



# Status of $\pi^0$ calibration

#### (review of results from last year)

Hao Huang

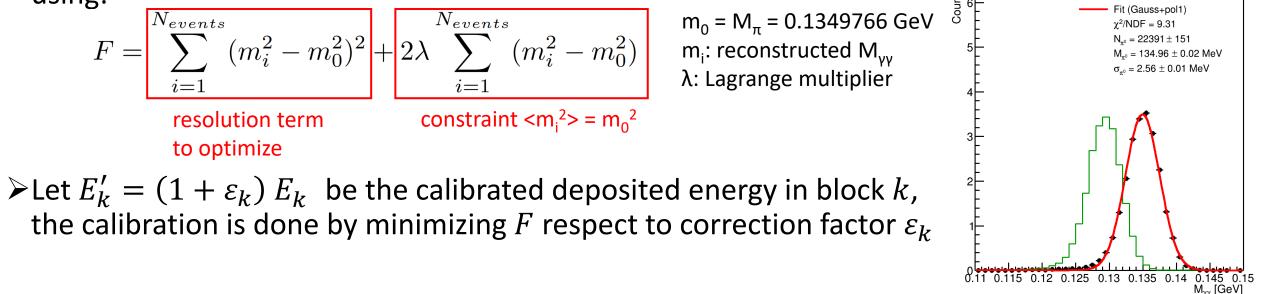
NPS Collaboration Meeting

2025.05.05

# Method of $\pi^0$ calibration



- "A bootstrap method for gain calibration and resolution determination of a lead-glass calorimeter" (Nuclear Instruments and Methods in Physics Research A 566 (2006) 366–374)
- > Optimize the width of  $\pi^0$  invariant mass peak while constrain the peak position simultaneously using:



 $\succ$  Iterations are required till the mean and width of  $\pi^0$  are converged ( $\varepsilon_k \rightarrow 0$ )

#### Performance of $\pi^0$ calibration with simulation



 $M_{\gamma\gamma}$  (E<sub>1</sub> > 1 GeV && E<sub>1</sub> > 1 GeV)

Data

Fit (Gauss+pol1)  $\chi^2/NDF = 9.31$ 

 $N_{\pi^0} = 22391 \pm 151$ 

 $M_{\pi^0} = 134.96 \pm 0.02 \text{ MeV}$ 

 $\times 10^{\circ}$ 

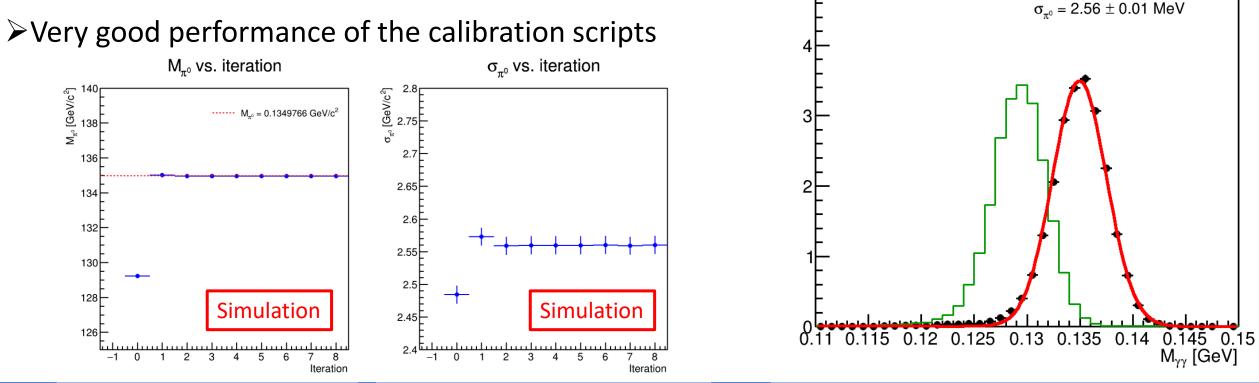
Simulation

Counts

6

#### ➤MC data reconstructed using Geant4

- ~300k events of  $\pi^0\!\rightarrow\gamma\gamma$  were generated
- HMS momentum = -6.667 GeV/c, angle = 12.493 degree
- SHMS angle = 36.88 degree, NPS angle = 20.58 degree
- NPS at 3 meter (the first kinematic we took)

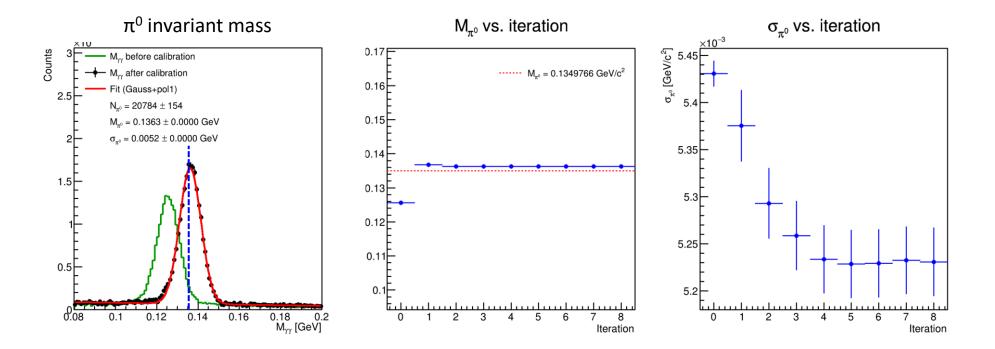


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### Results of $\pi^0$ calibration with real data



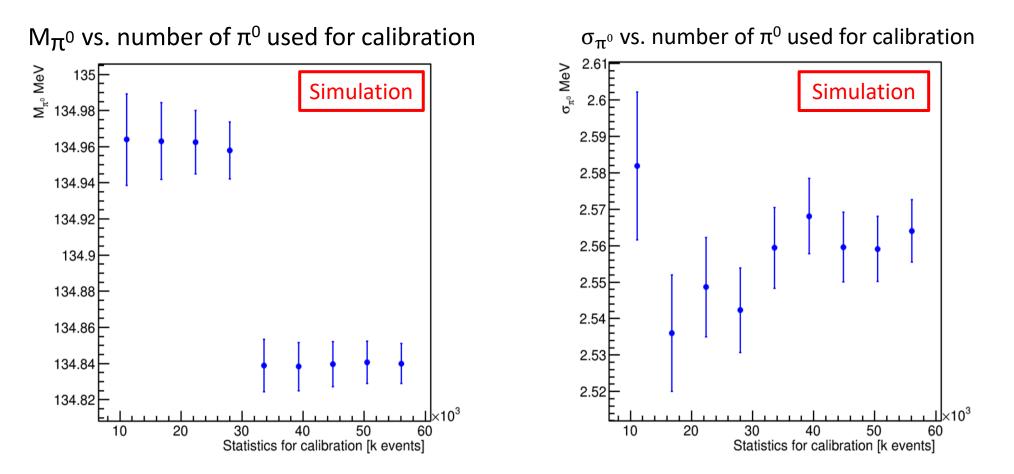
- $\geq$  Mean value of  $\pi^0$  mass is stable after 3 iterations
- >At least 5 iterations are required to make its width stable
- ➢Both mean and width are improved after calibration



## Required statistics for calibration



>20k of π<sup>0</sup> events seems to be enough for calibration based on the width (0.5 hours of beam time with KinC\_x36-5; 2-3 hours with x60-3 and x60-4 on LH2)



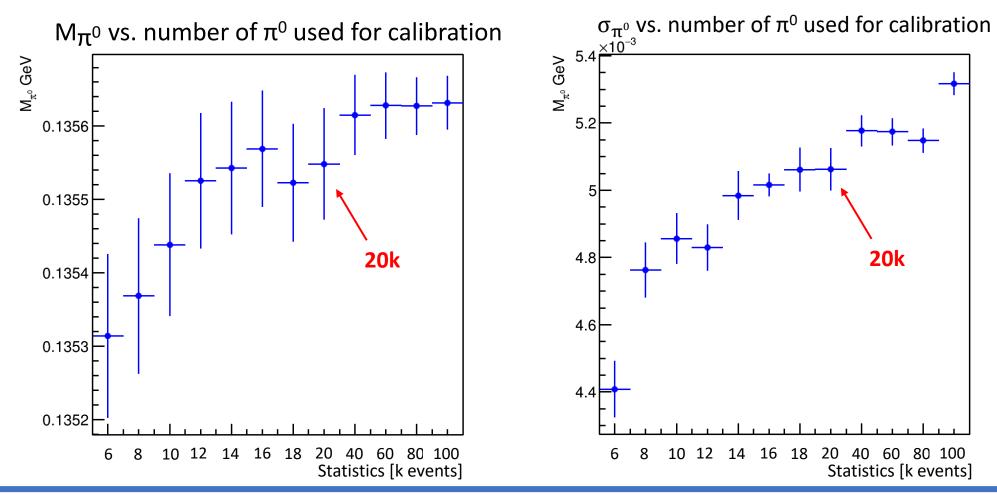
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### Required statistics for calibration with data



#### ➢Kinematics: KinC\_x36-5

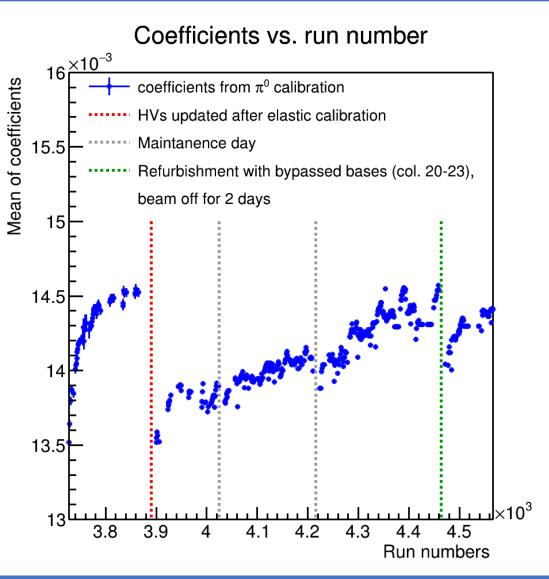
> Same conclusion as simulation: 20k of  $\pi^0$  events may be enough



#### Results of calibration as a function of run number

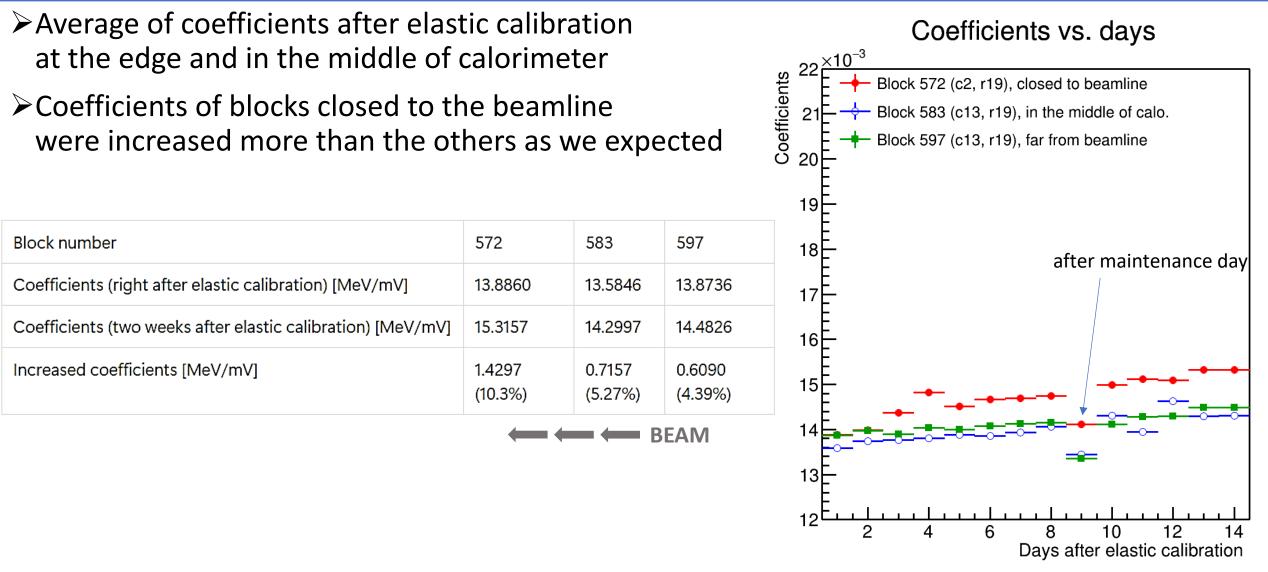


- ➢ First month of data in 2024
- ▶8 kinematics, run 3728-4550
- > Calibrated using ~100k  $\pi^0$  events
- Elastic calibration was done after taking 7 days of production data
- Decrease of coefficients after updating HVs and long time of beam OFF



### Comparison between different blocks





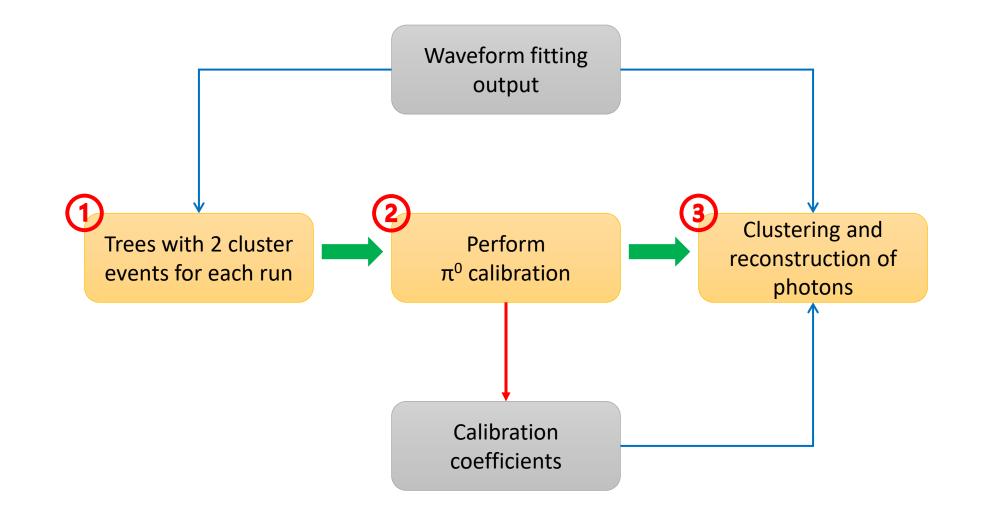
## Conclusion



- > The script for  $\pi^0$  calibration is ready
- > Study of the  $\pi^0$  calibration performance was done using simulated and real data
- > 20k of pure  $\pi^0$  events seems to be enough for calibration
- > The frequency of calibration depends on kinematics and beamtime
- $\succ \pi^0$  calibration using the 1<sup>st</sup> month of pass0 data in 2024 was done
- > Calibration coefficients changed when the beam was OFF or elastic calibration was performed
- > The new calibration will start once we have the output from waveform analysis

#### Calibration workflow





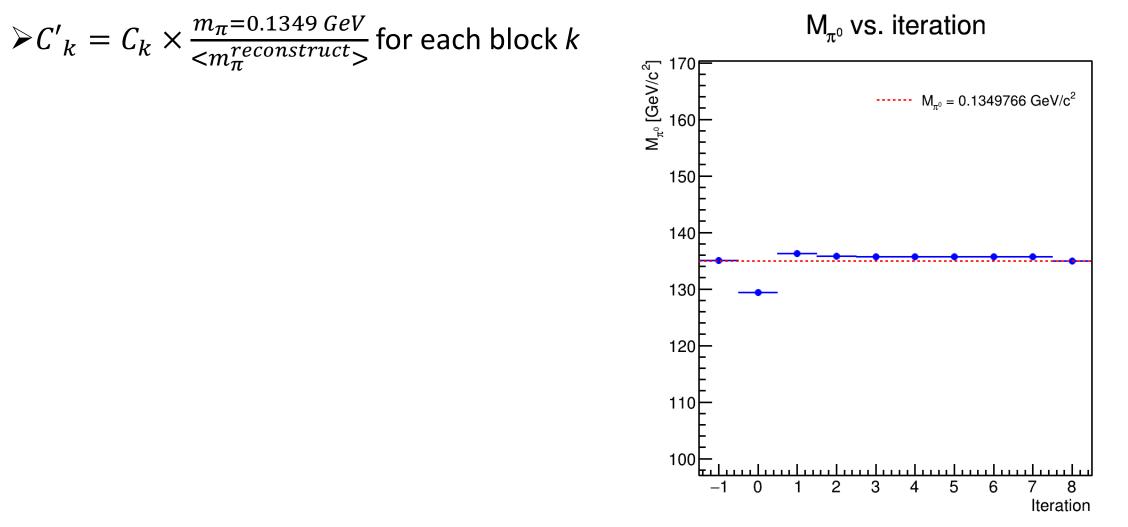


# Backups

## Additional correction for $\pi^0$ calibration



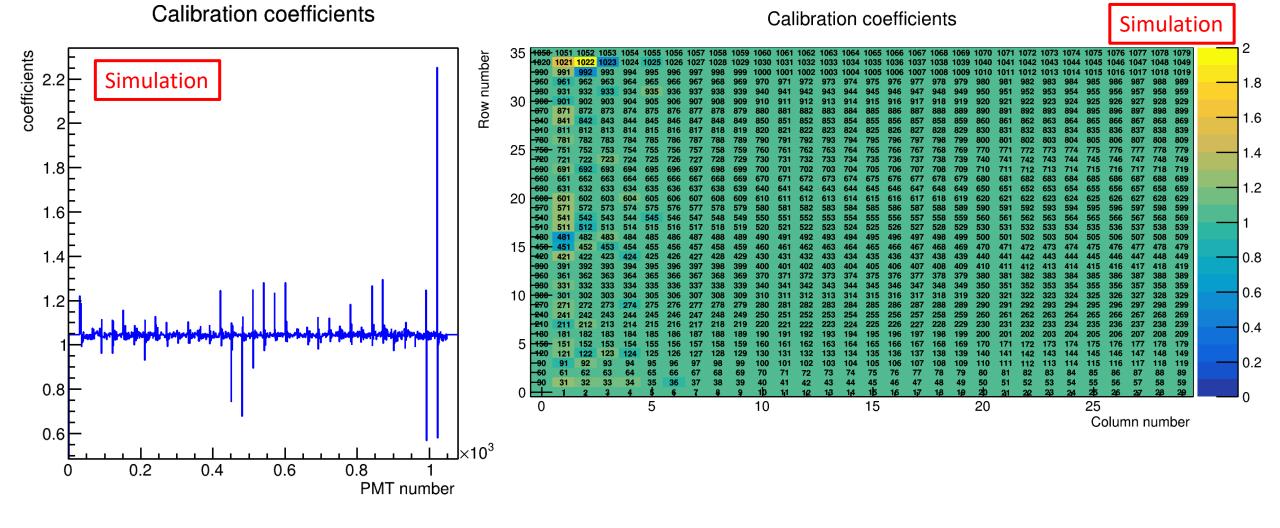
>Used in previous DVCS experiment in Hall A for the fast darkening of crystals



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#### Calibration performance with 20k $\pi^0$ events





#### Number of photons per block with 20k $\pi^0$ events



Simulation

Number of hits block

35	1050-	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	
00	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	 12
	-990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	
	-960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	
	-930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	
30	-900-	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	
	-870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	 1(
	-840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	L ''
	-810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	
~ -	-780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	
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	-720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	
	-690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	 8
	-660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	
00	-630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	
20	-600-		602	603	604 574	605	576	577	608	609	610	611	612	613	614	615	616	617 597	618	619	620	621	622	623	624	625	626	627	628	629	
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	-5-10	541 511	542	543 513	544	545 515	546 516	547	518	549	550 520	551 521	552 522	553 523	554 524	555 525	526	557 527	558 528	559 529	560 530	531	532	533	534	535	536	537	538	539	6
	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	6
15	-450-		452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	174	475	476	477	478	479	
15	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	4/2	443	444	445	446	447	448	449	
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	-360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	
	-330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	 4
10	-300-	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	L .
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	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	
	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	
	-180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	
5	150-	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	 2
•	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	
	-90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	
	-60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	
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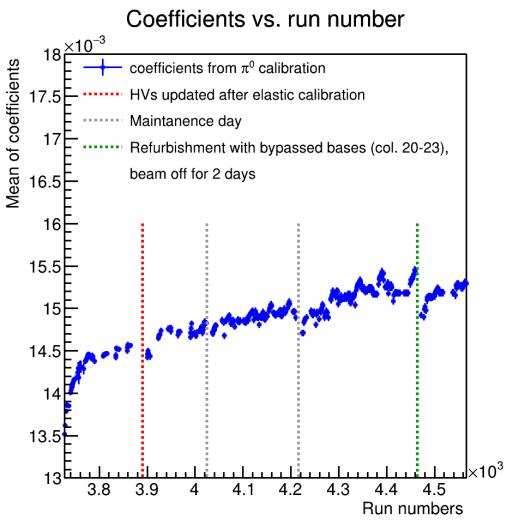
## If we didn't update HVs

Laboratoire de Physique

Restore to the old coefficients with

$$C_{old}^{k} = C_{new}^{k} \times \left(\frac{\mathrm{HV}_{new}}{\mathrm{HV}_{old}}\right)^{b}, b = 5.9$$

- Radiation damages of the crystal were saturated and increased steady after some point
- Cure of the crystals might be meaningless if the damages come back too fast



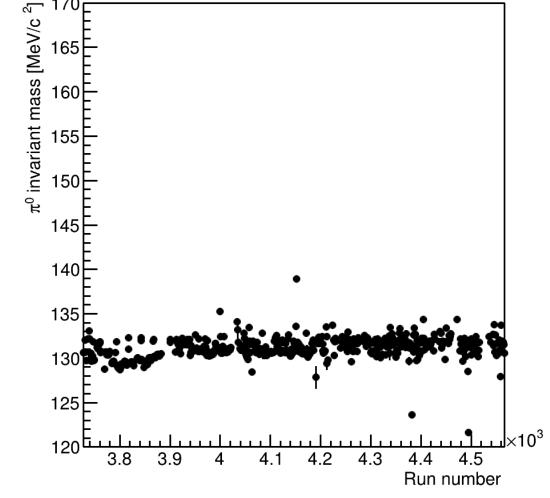
#### 2025/05/05

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#### $\pi^0$ mass position vs. run number (pass1)

- Stable around ~130 MeV
- > 130 MeV rather than 135 MeV may be due to a slightly wrong distance of NPS during previous calibration



 $\pi^0$  invt. mass vs. run number

