(43)
$\mu^+\,\mu^-\,e^+\,e^-$	???	137.18(90)	???	43.80(38)
$\tau^+\,\tau^-\,e^+\,e^-$	???	54.49(18)	???	16.860(61)
$\mu^+\,\mu^-\,\nu_e\,\bar{\nu}_e$	17.803(13)	17.780(18)	24.117(46)	24.031(92)
$\tau^+\,\tau^-\,\nu_e\,\bar{\nu}_e$	11.705(6)	11.721(10)	21.378(28)	21.389(90)
$\nu_e\,\bar{\nu}_e\,\nu_\mu\,\bar{\nu}_\mu$	11.444(4)	11.448(8)	24.762(22)	24.728(47)
$\nu_\mu\,\bar{\nu}_\mu\,e^+\,e^-$	???	23.503(22)	???	9.453(14)
$\mu^+\,\mu^-\,\mu^+\,\mu^-$	6.878(8)	6.747(13)	1.5255(16)	1.5106(36)
$\tau^+\,\tau^-\,\tau^+\,\tau^-$	3.7308(11)	3.7283(30)	1.0346(4)	1.0341(11)
$\nu_\mu\,\bar{\nu}_\mu\,\nu_\mu\,\bar{\nu}_\mu$	5.2660(12)	5.2660(23)	2.0657(12)	1.9577(15)
$e^+\,e^-\,e^+\,e^-$	50.83(36)	50.53(10)	13.965(64)	13.927(32)
$\nu_e\,\bar{\nu}_e\,\nu_e\,\bar{\nu}_e$	5.9843(20)	5.9815(27)	22.449(20)	22.482(61)

	$\sqrt{s}$ = 200 GeV		$\sqrt{s}$ = 500 GeV	
final state	AMEGIC++	F.J.	AMEGIC++	F.J.
neutral semi-leptonic channels				
$u\,\bar{u}\,\mu^+\,\mu^-$	27.332(10)	27.341(30)	6.862(3)	6.855(10)
$u\,\bar{u}\,\tau^+\,\tau^-$	19.491(6)	19.543(17)	5.9138(56)	5.9096(69)
$u\,\bar{u}\,\nu_\mu\,\bar{\nu}_\mu$	22.633(5)	22.614(14)	8.3860(41)	8.3860(99)
$c\,\bar{c}\,\mu^+\,\mu^-$	27.258(30)	27.287(27)	6.9809(33)	6.9946(88)
$c\,\bar{c}\,\tau^+\,\tau^-$	19.471(5)	19.560(16)	6.0579(27)	6.0566(68)
$c\,\bar{c}\,\nu_\mu\,\bar{\nu}_\mu$	22.612(5)	22.655(13)	8.6792(42)	8.6652(83)
$t\,\bar{t}\,\mu^+\,\mu^-$	–	–	0.1827(1)	0.1832(2)
$t\,\bar{t}\,\tau^+\,\tau^-$	–	–	0.12002(4)	0.11991(10)
$t\,\bar{t}\,\nu_\mu\,\bar{\nu}_\mu$	–	–	0.07012(2)	0.07010(2)
$d\,\bar{d}\,\mu^+\,\mu^-$	29.549(9)	29.541(24)	7.0680(31)	7.0683(80)
$d\,\bar{d}\,\tau^+\,\tau^-$	21.192(5)	21.256(16)	6.2903(26)	6.2854(61)
$d\,\bar{d}\,\nu_\mu\,\bar{\nu}_\mu$	24.659(5)	24.634(15)	9.0204(47)	9.0094(91)
$s\,\bar{s}\,\mu^+\,\mu^-$	29.540(9)	29.542(25)	7.0667(31)	7.0702(73)
$s\,\bar{s}\,\tau^+\,\tau^-$	21.190(5)	21.257(16)	6.2934(26)	6.2907(62)
$s\,\bar{s}\,\nu_\mu\,\bar{\nu}_\mu$	24.658(5)	24.637(15)	9.0238(48)	9.0125(89)
$b\,\bar{b}\,\mu^+\,\mu^-$	29.524(9)	29.536(23)	8.6917(34)	8.6899(74)
$b\,\bar{b}\,\tau^+\,\tau^-$	21.354(5)	21.349(16)	7.9195(29)	7.9184(66)
$b\,\bar{b}\,\nu_\mu\,\bar{\nu}_\mu$	25.037(5)	25.019(15)	12.323(5)	12.322(9)
$u\,\bar{u}\,e^+\,e^-$	77.41(7)	77.31(26)	28.24(4)	28.37(11)
$c\,\bar{c}\,e^+\,e^-$	76.79(7)	77.02(19)	28.995(34)	29.030(91)
$t\,\bar{t}\,e^+\,e^-$	–	–	???	172.63(30)
$d\,\bar{d}\,e^+\,e^-$	58.750(31)	58.759(82)	23.678(23)	23.668(46)
$s\,\bar{s}\,e^+\,e^-$	58.720(32)	58.734(80)	23.671(24)	23.702(46)
$b\,\bar{b}\,e^+\,e^-$	58.027(29)	58.082(66)	29.48(3)	29.38(11)
$u\,\bar{u}\,\nu_e\,\bar{\nu}_e$	25.507(9)	25.502(19)	49.02(5)	49.18(22)
$c\,\bar{c}\,\nu_e\,\bar{\nu}_e$	25.910(11)	25.907(21)	55.39(6)	55.13(26)
$t\,\bar{t}\,\nu_e\,\bar{\nu}_e$	–	–	0.07405(2)	0.07400(4)
$d\,\bar{d}\,\nu_e\,\bar{\nu}_e$	26.826(8)	26.820(20)	57.12(5)	57.03(27)
$s\,\bar{s}\,\nu_e\,\bar{\nu}_e$	26.824(8)	26.824(22)	57.261(63)	57.320(28)
$b\,\bar{b}\,\nu_e\,\bar{\nu}_e$	31.363(10)	31.346(28)	130.47(15)	128.31(65)

	$\sqrt{s} = 200$ GeV		$\sqrt{s} = 500$ GeV	
final state	AMEGIC++	F.J.	AMEGIC++	F.J.
neutral hadronic channels				
$u\,\bar{u}\,s\,\bar{s}$	83.72(4)	83.63(12)	32.595(20)	32.561(51)
$u\,\bar{u}\,b\,\bar{b}$	86.627(39)	86.565(95)	38.484(20)	38.475(45)
$c\,\bar{c}\,d\,\bar{d}$	84.34(4)	84.41(12)	33.362(20)	33.150(92)
$c\,\bar{c}\,b\,\bar{b}$	87.308(33)	87.209(83)	39.223(20)	39.237(42)
$t\,\bar{t}\,d\,\bar{d}$	–	–	0.9030(4)	0.903(1)
$t\,\bar{t}\,s\,\bar{s}$	–	–	0.9033(4)	0.903(1)
$d\,\bar{d}\,s\,\bar{s}$	79.750(32)	79.658(95)	29.809(18)	29.812(39)
$d\,\bar{d}\,b\,\bar{b}$	82.569(30)	82.486(87)	37.424(19)	37.435(39)
$u\,\bar{u}\,c\,\bar{c}$	87.12(4)	87.06(13)	35.870(22)	35.826(61)
$u\,\bar{u}\,t\,\bar{t}$	–	–	0.9074(4)	0.9071(11)
$u\,\bar{u}\,u\,\bar{u}$	42.510(42)	42.465(45)	17.433(23)	17.410(27)
$c\,\bar{c}\,c\,\bar{c}$	43.306(41)	43.323(44)	18.121(14)	18.076(23)
$d\,\bar{d}\,d\,\bar{d}$	39.229(45)	39.173(32)	14.763(9)	14.758(15)
$s\,\bar{s}\,s\,\bar{s}$	39.211(45)	39.167(32)	14.768(11)	14.767(15)
$b\,\bar{b}\,b\,\bar{b}$	41.729(55)	41.667(24)	22.243(11)	22.242(14)

Sfermion pair production (SPS1a)

final state	$\sqrt{s}$ [GeV]	AMEGIC++ [fb]	Value [fb]	Ref.
Sleptons and sneutrinos				
$\tilde{\nu}_1^* \, \tilde{\nu}_1$	500	529.5(3)	529.1	hep-ph/0107316
$\tilde{\nu}_2^* \, \tilde{\nu}_2$	500	16.015(7)	16.007	hep-ph/0002115
$\tilde{\nu}_3^* \, \tilde{\nu}_3$	500	16.316(7)	16.307	hep-ph/0002115
$\tilde{e}_L^* \, \tilde{e}_L$	500	63.17(5)	63.12	hep-ph/0107316
$\tilde{e}_R^* \, \tilde{e}_R$	500	321.95(33)	321.71	hep-ph/0107316
$\tilde{e}_L^* \, \tilde{e}_R$	500	86.18(11)	86.17	hep-ph/0107316
$\tilde{\mu}_L^* \, \tilde{\mu}_L$	500	25.01(1)	25.00	hep-ph/0002115
$\tilde{\mu}_R^* \, \tilde{\mu}_R$	500	60.09(3)	60.06	hep-ph/0002115
$\tilde{\tau}_1^* \, \tilde{\tau}_1$	500	64.23(3)	64.19	hep-ph/0002115
$\tilde{\tau}_2^* \, \tilde{\tau}_2$	500	21.35(1)	21.34	hep-ph/0002115
$\tilde{\tau}_2^* \, \tilde{\tau}_1$	500	1.497(1)	1.496	hep-ph/0002115
Squarks				
$\tilde{u}_L^* \, \tilde{u}_L$	1200	3.398(2)	3.396	hep-ph/0002115
$\tilde{u}_R^* \, \tilde{u}_R$	1200	3.088(1)	3.087	hep-ph/0002115
$\tilde{d}_L^* \, \tilde{d}_L$	1200	2.014(1)	2.013	hep-ph/0002115
$\tilde{d}_R^* \, \tilde{d}_R$	1200	0.7763(3)	0.7759	hep-ph/0002115
$\tilde{s}_L^* \, \tilde{s}_L$	1200	2.014(1)	2.013	hep-ph/0002115
$\tilde{s}_R^* \, \tilde{s}_R$	1200	0.7763(3)	0.7759	hep-ph/0002115
$\tilde{c}_L^* \, \tilde{c}_L$	1200	3.398(2)	3.396	hep-ph/0002115
$\tilde{c}_R^* \, \tilde{c}_R$	1200	3.088(1)	3.086	hep-ph/0002115
$\tilde{b}_1^* \, \tilde{b}_1$	1000	0.1692(1)	0.1691	hep-ph/0002115
$\tilde{b}_2^* \, \tilde{b}_2$	1200	0.7116(3)	0.7112	hep-ph/0002115
$\tilde{b}_2^* \, \tilde{b}_1$	1200	0.6956(3)	0.6952	hep-ph/0002115
$\tilde{t}_1^* \, \tilde{t}_1$	800	1.702(1)	1.701	hep-ph/0002115
$\tilde{t}_2^* \, \tilde{t}_2$	1200	0.7482(3)	0.7478	hep-ph/0002115
$\tilde{t}_2^* \, \tilde{t}_1$	1200	1.2598(6)	1.2591	hep-ph/0002115

Gaugino pair production (SPS1a)

final state	$\sqrt{s}$ [GeV]	AMEGIC++ [fb]	Value [fb]	Ref.
Charginos				
$\chi_1^+ \chi_1^-$	500	175.1(1)	174.9	Z. Phys. C **30** (1986) 441
$\chi_2^+ \chi_2^-$	800	72.121(6)	72.127	Z. Phys. C **30** (1986) 441
$\chi_1^+ \chi_2^-$	800	20.132(1)	20.130	Z. Phys. C **30** (1986) 441
Neutralinos				
$\chi_1^0 \chi_1^0$	500	275.49(9)	275.47	Nucl. Phys. B **278** (1986) 1
$\chi_1^0 \chi_2^0$	500	68.69(2)	68.67	Nucl. Phys. B **278** (1986) 1
$\chi_1^0 \chi_3^0$	500	9.2324(3)	9.2327	Nucl. Phys. B **278** (1986) 1
$\chi_1^0 \chi_4^0$	500	1.501(6)	1.501	Nucl. Phys. B **278** (1986) 1
$\chi_2^0 \chi_2^0$	500	76.20(3)	76.19	Nucl. Phys. B **278** (1986) 1
$\chi_2^0 \chi_3^0$	800	11.5195(1)	11.5195	Nucl. Phys. B **278** (1986) 1
$\chi_2^0 \chi_4^0$	800	8.987(3)	8.985	Nucl. Phys. B **278** (1986) 1
$\chi_3^0 \chi_3^0$	800	2.772(1)E-03	2.771E-03	Nucl. Phys. B **278** (1986) 1
$\chi_3^0 \chi_4^0$	800	33.2398(6)	33.2393	Nucl. Phys. B **278** (1986) 1
$\chi_4^0 \chi_4^0$	800	4.439(1)E-02	4.438E-02	Nucl. Phys. B **278** (1986) 1

Higgs pair production (SPS1a)

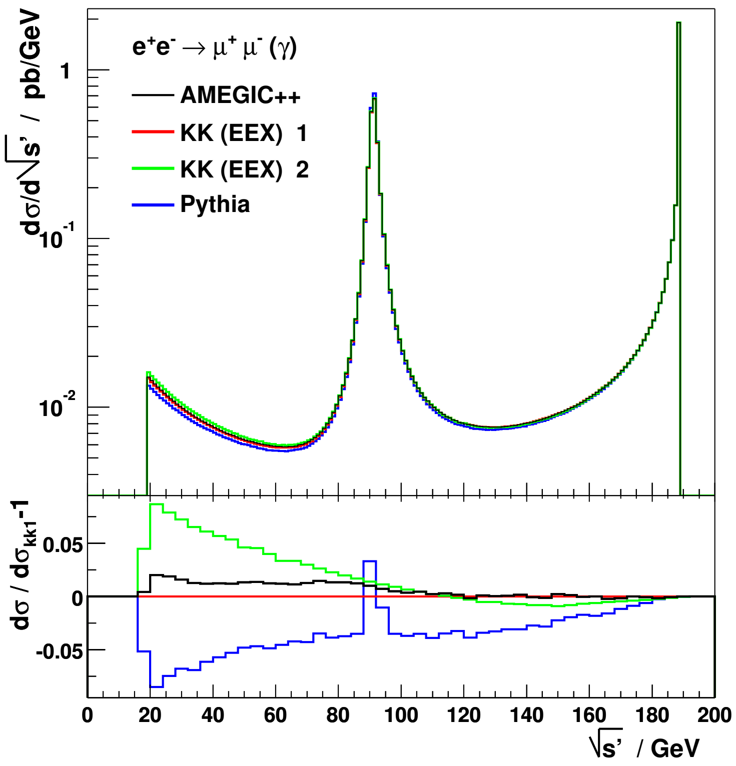
final state	$\sqrt{s}$ [GeV]	AMEGIC++ [fb]	Value [fb]	Ref.
$A^0 h^0$	800	9.155(5)E-04	9.150E-04	Z. Phys. C **57** (1993) 569
$A^0 H^0$	800	8.187(4)E-02	8.182E-02	Phys. Lett. B **375** (1996) 203
$H^+ H^-$	1000	5.779(3)	5.777	Z. Phys. C **57** (1993) 569

ISR in e^+e^-

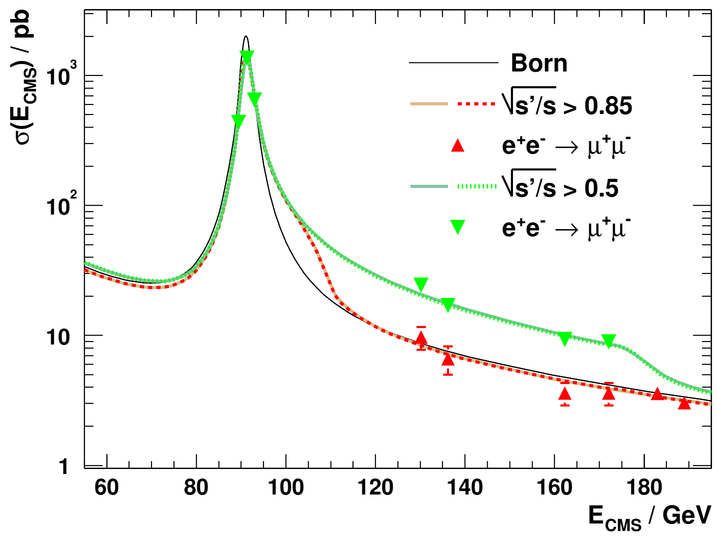
- This is in most of the cases the most important higher order correction.
- Loop corrections might be important, treatment of ISR is paramount.

Treatment within `AMEGIC++` : Yennie-Frautschi-Suura method

exact in 1st order α + Resummation of large logs



AMEGIC++ vs. ZFITTER vs. Data



Combine matrix elements + parton showers

work in parts with S. Catani, R. Kuhn, B. Webber

Goal: Universality of fragmentation parameters (energy dependent)

Goal: Combination procedure of ME + PS:

Produce jets (energetic particles, large angles) by ME

Evolve jets by PS down to fragmentation scale

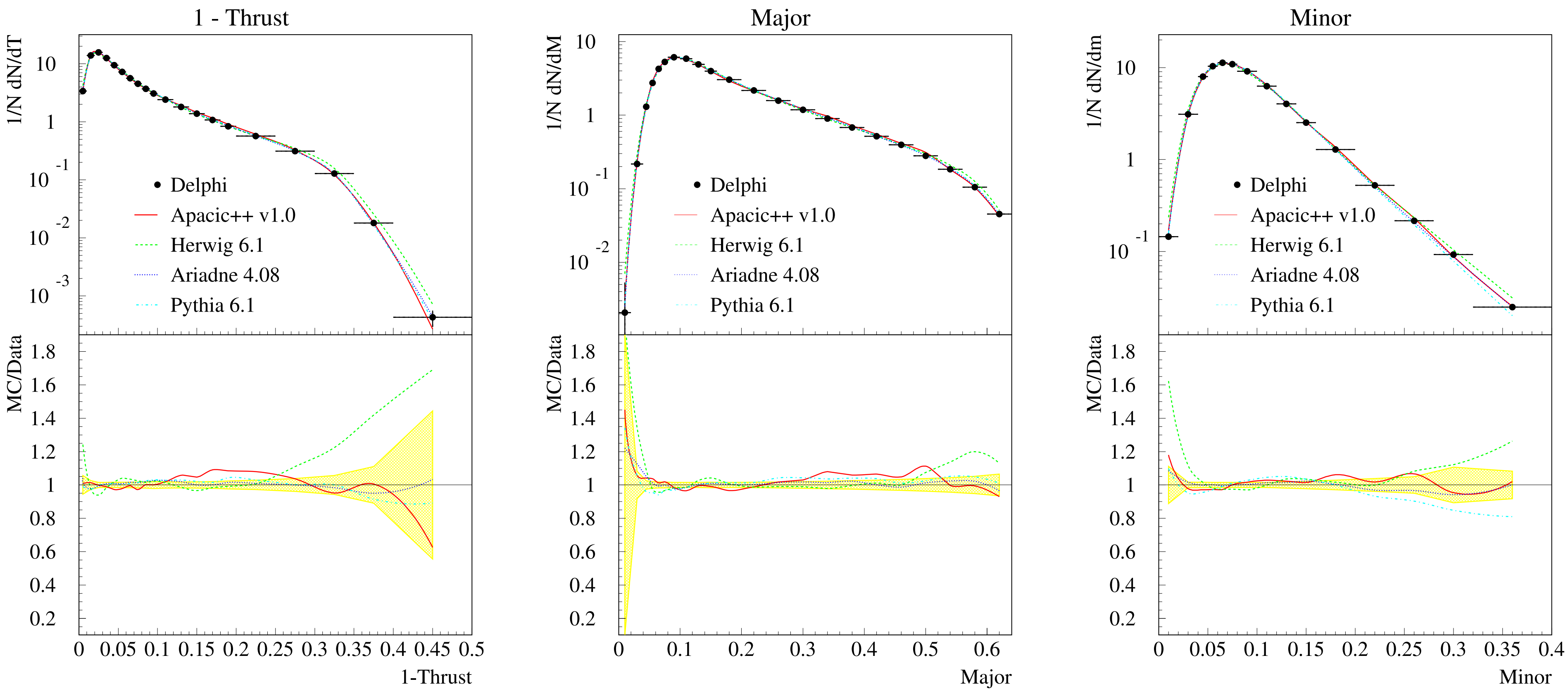
Strategy: Divide phasespace into jet production & jet evolution via $y_{\rm jet}$:

$$2 \cdot \min\{E_i^2,\ E_j^2\} \cdot (1 - \cos\theta_{ij}) \gtrless y_{\rm jet} E_{\rm cm}^2$$

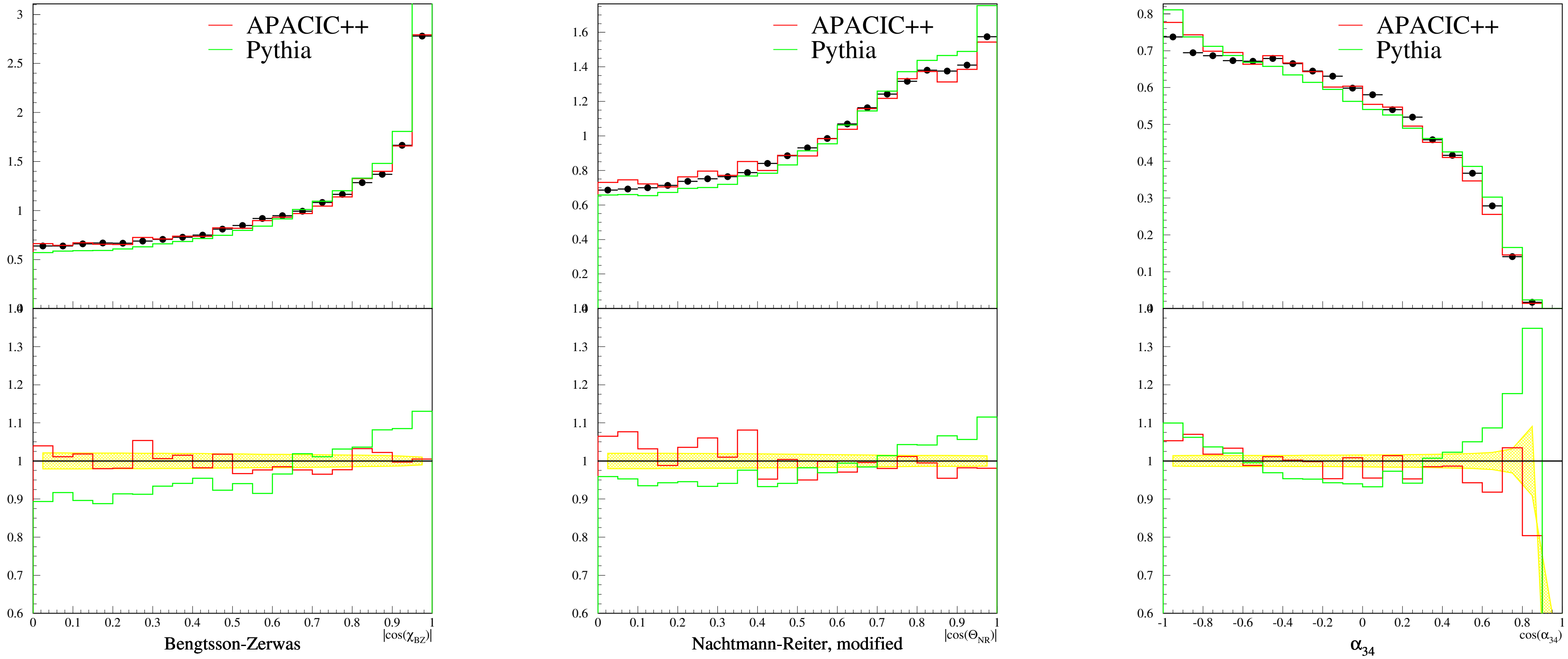
Weight ME's, Veto on PS.

$\Longrightarrow$ Implementation in `APACIC++`

Results for LEP (e^+e^- at 91GeV):



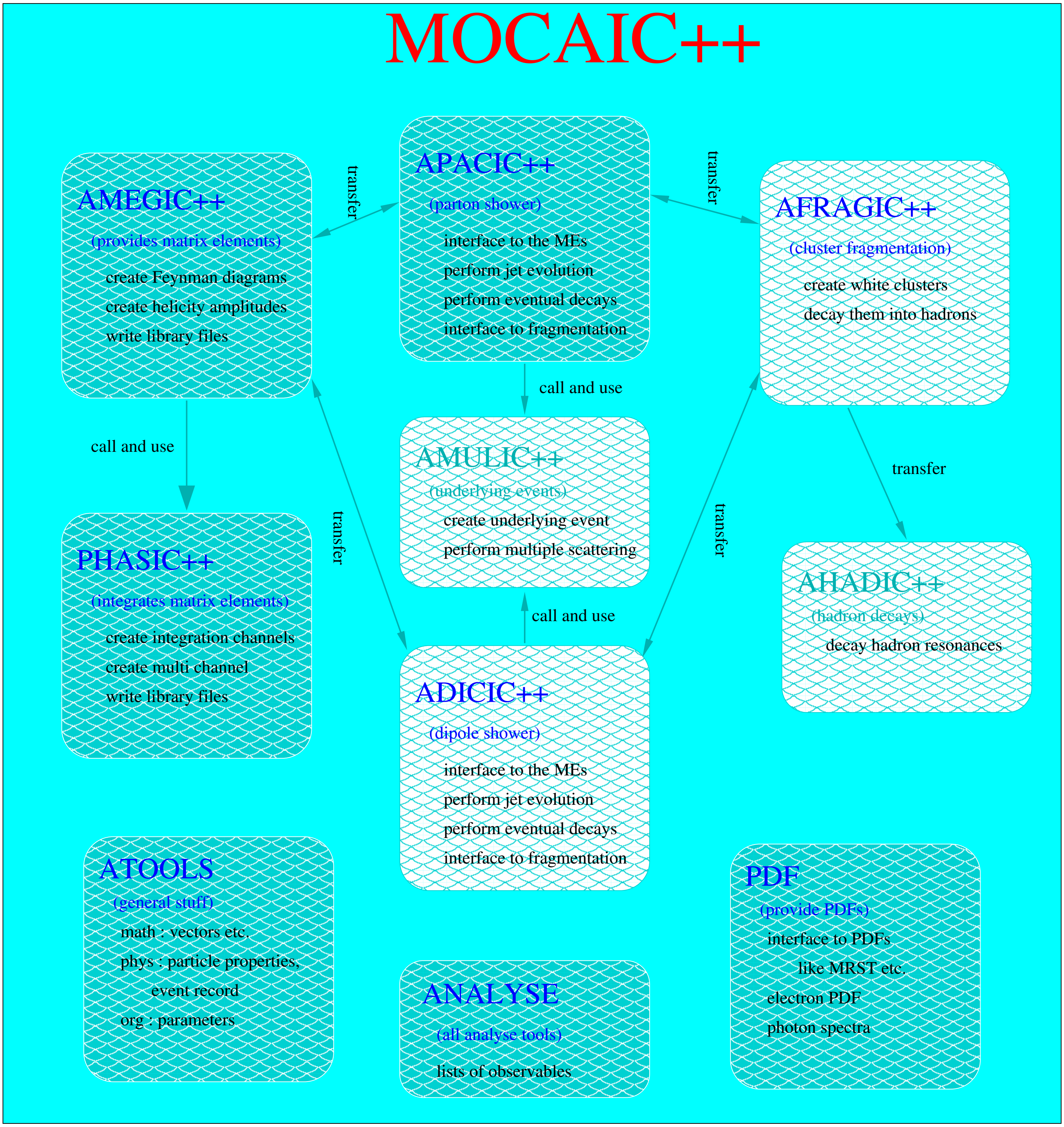
Results for LEP (e^+e^- at 91GeV):



Plans for the near future

- AMEGIC++ :
  1. Finish checks for e^+e^-: Add photon(s) to the final state.
  2. Check 6 fermion final states.
  3. Finish checks of MSSM in e^+e^-.
  4. Check polarized cross sections.
  5. Check cross sections in pp collisions.
  6. Improve library handling.
  7. Improve user-interface.
  8. Write manual for version 2.0 and create homepage for the code.

- APACIC++ :
  1. Tune the code again after recent re-write (e^+e^- at 91.2 GeV).
  2. Finish implementation of combination of ME+PS for hadronic initial state.
  3. Check simulation of hadronic initial states (vs. Tevatron data).
  4. Write manual for version 2.0 and create homepage for the code.
- "Wrapper" :
  1. Create a common structure (like PYTHIA 7) for modules.
  2. Tentative names : SiC++ (Something in C++), MOCAIC (MOnte CArlo In C++).


MOCAIC++
AMEGIC++
(provides matrix elements)
create Feynman diagrams
create helicity amplitudes
write library files
transfer
APACIC++
(parton shower)
interface to the MEs
perform jet evolution
perform eventual decays
interface to fragmentation
transfer
AFRAGIC++
(cluster fragmentation)
create white clusters
decay them into hadrons
call and use
call and use
AMULIC++
(underlying events)
create underlying event
perform multiple scattering
transfer
transfer
transfer
PHASIC++
(integrates matrix elements)
create integration channels
create multi channel
write library files
AHADIC++
(hadron decays)
decay hadron resonances
call and use
ADICIC++
(dipole shower)
interface to the MEs
perform jet evolution
perform eventual decays
interface to fragmentation
ATOOLS
(general stuff)
math : vectors etc.
phys : particle properties,
event record
org : parameters
ANALYSE
(all analyse tools)
lists of observables
PDF
(provide PDFs)
interface to PDFs
like MRST etc.
electron PDF
photon spectra