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W mass precision due to EWK simulation

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Overview and goals

Present some results and the issues we encountered

Starting point for a discussion

goal to agree on a prescription of how to get the EWK uncertainty
(one which the theorists are willing to sign under...)

We need to propagate the leptons and the photons through
a detailed and fine-tuned detector simulation

interface (weighted) generated events to our simulation code

We have interfaced:
- a tuned Behrends&Kleiss (gives nearly exact WGRAD1 results)
- Photos (on top of Born)
- Horace 3.1
- (started working on WGRAD2, put on hold)
- Sampling a WGRAD(1) histogram (see Chris Hays's talk)

Sources of uncertainty

generator validation

sources of uncertainty

parameters/
assumptions

the "missing" parts

- truncated perturbation
- missing processes
- interference with QCD

interested in the size of the shift
the effects introduce to the measured W mass

Generator comparisons

Does "O(a)" have the same definition for different generators?

Inclusive comparisons done regularly
- need also differential comparisons

Are there any issues when comparing angular and energy distributions?

subtraction terms?

$$y = E_\gamma/(E_\ell + E_\gamma) \qquad dR = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$$

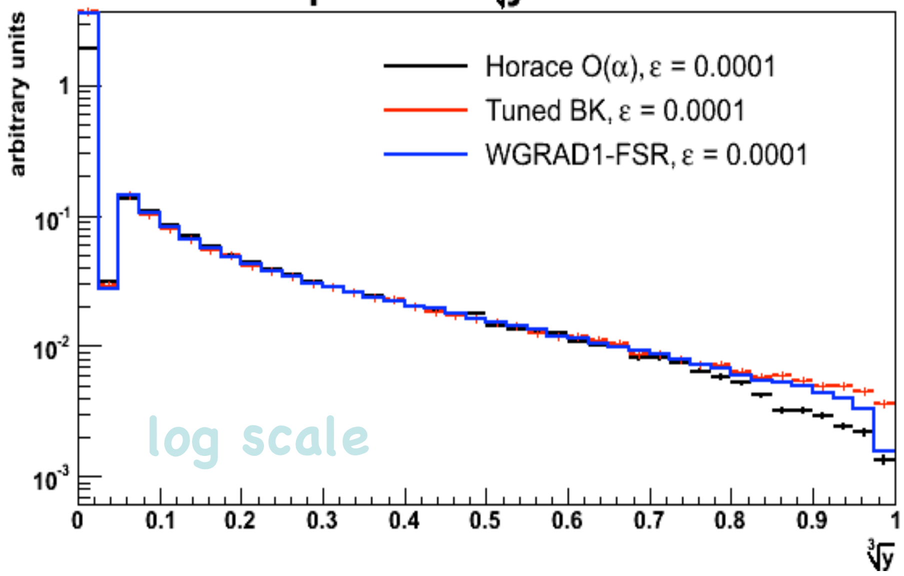
$$\sqrt[3]{y} \qquad \sqrt{dR}$$

(Ultimately fit one against another - if we had them all interfaced)

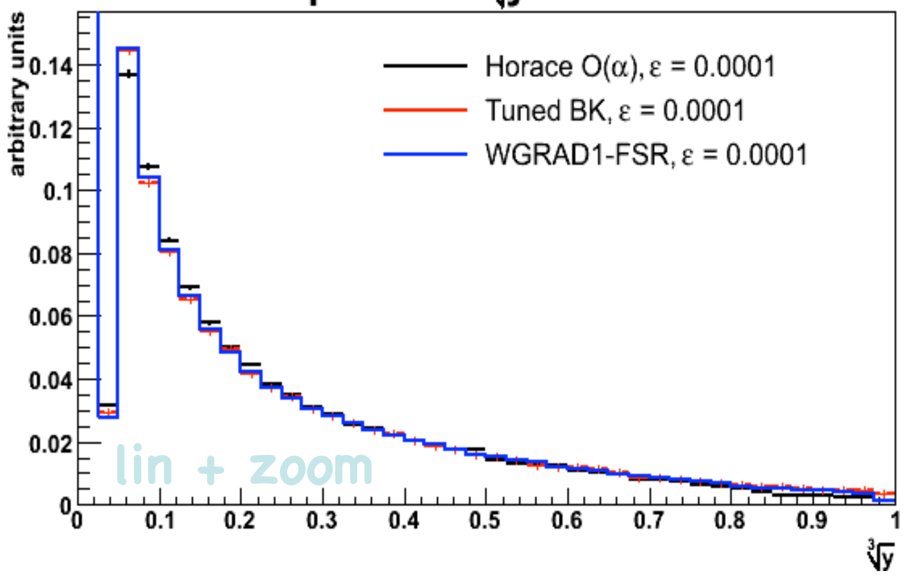
photon distributions ($W \rightarrow \mu\nu$)

Horace contains ISR

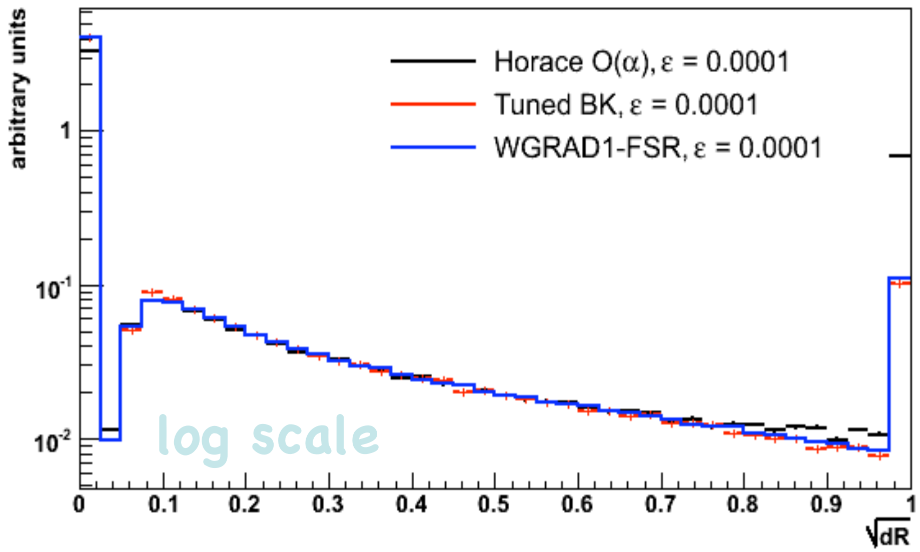
Generator comparison: $\sqrt[3]{y}$



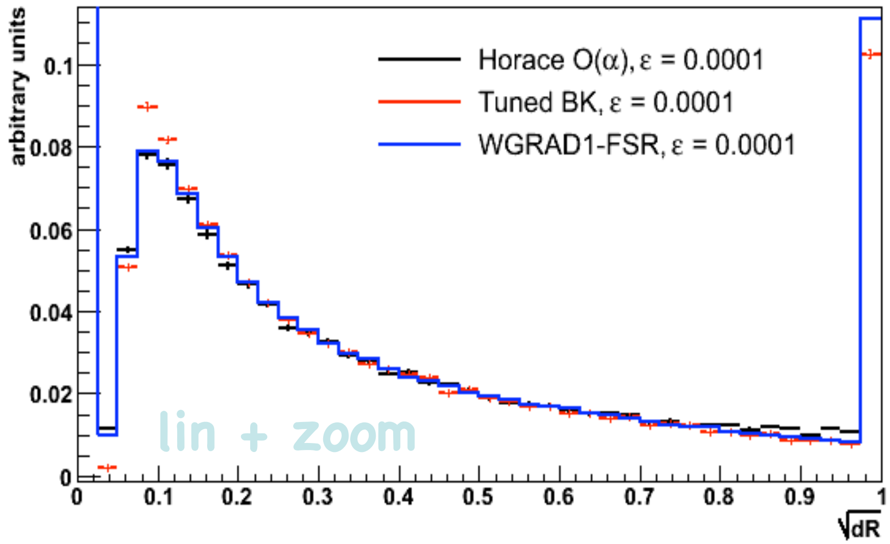
Generator comparison: $\sqrt[3]{y}$



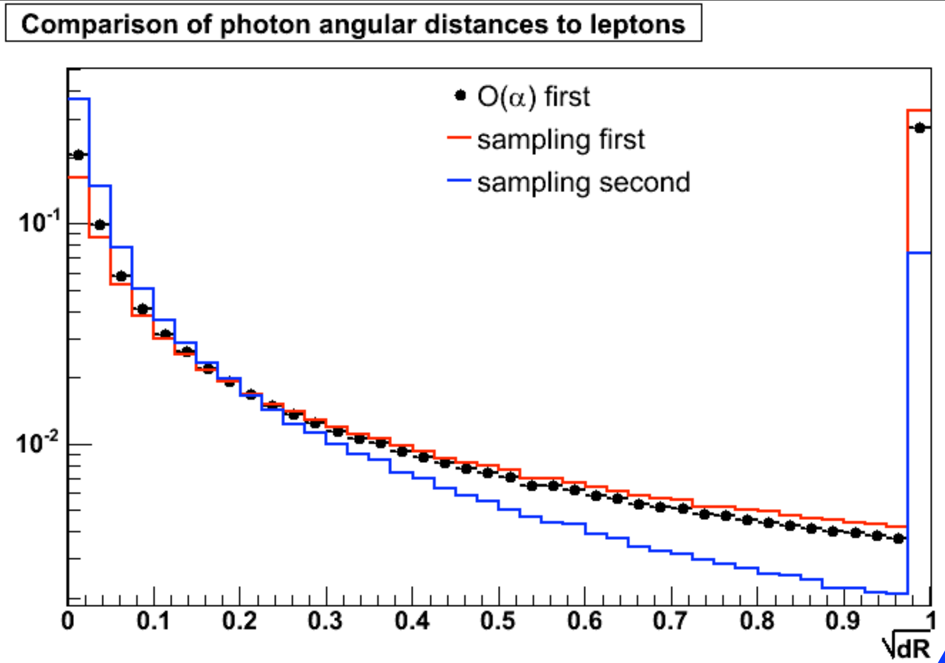
Generator comparison: $\sqrt{dR}$



Generator comparison: $\sqrt{dR}$

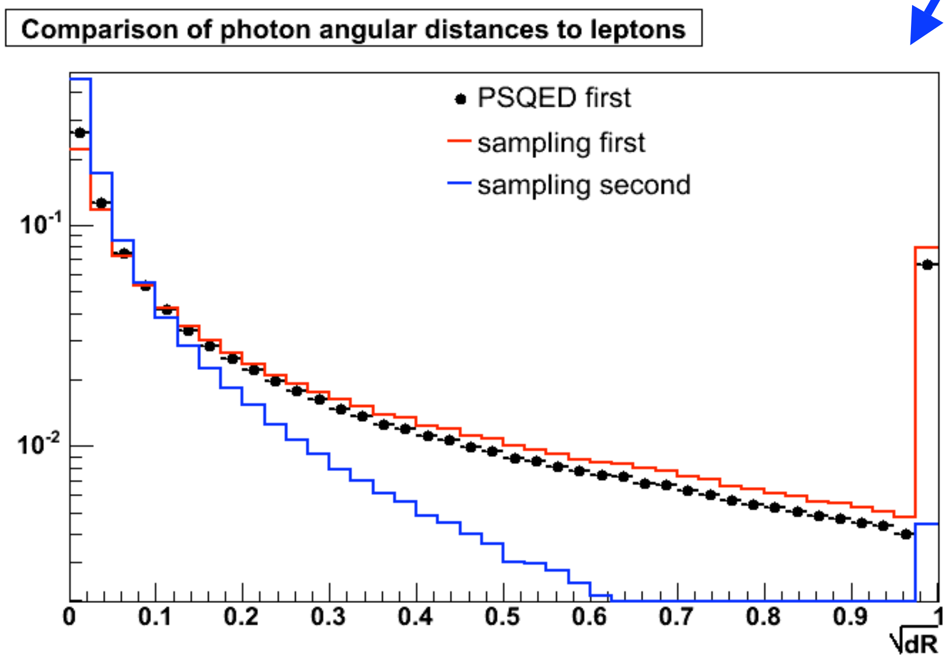


1st / 2nd photon

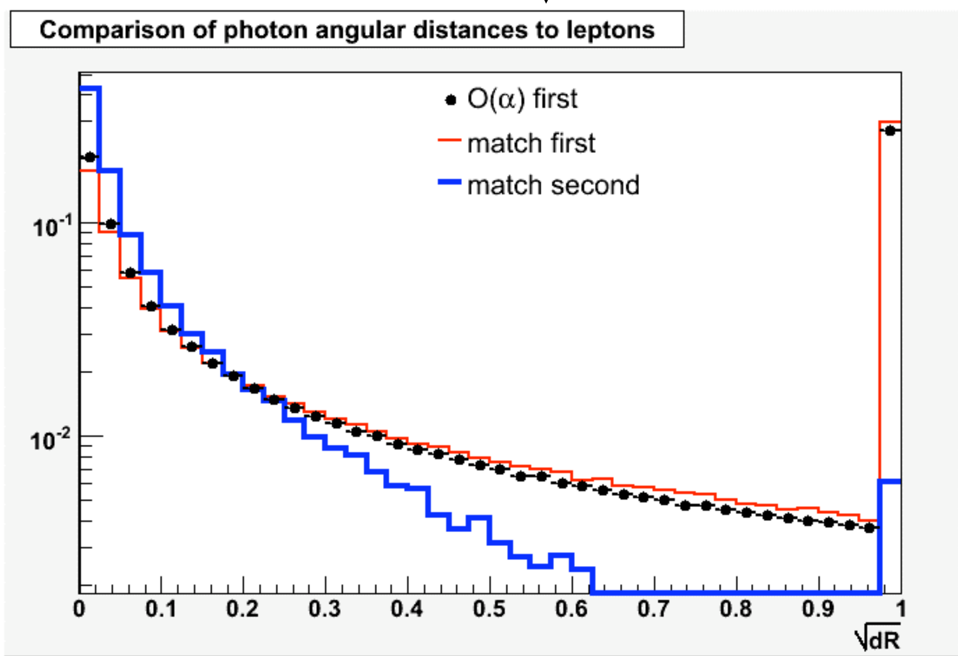


Predicted by sampling O(a)

Predicted by sampling PSQED



generated with Horace



Observed shifts on W mass

	m_T		p_T		$\not{E}_T$	
	e	μ	e	μ	e	μ
born - O(α)	147 ± 2.0	154 ± 1.8	174 ± 2.5	208 ± 2.5	105 ± 2.6	93 ± 2.0
born - match	137 ± 2.1	136 ± 2.4	163 ± 2.6	187 ± 2.4	96 ± 2.8	76 ± 1.9
O(α) - match	11 ± 2.4	19 ± 2.0	12 ± 2.9	22 ± 2.8	9 ± 3.1	18 ± 2.2
born - LL 1g	143 ± 2.2	148 ± 1.5	167 ± 2.6	198 ± 2.2	104 ± 2.8	89 ± 1.8
born - LL ng	138 ± 2.2	138 ± 1.5	162 ± 2.6	184 ± 2.2	104 ± 2.8	85 ± 1.8
LL1g - LL ng	5 ± 2.5	10 ± 1.6	5 ± 3.1	15 ± 2.3	1 ± 3.2	5 ± 1.8
LL1g - O(α)	1 ± 2.4	3 ± 1.8	3 ± 2.9	5 ± 2.6	1 ± 3.1	1 ± 2.1
LLng - match	4 ± 2.5	5 ± 1.7	4 ± 3.0	2 ± 2.5	10 ± 3.2	10 ± 2.0

Going to more photons reduces the EWK effect on the W mass
The shift is -11 MeV and -19 MeV

The difference between O(a) and LL1g is small (a few MeV)

Uncertainty of the matched Leading Log QED PS

$F_H = 1 + \delta$

- $F_{SV} = 1 + (C_\alpha - C_{\alpha,LL})$ $\quad F_H = 1 + \frac{|\mathcal{M}_1|^2 - |\mathcal{M}_{1,LL}|^2}{|\mathcal{M}_{1,LL}|^2}$

- $d\sigma^\alpha_{exact} \overset{\text{at } \mathcal{O}(\alpha)}{=} F_{SV}(1 + C_{\alpha,LL})|\mathcal{M}_0|^2 d\Phi_0 + F_H |\mathcal{M}_{1,LL}|^2 d\Phi_1$

$$d\sigma^\infty_{matched} = F_{SV}\ \Pi(Q^2, \varepsilon)\ \sum_{n=0}^\infty \frac{1}{n!}\ \left(\prod_{i=0}^n F_{H,i}\right)\ |\mathcal{M}_{n,LL}|^2\ d\Phi_n$$

correction to all orders

n-photon correction a product of 1-photon corrections

fully differential calculation

$(1 + \delta_1)(1 + \delta_2)(1 + \delta_3) \ldots$

1-photon corrections exact, n-photon corrections approximated as δ^n

As $\delta \approx 3/140 \approx$ 2%, the uncertainty of the procedure of the order of

140 MeV x δ^2 = 0.1 MeV ?

perturbation validation

Horace authors have implemented the calculation in **2 EWK schemes**, G_μ and α, which truncate the perturbative series in a different way

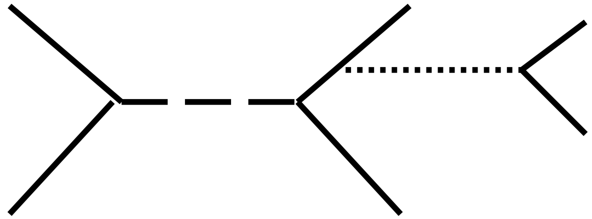
The difference should give a sense of the size of the "second photon" error

The difference should fall from O(a) to match (next order)

	m_T		p_T		E_T	
	e	μ	e	μ	e	μ
$G\mu$ / α … $O(\alpha)$	9 ± 2.3	9 ± 2.1	10 ± 2.8	12 ± 2.9	5 ± 2.9	6 ± 2.3
$G\mu$ / α … match	0.3 ± 2.5	0.4 ± 1.9	0.1 ± 3.0	0.1 ± 2.6	0.5 ± 3.2	0.3 ± 2.1

Missing processes

Pair creation is not included
in the current version of Horace



the two leptons can have low p_T and do not reach the calorimeter

Same order as 2-photon emission ⇨ A potential 10MeV effect?

The effect might be reduced due to soft-virtual cancellations

We need to find a reliable way of estimating its effect

Assumptions and parameters

Input EWK parameters, the soft separator (ϵ/δ_c), any others?

vary within their uncertainties and observe the M_W shift

are their uncertainties absorbed in the tunes to data?

$\alpha\alpha_s$ effects - interference between EWK and QCD

see Mark's talk tomorrow
What is the right way to combine p_T boosts of ISR EWK and QCD

$\alpha_s > \alpha$, so gluon emission faster than ISR photon

boosting or not the ISR photons has ≈5±3MeV effect
(can be better understood using WGRAD2)

Resbos-A? Playing around with the PDF scale?

Conclusions

We have studied the effects of using a matched LL QED PS generator (Horace 3.1) for simulating EWK effects

The uncertainty on the W mass =

$$\Delta M_W^{tot} = \Delta M_W^{matching} \oplus \Delta M_W^{missing\ p.} \oplus \Delta M_W^{pars} \oplus \Delta M_W^{\alpha\alpha_s}$$

< 2MeV 10MeV? n/a ≈ 5MeV?

Are there other contributions?

How can we reliably estimate the effect of the missing process(es) ?